

Viggo Nordvik

Analysis of Rental Housing Markets: Five Essays

Levert til bedømmelse for Dr.polit-graden ved Økonomisk institutt, Universitetet i Oslo

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Norges byggforskningsinstitutt

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Introduction

This thesis represents an attempt to understand various aspects of the Norwegian rental housing markets. In the introduction I will start by giving a brief description of the background and motivation for this study, followed by some important facts about the Norwegian housing market.

I will start with a brief overview of the Norwegian rental housing market. This overview is organised around three themes. Firstly, I will report briefly on the historical development of the tenure distribution of the Norwegian housing stock. Secondly, the composition and development of the rental sector over the last 25 years is described. Lastly, non-neutralities in the taxation of housing capital in different tenures and within the rental sector are described.

A brief overview on important lines in the economic literature on rental housing markets and a summary of the five essays that form the main body of the thesis concludes the introduction.

Motivation for the study

Two observations on the nature of the Norwegian rental housing market formed the starting points for the work on this thesis. At first sight these observations can be formulated as two paradoxes.

- i) The return of owner-occupied housing capital is taxed at a very low effective rate. The return on rental housing capital, on the other hand, is taxed at the same rate as the return on other assets. With a uniform marginal tax rate, this implies that the rent that gives a landlord a normal after-tax return on capital is higher than the user cost an owner-occupier would face in a similar housing unit. Under such circumstances, it seems paradoxical that more than one out of five Norwegian households are tenants.
- ii) Even though more than 20% of the Norwegian households are renting, we have, in a strict physical sense few rental housing units. By this I mean that few housing units have been set up as rental housing units and remain within the rental sector throughout their life span. The housing stock is tenure flexible and housing units are transformed between tenures without any physical transformations taking place.

Even though the observations/paradoxes are taken from the Norwegian housing market, similar phenomena can be observed in other countries. This whole thesis can be read as an attempt to understand the mechanisms behind these two apparent paradoxes.

A brief overview of the rental sector in Norway

After the Second World War, Norway has become a country dominated by homeowners. The 1960 Census showed that around 40% of the Norwegian households were tenants. Up to 1990 this proportion decreased steadily to about 20%. This reduction of the rental shares (or increase in home ownership) has been one of the principal goals of Norwegian housing policy. The primary means employed to reach this goal were access to credit at a favourable rate of interest and municipal supply of land at subsidised prices for new construction. During the 1990s there has been a slight increase of the rental share.

The stock of rented housing units is quite heterogeneous as regards both the distribution of different types of landlord and the size and type of house. Table 1, taken from Nordvik (1996), summarises how rented dwellings are distributed over different types, and how this distribution has changed over time. The figures describing the rental sector in this section are taken from the Norwegian Surveys of Housing Conditions.

Table 1 - Distribution of rented dwellings in Norway (percent of rented dwellings)

	1973	1981	1988	1995
Secondary units in single-family houses	16.9	15.0	14.7	26.1
Secondary units other house types	4.2	4.5	4.2	3.3
Other private, non-professional	21.9	32.3	37.8	39.0
Privately owned for employees	15.2	9.7	4.6	2.6
Publicly owned for employees	6.2	4.5	5.5	5.3
Social rental housing	8.2	11.7	16.6	13.4
Private, professional	25.9	18.7	14.7	9.8
Other	1.5	1.1	2.0	0.2
Total, in thousands	402	359	307	418

Before entering into a brief discussion of the development of the rental sector it is necessary to explain some of the categories in Table 1. The first two categories are secondary units. By a 'secondary unit' it is meant housing units that can either be included as a part of a larger housing unit or used as units on their own. Secondary units in single-family houses are used

as a category because they form a quantitatively important part of the rental housing market in Norway. The category 'Other private, non-professional' includes independent housing units owned by single persons (or households).

The first thing to be noted is the low share of the rental market held by professional landlords. A rental dwelling is classified as being owned by a professional landlord if either a company owns it or if it is privately owned and situated in a multi-family building in which the majority of the dwellings are rental units. According to this definition, only one in ten rental dwellings is owned by a professional landlord. Hence an analysis of the supply of rental housing in Norway must be based on an understanding of the motives of the 'non-professional' landlords and of the framework under which they make their decisions. This statement is a central starting point for my thesis.

Table 1 not only reveals that the professional landlords' share of the rental market is low, but also that their share has undergone a sharp decline over the last 25 years. Furthermore, the size of the professional rental sector has declined in absolute terms as well, from 100,000 units in 1973 to 40,000 in -95. There are probably two important reasons for this development. Firstly, as part of urban renewal programmes during the 1980s a large number of blocks of rental flats were rehabilitated and converted to condominiums and co-ops. Secondly, a new legal framework for condominiums also emerged in the 1980s. This led to tenure conversions of blocks of flats even beyond the scope of the urban renewal programmes. Wessel (1996) describes this development in more detail. At the turn of the century a new wave of urban renewal is about to start. This may lead to a further decline in the professional supply of rental housing.

Rental housing units owned by employers and let to employees also constitutes a low share of the Norwegian rental market. There has been a steady decline - in both relative and absolute terms - over the period reported for this kind of rental housing. Hospitals and the armed forces mostly own those few dwellings of this kind that are still present in the housing stock.

The two dominant types of private rental arrangements in 1995 were 'Secondary units in single-family houses' and 'Other private, non-professional'. These have one thing in common: the landlords are single persons or households. Furthermore, they typically own only one, or a

small number of, rental units. The choices of these two types of landlord are the themes of Essay 1 and 3 of my thesis.

Quite a large proportion of the single-family house in Norway is built so that it is possible to let a dwelling on the first floor. It is also possible to include it as a part of the owner's own housing unit. Hence these single-family houses with an 'secondary unit' offer their owners an opportunity to adjust their housing consumption without having to move. This type of extra units in single-family houses is described in more detail in Essay 3 of this thesis and in Lappegård and Nordvik (1998). Poulton (1995) shows that such flexible single-family houses can also be found in other countries.

Together, these two types of rental supply from individuals or households constitute 65.1% of the total rental supply and 80.1% of the private rental supply. Back in 1973 only 45% of the private rental market consisted of these two types of dwellings. A similar development whereby the rental supply from individual small-scale landlords has become increasingly important is also reported in many other countries. Examples include the description of the Canadian rental market in Steele (1993), while Crook and Kemp (1996) and Yeates (1996) report similar findings from respectively Great Britain and Australia.

In some countries, tenure choice is virtually the same as choice of house type and size. Sweden is one example of this. Even though the distribution of house type and size differs between tenures, I will claim that data from the Survey of Housing Conditions show that Norwegian households do face a real tenure choice irrespective of which house type and size preferred.¹ The proportion of small dwellings is very much higher in the rental than in the owner-occupied sector. Almost 50% of all rented dwellings have only one or two rooms, while the corresponding share in the owner-occupied sector is only 8%. If we look at large housing units, we find that 75% of owner-occupied units have four or more rooms, the same figure in the rental sector is 27%. Hence, it is possible to find small owner-occupied units and it is possible to find large rental units.

¹ Of course there are some sparsely populated areas where the housing supply is thin. This also applies to the tenure-dimension.

It is also possible to find rental accommodation in different types of building. About 18% of the housing units in Norway are situated in blocks of flats. In the rental sector, this share is higher, but not very much so (25.6%).

The relative size of the rental market is, somewhat surprisingly, quite similar in rural and more urban parts of Norway. In the most sparsely populated areas the rental share is 18% while the rental share in the largest cities is just over 25%. In smaller towns the rental share varies around the 21% mark.

Taxation of owner-occupied and rental housing capital

Owner-occupiers in Norway pay income tax based on an imputed rental income (i.e. on an assessed return on housing capital). The imputed rental income is, however, calculated in a way that leads to a very low effective tax on the return of owner-occupied housing capital. The base of the imputed rental income is an assessed value of the housing unit. This assessed value is typically quite low compared to the market value of the housing unit. Based on 1995-data it is found that the assessed values are, on average, about 25 % of the market value.²

Before the imputed rental income is calculated a 'bottom deduction' is subtracted from the assessed value. Presently the size of the bottom deduction amounts to 52,500 NOK. Imputed rental income is set to 2.5% of the difference between the assessed value and the bottom deduction. The rate 2.5% has been employed since the end of the 1950's. Formally, there is also a progressive element in the system. This applies to very few households, and is briefly described in Essay 3.

For a typical housing unit with a market value of, say, 1 million NOK, the assessed taxable return, or the imputed rental income (I) will be:

$$I = 0.025 * (0.25 * 1,000,000 - 52,500) = \underline{\underline{4,937}}$$

In other words, the typical assessed annual return on housing capital is close to 0.5%. The tax rate for imputed rental income is 28%, the same as on income from other assets. This rate

applies for all taxpayers (personal and non-personal tax subjects) that are in a position to pay capital income taxes. This numerical example justifies my claim, in the motivation above that 'The return of owner-occupied housing capital is taxed at a very low effective rate'.

Negative capital income, i.e. interest payments, is fully deductible in taxable income. This applies for both personal and non-personal taxpayers. The deductibility of interest payments is a general characteristic of the Norwegian tax system, and is not tied to loans intended for specific purposes. Both owner-occupiers and landlords can deduct interest payments from the taxable income.

One effect of the combination of low imputed rental income and full deductibility of interest payments is that an owner-occupier with zero wealth (that is: a loan-to-value-ratio of unity) pays (far) less income tax than tenants with zero wealth. More generally, owner-occupiers pay less income tax than tenants with the same wealth and income do. For landlords to receive a normal after-tax return on investments, the rent must cover the normal return before tax. With a real interest rate of 4.5% the minimum rent required for a dwelling that can be sold at a price of 1 million NOK equals 45,000 NOK plus operating costs. The tax on this is 12,600, or 2.5 times the tax paid by an owner-occupier in a similar housing unit.

As a main rule, actual income, net of operating costs, from rental property is taxed as 'normal' capital income with a tax rate at 28%. For a landlord to obtain a return on her housing capital as high as the return on alternative assets the rent paid by the tenant must cover operating costs, the normal pre-tax return and tax. Hence the 'user cost' of rented housing capital is higher than that of owner-occupied housing capital. Equivalently one can argue that the ownership cost of rental housing capital is higher than that of owner-occupied housing capital. The phrase 'tenure-non-neutrality in the taxation of the return of housing capital' refers to precisely the cost differences described above. The high tax advantage of owner-occupiers is probably an important part of the explanation of the relatively high rate of homeownership in Norway.

² It might also be noted that there are very large unsystematic variations in the assessed value to market value ratio. This unsystematic variation is probably the most problematic characteristic of the taxation of housing capital.

There are quite a few exceptions to the main rule that net rental income is taxed in the same way as return on other assets. During a short temporary absence from home, owners can let their housing unit without being taxed on the rental income, i.e. they will still be paying only the tax on imputed rental income. A short temporary absence is defined as less than 50% of the tax year. Consequently 'absentee owner-occupiers' can let their homes from 2 July in year t to the 29 June year $t+1$ and still pay only the favourable imputed rental income tax. As shown in Table 1; almost five out of ten privately owned rented dwellings are categorised as 'Dwellings owned by single persons'. We do not know how many of these that is let by absentee owner-occupiers.

In addition one can let less than 50% of ones own housing unit without being subject to taxation in excess of the imputed rental income tax. Thus all dwellings in the category 'Extra units in single-family houses' are exempted from the normal income tax for rental dwellings. Taken together, these numbers imply that one can not reject the possibility that less than fifty percent of the private rental supply is taxed according to the 'main rule' for taxation of rental income. Consequently, one can say not only that the Norwegian tax system lacks tenure-neutrality, but that there also is clear non-neutralities in the treatment of different types of rented housing capital. Analyses of the supply of private rental housing should take into account the heterogeneity of the taxation of rental income.

Both owner-occupied and rental housing capital enters taxable wealth by the assessed value of the housing capital. Owner-occupied dwellings are exempted from the capital gains tax. Nominal capital gains on rented units are taxed on realisation rather than on accrual basis. This implies that some rental units have a rather high tax credit attached to them. The size and distribution of these tax credits are probably affecting the supply elasticity of private rental housing.

The thesis

This thesis consists of five essays. Each of them can be read as a part of my attempt to answer the question of why there exists such a large rental housing market in Norway and also in most other countries. The reason as to why I chose to look into this question in more depth has already been discussed in the section entitled 'Motivation for the study'. Choosing owner-

occupancy rather than renting gives households cost advantages because of the favourable taxation of the return on owner-occupied housing capital.

Before commencing a description of the five essays of my thesis, I will provide an overview of some important parts of the economic analysis of rental housing markets. Note that I am not attempting to write a fair history of the economic analysis of rental housing markets dealing with issues such as who was the first person to introduce new ideas, and which articles are the most important ones. The five essays of this thesis are briefly related to the important parts outlined in the section entitled 'A general overview'. Each of the five essays is thereafter described in somewhat more detail in the section entitled 'Parts of the thesis'.

A general overview

Demand for housing can be seen as a choice of a housing unit. This provides a starting point for numerous studies of housing demand as a discrete choice from a limited number of types of housing units. One argument in favour of the discrete choice approach is that many of the dimensions of housing consumption really are discrete and can not be continuously varied. Tenure, house type and number of rooms are examples of this. Another particular nice feature of this method of analysing housing demand is the strong and explicit link between theoretical and empirical analysis that can be given in the case of discrete choice.

The link is provided by the stochastic utility approach (see McFadden 1981). The utility of each possible housing alternative is assumed to be composed of a common and an individual component. From the analyst's point of view, the individual, or stochastic, components are not observable. Anas and Arnott (1991) assume that the individual components capture 'idiosyncratic taste dispersion'. The first order conditions for the maximum of the (stochastic) utility function, together with an assumption on the distribution of the stochastic component, form directly estimable econometric specifications. The most frequent distributional assumption is to assume that the individual components are distributed according to the extreme value distribution. This yields the logit model for housing choices.

Rosen, Rosen and Holtz-Eakin (1984), Boehm (1982) and Mills (1990) are just a few of many examples of empirical analysis of tenure choice based upon this discrete choice approach.

Börsch-Supan (1986) and Börsch-Supan and Pitkin (1988) discussed the use of multinomial logit (MNL) models for housing choices. It is shown that the MNL imposes an implausible substitution structure between different types of housing units. The problem with MNL is that all dwelling types are treated as close substitutes for one another. This is a consequence of the treatment of the stochastic terms in the utility function as independent across housing types. These articles argue that this imposed substitution pattern is intuitively implausible. This argument seems reasonable, and the claim that different small rental units are closer substitutes to one another than a small rental unit and an owner-occupied single-family house really does seem to make sense.

Because of the implausible substitution structure in the MNL model, the nested MNL-model is put forward as an alternative - and preferable - specification. The nested MNL model starts from a clustering of alternative housing choices. The substitutability within clusters is assumed to be stronger than the substitutability between dwellings in different clusters. The authors use an American data set to test the MNL model against the nested MNL model and find that the latter do fit data significantly better than the former.

Both the articles by Börsch-Supan and most others using the discrete choice approach use, either implicitly or explicitly, linear utility functions. My third essay formulates a discrete housing choice model for a quite specific situation. The essay analyses the decision made by owner-occupiers on how to utilise their single-family houses. The choice set consists of letting a part of the house or using all the floor space in the house for their own use. The utility function applied in my paper is not constrained to be linear. Among other things, this allows for household income to affect the choices. Even though in the paper I focus on how the choices of the owners affect rental supply, the essay can be said to be a part of the tradition of discrete demand studies of the housing market.

Planned housing careers (or the optimal timing of an endogenously determined number of moves over a lifetime), and how these are affected by transaction costs, are analysed by, among others Amundsen (1985) and Goodman (1995). The central conclusion of these articles is that there is a tradeoff between a mismatch in the consumption of housing services and moving costs. A household will accept a less than ideal dwelling because moving will incur moving costs. This mechanism not only reduces the propensity to move, it also affects the housing choices upon moving. When moving, these models predict that households will

not choose the level of housing consumption that - in a myopic sense - is ideal at the time of moving. Rather, they will choose a housing unit that serves its needs fairly well over a period of time. 'Fairly well' in this context means that housing consumption is chosen so that the average discounted marginal rate of substitution between housing and other consumption goods is equal to the average price ratio over the defined period of time. An early example of a similar mechanism can be found in Muth (1974), which shows that the housing consumption chosen upon moving depends on the expected stay in the housing unit. In Muth's analysis the myopic mismatch at the start of a stay is increasing in expected length of stay.

The articles mentioned above clearly demonstrate that planned housing careers, or the dynamics of housing demand, are affected by moving costs. Even though none of these articles deals with tenure choice, I would claim that an understanding of the mechanisms explored in these articles is important to the understanding of the presence and the role of the rental housing market. Moving costs are probably very much lower in the rental than in the owner-occupied sector of the housing market. Consequently, renting may be a sensible choice for households who plan to stay for quite a short time in a dwelling.

Essay 4 of my thesis takes the same starting point as Amundsen (1985) and Goodman (1995) do. The results are extended by showing that endogenous moving activity should be analysed together with exogenous moving activity, and that these two types of moves are not independent. A high probability of being forced to move can increase planned moving activity. Neither my study nor others in this tradition incorporates tenure choice into the model of the dynamics of housing demand.

The idea that moving costs differ between tenures and that this leads to a decreasing relationship between (expected) length of stay and the ratio of user cost of owner-occupancy to the cost of tenancy was utilised by Rosenthal (1988). His estimates show that the likelihood of a moving household choosing owner-occupancy is increasing in expected length of stay. While Rosenthal's model is sequential (tenure is chosen after the expected length of stay is determined) Henderson and Ioannides (1989) brings the analysis one step further forward. They estimated the choice of tenure and planned length of stay as simultaneously determined. In a manner somewhat similar to Henderson and Ioannides (1989), Essay 5 uses cross-sectional data to perform an analysis of the determinants of the dynamics of housing demand.

The literature on the supply of rental housing is quite thin. In Anas and Arnott (1991) an equilibrium model of a rental housing market is presented. Supply of rented units in different quality segments of the market is determined by a zero-profit condition. Rental housing has, in their model, no alternative use. Similar descriptions of the supply side of rental housing markets can be found in Igarashi (1991), Arnott (1989) and Read (1991). The three latter articles model landlord's search for tenants and consumers search for suitable rental housing units.

Henderson and Ioannides (1983) notes that for there to be owners of rental housing in equilibrium the rent must cover both capital costs and operating costs. If the rent gives a return above the normal rate of return on capital, new landlords will enter the market and the rents will be pushed down until the return on rental housing equals the normal return. Swan (1984) describes landlord behaviour in the same way. Hence in both these articles, private rental supply is determined by a no-arbitrage condition. The no-arbitrage rent (or reservation rent) is related to the asset market for housing capital in which rental and owner-occupied dwellings are priced in the same way. A landlord who gets a rent equal to her reservation rent will be indifferent between letting and selling the housing unit. This is also the starting point of essay 1 and essay 2 of this thesis.

Capital gains on rental housing are treated in a cursory way in both the articles mentioned above. Henderson and Ioannides assume capital gains away by assuming that the price of housing assets is constant. Swan allows for changes in the market value of housing capital and implicitly assumes that a rental dwelling is sold at a given point in time. The effect of these assumptions is that the size of a capital gain is exogenous to the decision to let or sell. Hence capital gains are treated as being beyond the control of the owners. Contrary to this, the central idea in my essays 1 and 2 is that the capital gain is endogenous because the timing of a sale is a part of the optimisation of an owner of a rental dwelling.

The no-arbitrage rent in Henderson and Ioannides article is independent of the characteristics of the landlords. In Swan the distribution of marginal tax rates determines a distribution of reservation rents among landlords. This implies that there is an increasing supply function of rental housing in Swans model while the size of the rental market in Henderson and Ioannides model is determined from the demand side of the housing market.

My essay 1 analyses the reservation rent in a partial supply side analysis where asset prices of housing capital and rents are assumed to be stochastic. It shows that by letting, rather than selling, a landlord retains a put option to sell the rental unit later whenever an advantageous price occurs, while a sale kills this option. The central result of this essay is that the no-arbitrage rent is pushed down by the value of the real option, and that this may be a source of mutually advantageous contracts between a landlord and a tenant. Hence the value of keeping the put option may be larger than the tax advantage to the consumer would had he been an owner-occupier.

Essay 2 shows that this result holds also in a partial equilibrium setting where landlords differ with regard to their costs of operating a rental housing unit. In other words, the put option is positively valued even when the value of the consumer's option to change tenure is taken into account.

Parts of the thesis

The first two essays in the thesis analyse the consequences for rental housing markets, of the housing stock being 'tenure flexible'. In **Essay 1** 'Tenure Flexibility and the Supply of Private Rental Housing' I analyse the choices of the owner of a housing unit that she either can sell or let. The prime focus in this analysis is on the determinants of the reservation rent. The reservation, or no-arbitrage, rent is the rent that makes a landlord indifferent between selling and letting.

The reservation rent under certainty is calculated as a point of reference. The reservation rent consists of operating costs and a normal return, before tax, on the housing capital held by the landlord. This is compared to the user cost of an owner-occupier in a similar dwelling. If owner-occupiers and landlords have identical operating costs, the reservation rent will be greater than the user cost. The reason of this is the tax advantage enjoyed by owner-occupiers. Hence the set of mutually advantageous contracts between landlord and tenant is empty.

The main part of this essay is formed by an analysis of the determinants of the reservation rent when a stochastic process generates the future price of housing capital and rents. This problem is analysed within a discrete three-period setting. Throughout the analysis it is

assumed that the agents are risk-neutral. If the housing unit is still held at the start of the terminal period, it is sold at the prevailing market price.

The period one reservation rent is calculated by equalising the certain value of the strategy sell to the expected net present value of the uncertain payoff of the letting strategy. The expected value of the letting strategy is the solution to a dynamic programming problem. This can be illustrated by going through the components of the expected value of the letting strategy, measured when the decision of whether to let or sell at the start of period one is made. Firstly, there is the observable, and consequently certain, period one rent net of operating costs. The second component is the expected value of selling the unit at the start of period two, given that this is the optimal choice after the period two price and rent are revealed. This expected value is weighted with the probability that a period two sale is optimal. The third component is the expected value of the period two rent and period three price, weighted by the probability that continuing to let in period two is optimal.

The analysis of reservation rents in the dynamic stochastic framework reveals that the option of choosing whether or not to sell in period two, after prices and rents of this period are revealed yields a positively valued real (put) option. In the essay, this option is termed a tenure flexibility option. A sale in period one 'kills the option'. The option consequently pushes the reservation rent downwards. When the value of the real option is taken into account, it turns out that there may be a non-empty set of mutually advantageous contracts between landlord and tenant. Given the size of the rental market, it is clearly satisfying to identify such a source of mutually advantageous rental contracts.

Hence the choices of a risk-neutral agent are not similar to the choices of an agent acting in a certain environment where expectations in the uncertain environment equal the true values under certainty. It is shown in the essay that such a result frequently occurs when the value of real options is included in the analysis of the markets for real estate assets. By using the concept of mean preserving spread as introduced in Rothschild and Stiglitz (1970) it is demonstrated that the value of the real option is increasing in the size of the uncertainty of the price of housing capital. Hence the no-arbitrage rent is decreasing in the volatility of house prices.

Through a theoretical analysis of a simple model of a housing market, **Essay 2** 'Cost Dispersion, Re-entry Costs and Rental Housing Markets' investigates two questions central to the interpretation and relevance of the results in essay 1. Firstly, is the value of the tenure flexibility option as described in the partial supply analysis in essay 1 different from zero also in equilibrium? Secondly, is the conclusion that there might exist a non-empty set of mutually advantageous contracts between landlords and tenants valid also when the consumers' option to change tenure is taken into account? Essay 2 reveals that both these questions can be answered in the affirmative.

In the model, landlords are (continuously) distributed according to their operating costs. Rents are determined so that marginal suppliers earn zero profit, while intra-marginal suppliers earn a positive profit. An intra-marginal supplier is a landlord whose operating costs are below those of a marginal supplier. An exogenous stochastic price process produces uncertainty as to whether a marginal supplier in a particular period will become an intra-marginal supplier next period. This uncertainty together with cost heterogeneity among landlords and re-entry costs, produces a positively valued tenure flexibility option also for a marginal supplier.

Consumers choose the tenure that yields the expected lowest net present value of the costs of their housing consumption over their housing career. If they change tenure, they incur moving costs. Within this framework, it turns out that the net present value of the cost of choosing owner-occupancy can be written as a sum of three components. The first two components correspond to the traditional measure of the user cost of owner-occupied housing capital for respectively the first and the second period. The last component can be interpreted as a real option. It is the value of switching over to rental housing if this results in lower costs in period two. Hence this analysis indicates that user costs should be 'corrected' for the value of the option to step out of owner-occupancy whenever beneficial. This again implies that the traditional measure of the user cost is biased upwards! Also there is a tenure change option connected to renting that pushes the expected cost of choosing a rental dwelling downwards.

In order to check for the existence of mutually advantageous contracts between landlords and tenants the essay starts by assuming that a landlord earns zero profit by letting and then check whether a cost-minimising consumer will be willing to rent from this landlord. The discussion shows that it is indeed possible that such mutually advantageous contracts exist. The reason of this is, of course, the value of the landlords' tenure flexibility option. For sufficiently large

volatility in the house prices a situation might even emerge where a consumer is renting from a less efficient landlord. A less efficient landlord in this instance means a landlord who has higher operating costs than the consumer would have had had she been an owner-occupier. It should be noted that this result emerged even though the tax advantage associated with owner-occupancy is taken into account.

The letting of a part of a single-family house is the theme of **Essay 3** 'Utilisation of the Stock of Owner Occupied Single Family Houses- an Econometric Analysis'. A large share of the single-family houses in Norway is designed so that a secondary housing unit, normally situated in the basement of the house, can either be let or used as a part of the home. The decision as to whether or not to let is formulated as a discrete choice between two different consumption bundles. Letting corresponds to low housing consumption and high consumption of other consumption goods, while not letting corresponds to high housing consumption and low consumption of other goods. Subletting of a part of one's home in other types of housing can be analysed in a similar way.

The discrete choice is modelled as a comparison of utility of each of the two consumption bundles and the parameters of a utility function is estimated by a logit procedure. Anas (1980) and Anas and Arnott (1991) use this same type of stochastic utility maximisation in empirical analysis of housing market choices. The model differs from other empirical discrete choice models used to analyse housing market behaviour insofar as I do not constrain the utility function to be linear. By imposing suitable restrictions on the parameters the linear utility function emerge. In the essay this is used to test whether the linear utility function is an appropriate simplification. It turns out that the linear utility function fit my data worse than the utility function employed at a level of significance well below 1%.

The empirical model can be interpreted as a model of households' demand for floor space within their own single-family houses. In this way, it is possible to obtain estimates of price and income elasticities. These demand elasticities are quite interesting, as they are estimated on the basis of households who are able to vary their housing consumption without incurring moving costs. Housing consumption is varied by changes in the utilisation of their own single-family house. The price of the floor space is equal to the rent lost when not letting. An average (current) income elasticity of 0.39 is found. The average price elasticity is -0.77. It might be noted that these elasticities correlate quite strongly with household income.

Within a model with only one tenure, **Essay 4** 'Moving Costs and the Dynamics of Housing Demand' shows that in the presence of moving costs housing demand at any moment of time should be regarded as part of a dynamic plan. The starting point for this essay is the observation that even though house prices changes quite frequently, most families move infrequently. It can also be frequently observed that changes in family size, and presumably in the need for housing services, do not induce families to move.

In the model of the dynamics of housing demand under certainty, every move is a part of a planned housing career. Amundsen (1985) states that by using this type of model one can explain *the part of intra-urban mobility that is explained by long-term planning*. Essay 4 incorporates an exogenous stochastic process that can produce forced moves. Not surprisingly, it turns out that the path of planned moves is affected by the probability of being forced to move. It is demonstrated, within a fairly simple two-period model, that a high probability of being forced to move may induce households to move voluntarily. The economic mechanism behind this is that household will not be very inclined to accept a mismatch in housing consumption in order to avoid moving costs if the probability of having to pay moving costs anyhow is high.

The idea that planned and also actual housing careers are affected by moving costs is also central in the empirical study in **Essay 5**, 'Tenure Choice and Residential Mobility'. As Edin and Englund (1991) did, this paper attempts to capture the dynamics of housing demand, using data from a cross-section sample. Planned length of stay in present dwelling and tenure are simultaneously determined dimensions of a planned housing career. Consequently, estimated coefficients of a one-equation model of tenure choice will suffer from simultaneity bias. Therefore, a simultaneous two-equation model of planned length of stay and tenure is estimated. These estimations are made using a two-stage method proposed by Maddala (1983).

The estimated model is primarily used as a framework for statistical tests of a set of hypotheses on the determinants of the dynamics of housing market behaviour. There are two reasons for the emphasis on such tests. Firstly, Henderson and Ioannides (1989) and Essay 4 of this thesis demonstrate that a theoretic analysis of the dynamics of housing market behaviour is very open. It is open in the sense that even if one specifies the form of the utility

functions, the analyst is left with very few constraints around which a model can be built. In such a situation it should be justified to base the discussion of the empirical results on a wide set of specification tests, even if the testing resembles data mining.

The second reason for concentrating on the tests is the nature of my data on planned mobility. The data are given in a categorical form. In the estimated model I translate planned mobility data over from the categorical form to a continuous scale³. Such translation procedures can, in a way, be said to be somewhat arbitrary. Therefore, the discussion of the empirical results is centred on the specification tests and how correction for the simultaneity between planned length of stay and tenure affects the tenure choice equation.

The testing gave several interesting results. Of these, two are of particular interest. A hypothesis that tenure choice is partially independent of age of household head could not be rejected at any sensible level of significance. Planned length of stay, on the other hand, is significantly affected by age. The other important result concerns the effect which presence of school children in a family has on expected mobility, or planned length of stay. Planned length of stay is significantly higher for households including children attending school.

³ In an appendix to the essay it is shown that qualitatively the structure of the estimated model carries through also with alternative translation procedures.

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Tenure Flexibility and the Supply of Private Rental Housing^{#*}

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Abstract

This paper examines the decision by an owner on whether to sell or let a dwelling not used by the owner's family. The paper shows that both qualitatively and quantitatively different conclusions are drawn from an analysis under certainty compared to one within a dynamic stochastic framework, even when the owners are assumed to be risk neutral. The paper emphasises that when the decision on selling or letting is analysed, the value of future flexibility of the 'let'-strategy should be taken into account. The value of future flexibility might be denoted a real option value. When account is taken of the real option value, the reservation rent of a potential landlord may be lower than the user cost of a similar dwelling.

JEL-classification R31 - Housing Supply and Markets

Keywords: Rental Housing, Real Options, Tenure Flexibility, Reservation Rents, User Cost of Housing

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1. Introduction

The central idea behind this paper is that the rental housing stock of a country does not consist of a special type of dwelling. Much of the rental stock of dwellings can be sold to owner-occupiers, and owner-occupied dwellings can be transformed into rental dwellings. This paper argues that the tenure status of a housing unit should be treated as being determined as a part of the economy's general equilibrium, rather than as a characteristic of a dwelling. The paper shows how such transformations between tenures can be analysed in a way that provides insight into the workings of the supply side of rental housing markets.

My focus is solely on the supply side of the private rental housing market, i.e. only the reservation rents of suppliers are analysed. Only the decision made by a single decision-maker is analysed: I make no attempt to construct an aggregate supply function. The principal conclusion is that part of the value of a rental dwelling is an option to sell later. The option to sell later lowers the minimum rent required for a landlord to let a dwelling rather than sell it, which kills the option. A numerical illustration demonstrates that this effect may be sufficiently large to force the reservation rent below the user cost of an owner-occupier.

One of the most complete conceptual treatments of a rental housing market can be found in Anas and Arnott (1991). In their article a model of a heterogeneous rental market is developed. In the model, conversion of rental units is an element of the set of possible actions for the potential landlords. Short-run supply is determined by the historically given housing stock and the profitability of keeping dwellings vacant while physical conversions are carried out. Long-run supply depends on the expected profitability of new construction and conversion activities. Others, such as Read (1991) and Igarashi (1991), focus on the search processes of tenants and landlords, and show how these processes might lead to an equilibrium with vacancies. The supply of rental housing in long-run equilibrium in both these models is determined by a 'zero profit condition'.¹ The three articles mentioned above do not take into account the interaction between the rental market and the market for owner-occupied housing, which is the main theme of my paper. A decision to sell a dwelling to an owner-occupier can of course be interpreted as a conversion activity. I treat this specific conversion activity in a more explicit manner than Anas and Arnott (1991) do.

Over the last few years there has been an increasing awareness of the need to take account of the underlying real options when analysing the value of real estate assets and the markets of both the assets themselves and of the services they produce. A crucial aspect of many actions taken by real estate owners is that they are irreversible. A decision to undertake such an action is thus also a decision to kill the option to undertake the action at a later date. Pindyck (1991) gives a comprehensive description of the economics of irreversible investments. The value of the real option is a cost of the action. This factor must be taken account of when analysing the behaviour of real estate owners. For the individual owner of a rental dwelling, the sale of the dwelling is an example of such an irreversible action that kills the option of selling the dwelling at a later date.

Capozza and Helsley (1990) use a real option approach to show how development of land is delayed by uncertainty concerning the growth rate of rents in an urban economy, even if land-owners are not averse to risk. The reason is that agricultural land is not developed as soon as the rent of urban land net of the annual cost associated with the physical development of the land hits the rent on agricultural land from below. Rather the net rent on urban land must exceed the agricultural rent by the positive cost of killing the option of developing the land later on. Capozza and Sick (1991) show how observed differences between prices of long-term leases and land prices can be understood by reference to differences in the values of underlying real options to redevelop the land. Grenadier (1995) uses a real option approach to show how the owner of a real estate project selects tenants. A common feature of these three articles and others that utilise the real option approach to real estate is that explicit treatment of the real options connected to real estate yields qualitatively different conclusions than similar analyses that fail to take account of the real option aspect. This statement applies for my paper too.

My focus on the interaction between the rental market and the market for owner-occupied housing is based on the observation that a significant proportion of the rented housing units in Norway are owned by private households who typically own one dwelling in addition to their own residential property. Close to 30% of the rental housing stock consists of dwellings of this type. When dwellings owned by commercial firms are included, close to every second rental dwelling can easily be converted between tenures. This interaction between the rental and the owner occupied sector is not a Norwegian phenomenon. It is more a reflection of the fact that there is no physical reason for some dwelling units to be used by owner-occupiers and others

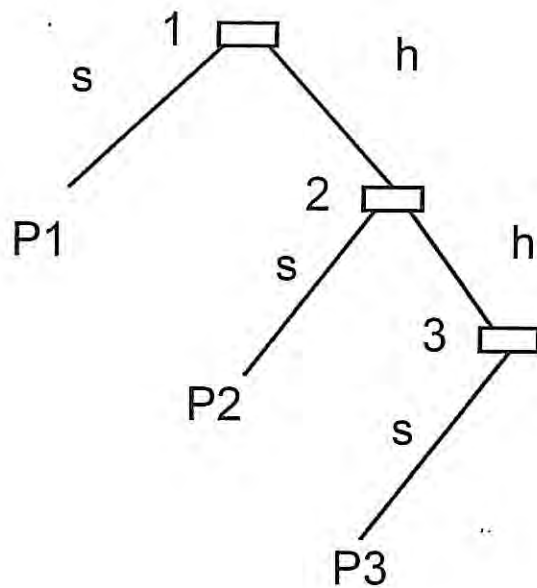
by tenants. Skifter Andersen (1993) supports this view when he states that, between 1975 and 1985, 10-15% of the rental dwellings in four U.S. cities were sold to owner-occupiers, with about the same number being moved from the owner-occupier sector to the rental sector. Housing economists has given remarkably little attention to these transformations.

This paper is divided in five sections including the introductory remarks. Section 2 analyses the decision of whether to let or sell a dwelling. To provide a benchmark I first analyse the decision in a framework without uncertainty. The core of the paper then addresses decision-making by landlords in an uncertain environment. Section 3 argues that increased volatility in house prices pushes reservation rents downwards. The characteristics of the model are further illustrated in the numerical example of section 4. Section 5 presents some concluding remarks.

2. A Formal Analysis of the Decision

The decision problem facing a household owning an extra dwelling can be described by the use of a decision tree (see Figure 1). Each box, or node, represents a point in time where the potential supplier (i.e. the potential landlord) must make a decision. Each of the lines descending from a node represents a possible course of action. To simplify the discussion a decision tree with just three periods is used. The figure shows that in the first and second periods the action set consists of sale (s), and let the dwelling (h).

Figure 1 - Decision tree of a potential landlord



If a household owns an extra dwelling at the start of period 3, it has only one possible action, s , which is to sell the dwelling. By using a final period with only one action, the dynamic programming problem can be solved by straightforward application of Bellman's principle², where the period 1 decision problem is solved by rolling it up backwards.

The decision tree will be used for a preliminary discussion of the decision problem of the potential landlord under different circumstances. Perfect foresight is discussed in Section 2.1. The core of the paper is Section 2.2 where I discuss how reservation rents are affected by an explicit treatment of the value of postponing the decision to sell until new information arrives, and Section 2.3 where the reservation rents calculated in Sections 2.1 and 2.2 are compared.

2.1 The decision under perfect foresight

It is assumed that the owner chooses her action in order to maximise the net present value, $V(\cdot)$, of the income stream generated by her asset. I will proceed assuming that the owner of the dwelling that either can be sold or let is risk neutral.

Capital gains made on the sale of a dwelling that has recently been owner-occupied are not taxed. If on the other hand the dwelling has been rented to someone else recently³ capital gains are taxed. The base of the capital gains tax is the difference between the sales price and the historic (nominal) purchase price. Capital gains are thus taxed on realisation rather than on an accrual basis. Marginal tax rates are independent of the level of income, and the tax rates applied to capital gains and rental income are identical. Both landlords and owner-occupiers are allowed to deduct interest payments in taxable income. These characteristics represent the main features of the tax system that Norwegian owner-occupiers and landlords face.

The base of the latent capital gains tax at the start of period 1 is shown in equation (1)⁴. Equation (1) can also be considered as a definition of the variable γ that expresses the growth in the nominal market value of the dwelling from the time of purchase up to the start of period one. Throughout this Section it will be assumed that the dwelling considered has been let during the last year. Hence, upon sale the nominal capital gain is taxed. All prices and rents are measured in nominal terms (see note 4). Symbols used in the description of reservation rents under certainty are:

P_t	the price of the dwelling at the start of period t
P_0	the historic purchase price of the dwelling
k	the annual growth rate of the market price of a house ($k = [(P_2 - P_1) / P_1]$)
τ	the uniform marginal tax rate
r_t	after-tax rent, net of operating costs received at the beginning of period t .
i	is the nominal interest rate before tax ⁵
φ	after-tax discount rate, which is assumed to be constant over time, i.e. $\varphi = i(1 - \tau)$
$V(h_1, h_2, s_3)$	net present value of a strategy consisting of letting the dwelling in the first two periods, and then selling it at the start of the third period. If a dwelling is sold at period t , the set of possible strategies in period $t+1$ is empty, o_{t+1} denotes such an empty strategy set.

$$P_1 - P_0 = \gamma P_0 \tag{1}$$

$$V(s_1, o_2, o_3) = P_1 - P_0 \gamma \tau \quad (2a)$$

$$\begin{aligned} V(h_1, s_2, o_3) &= r_1 + \{ P_2 - \tau(P_2 - P_0) \} / (1 + \varphi) \\ &= r_1 + \{ P_1 (1 + k(1 - \tau)) - P_0 \gamma \tau \} / (1 + \varphi) \end{aligned} \quad (2b)$$

$$V(h_1, h_2, s_3) = r_1 + \{ r_2 + [P_3 - \tau(P_3 - P_0)] / (1 + \varphi) \} / (1 + \varphi) \quad (2c)$$

To illustrate how the net present values may be written in different ways, growth rates are used in (2b) and absolute levels in (2c). Throughout the paper it is assumed that the growth rate of housing prices is lower than the after tax discount rate. If the opposite were true, investments in housing capital would yield a return in excess of the normal return even if the housing capital were not used in any way.

The reservation rent is defined as the rent at which the potential landlord is indifferent between selling and letting. The rest of this section on landlord behaviour under certainty will be based on the assumption (A-1):

$$V(h_1, s_2, o_3) \geq V(h_1, h_2, s_3) \quad (A-1)$$

Then the reservation rent for period 1 is implicitly defined by $V(s_1, o_2, o_3) = V(h_1, s_2, o_3)$ using (2a) and (2b). Assumption (A-1) also applies for the analysis in Section 2.3 where reservation rents in certain and uncertain environments are compared. Some rearranging gives the expression (3) for the after-tax net reservation rent for the first period \hat{r}_1 .

$$\hat{r}_1 = P_1 (\varphi - k(1 - \tau)) / (1 + \varphi) - P_0 \gamma \tau \varphi / (1 + \varphi) \quad (3)$$

In the absence of taxation (3) simplifies to $\hat{r}_1 = P_1 - \frac{P_2}{1 + \varphi}$. This after-tax net reservation rent

can be transformed to find the gross rent, \hat{g}_1 . The gross rent is the rent paid by a household that gives a landlord a net rent after tax that equals her net reservation rent.

$$\hat{g}_1 = c_T + \hat{r}_1/(1-\tau) = c_T + P_1\{i - k\}/(1+\varphi) - P_0\gamma\tau i/(1+\varphi) \quad (4)$$

c_T is the annual operating cost, including normal maintenance, of a rented dwelling

The last term on the right hand side of (4) is the value of postponing the payment of the latent capital gains tax accumulated up to the beginning of period one by one additional period. $P_0\gamma$ is the capital gain that would have been subject to capital gains taxation had the dwelling been sold at the start of period one. This tax credit can be thought of as a zero interest loan that the owner is allowed to hold as long as she owns the dwelling. Not surprisingly, it can be seen from (3) that the possibility of postponing tax payments lowers the compensation needed for holding a rental dwelling as a part of a portfolio, i.e. it reduces the after-tax net reservation rent.

It should be noted that the first-period reservation rent depends only on the difference between the period one price and the highest discounted expected price of the future periods. The structure of the solution of the net reservation price is therefore not affected by the number of periods.

A comparison of the gross rent paid by a renting household and the user cost (uc) of a household who buys a similar dwelling produces some interesting results. Equation (5) defines the user cost of housing capital in the same way as it is defined by among others Poterba (1984).

$$uc_1 = c_o + P_1 \{(\varphi - k + \tau a)/(1+\varphi)\} \quad (5)$$

c_o is the annual operating cost, including maintenance, of an owner-occupied dwelling
 a is the imputed taxable income for owner-occupiers as a fraction of the beginning of period house price

The user cost is the cost an owner must pay to obtain a unit of housing services by owning a

unit of housing stock. It is composed of out-of-pocket costs (amortisation not included), the opportunity cost of equity and changes in the asset value of the housing stock. The exact formulation of (5) is based on the (somewhat arbitrary) assumption that operating costs are paid at the start of a period, and that tax on imputed rental income is paid at the end of the period.

Calculating the difference between the user cost and the gross rent paid by a renting household to a landlord who gets a net rent after tax equal to her net reservation rent after tax gives us an expression for the net advantage of home ownership (Δ). The comparison is done under the assumption that future market prices are known by both landlords and owner-occupiers.

$$\begin{aligned}\Delta &= uc_r - \hat{g}_1 \\ &= (c_o - c_r) + P_1 \{ -\tau(i(1-\alpha)-a) \} / (1+\varphi)\end{aligned}\quad (6)$$

where α is the ratio of the unrealised (and therefore not yet taxed) capital gain to the period-one price, i.e.:

$$\alpha = \frac{P_1 - P_0}{P_1} = \gamma \frac{P_0}{P_1}$$

Henderson and Ioannides (1983) showed that there is an incentive asymmetry between owner-occupiers and renters that tends to push the annual operating costs, needed to keep depreciation at a given level, of rented dwellings above that of owner-occupied dwellings.⁶ This mechanism is termed '*the fundamental rental externality*'. Nordvik (1993) showed that if households differ in the operating costs they impose on a rented dwelling, and the household specific operating costs cannot be observed by landlords, average operating costs of rented dwellings will be higher than those for the owner-occupied sector. Thus, both a moral hazard and an adverse selection problem tend to push the operating costs in rented dwellings above those for owner-occupied dwellings. This means that the sign of the first bracket on the right hand side of (6) is very likely to be (strictly) negative.

If the likely dependency between tenure and operating cost is ignored, the sign of the difference between the gross reservation rent and the user cost will depend on which of two tax advantages is the higher. The tax advantages for owner-occupiers result from the fact that the

taxable return (i.e. the imputed rental income) on owner-occupied housing is very much lower than the return on alternative assets. The landlords' tax advantage stems, from the value of the tax credits arising when capital gains are taxed on realisation.

A theoretical consideration of equation (6) does not indicate whether user cost or gross reservation rents should be expected to be greater under a certainty framework. This will, depend on the relative size of the two different tax advantages. However, numerical considerations suggest that only for very large unrealised gains will reservation rents be below the user cost of a similar dwelling. In the Norwegian tax system the parameter α lies somewhere in the range 0.005 to 0.01. Assuming α to lie at the upper limit of the interval and nominal interest rate to be 8.5%, dwellings with unrealised capital gains less than 88% of the prevailing market price will have a reservation rent that exceeds the user cost of a similar dwelling. If the nominal rate of interest is lowered to 4%, this upper bound is reduced only to 75%. It can therefore be said that only for dwellings with a very large unrealised capital gain do there exist rents that are mutually advantageous for both tenants and landlords.

The conclusion that reservation rents are likely to exceed the user cost is a result of the low imputed return on owner-occupied housing capital, which is a characteristic of the Norwegian tax system. Some kind of favourable treatment of owner occupied housing capital is a part of the tax system in most (or perhaps even all) other countries.

2.2 The decision under uncertainty

This section considers the choices made by a risk neutral owner of a second dwelling that either can be sold or let. No account of capital gains taxes is taken in this section. In many economic contexts, the behaviour of a risk neutral agent is the same as that of an agent acting in a certain environment. This conclusion does not, however, apply to the problem analysed in this paper. The reason for this is that in taking a particular course of action (to let the dwelling) the landlord retains the option of making a further decision at a later date when new information is revealed. To describe the factors that influence the reservation rents in such a dynamic stochastic framework, I will evaluate the decisions made by a potential landlord who has a three-period planning horizon.

The decision whether to let or to sell a dwelling is treated in the same way as Pindyck (1991) analyses irreversible investments in an uncertain environment. A crucial point is that my model takes account of the trivial fact that selling a dwelling today 'kills' the opportunity to sell the same dwelling tomorrow.

As shown in figure 1 the decision to sell or let is taken at the start of period 1. At that point in time both the market price of the dwelling (P_1) and the rent (r_1) are observable. The economic consequences of a sale are therefore known with certainty. The consequences of letting are composed of one certain component, the first period rent, and one uncertain component. The value the potential landlord attaches to the uncertain component depends on three factors: the expected future prices of the dwelling, expected future rents, and the range of possible actions taken by the house owner herself in the future.

The third factor will lead to differences in the reservation rent of a risk-neutral landlord facing probability distributions over future prices and rents, and a potential landlord who makes her decisions in a certain environment. This is seen by inspection of the decision tree in figure 1. When a potential landlord decides whether to sell or to let in the first period, she will take into account that if she lets in period 1 the option to choose whether to let or sell in period 2 will be retained. This decision is made after the market rent and the price of period 2 are observed.

Before turning to the optimisation of the owner, I will make some assumptions on the stochastic processes that generate rents and prices. Prices and rents of a period are revealed at the beginning of a period, i.e. before the landlord/owner makes her decision. Furthermore I assume that the 'stochastic noise' of the period two rent and price are independent⁷. Realisations of the period two price affect the expected house price of period three. Expected period three price is written as (7).

$$E(P_3 | P_2) = (1+k) E(P_2) + \beta (P_2 - E(P_2)) \quad (7)$$

Different values of β give us different stochastic processes for the house prices. If $\beta=0$, growth rates of house prices are negatively serially correlated. Prices are expected to revert to a known pre-determined trend within one year following a stochastic shock. In this case, the realisation of P_2 will not contain any information on expected period three price as the trend and 'white

noise' determine house prices. A β equal to $(1+k)$ implies that house prices are a random walk process, with a trend. In this last case, a realisation of P_2 can be said to determine $E(P_3)$, and there is no reversion towards any pre-determined trend. The rule determining whether to sell or let after the period two price and rent have been revealed can simply be written as (8a).

$$P_2 > r_2 + E(P_3 | P_2)/(1 + \varphi) \quad \text{then sell the dwelling, if not let} \quad (8a)$$

Inserting (7) into (8a) and solving for P_2 gives (8b). It can be said that while (8a) represents an intuitive interpretable structural form, (8b) is a reduced form. Equation (8b) expresses the minimum P_2 needed to make a sale profitable without using P_2 on the right hand side of the inequality.

$$P_2 > W(r_2) = \frac{r_2}{1 - \frac{\beta}{1 + \varphi}} + \frac{(1 + k) - \beta}{(1 + \varphi) - \beta} E(P_2) \quad \text{then sell the dwelling, if not let} \quad (8b)$$

The price that leaves a risk neutral landlord indifferent between selling and letting equals the expected value of hiring out in period 2. This depends both on realised rent and on how the realised period two price affects the expected period three price. In the terms of (7) one can say that the indifference price depends on the magnitude of the parameter β . The expectation held in period 1 of the value of being able to make a choice in period 2 is a weighted sum of the expected price in period 2 given that the owner will choose to sell in period 2, $E(P_2 | P_2 > W(r_2))$, and the expected value of letting in period 2 given that the dwelling is hired out, $E(V(h_1, h_2, s_3 | P_2 < W(r_2)))$. The weights are the probabilities of each action being optimal. The probability of selling being optimal is:

$$\pi_2(s) = \int_{-\infty}^{\infty} \int_{W(r_2)}^{\infty} f(P_2) dP_2 g(r_2) dr_2 \quad (9)$$

Where $f(\cdot)$ and $g(\cdot)$ are the densities of P_2 and r_2 . As the possibility of keeping a dwelling vacant is ignored in this paper, the probability of hiring out the dwelling in period 2 is simply $\pi_2(h) = 1 - \pi_2(s)$.

The probabilities of each of the two strategies being optimal will of course also depend on the strength of the inter-dependency between the realised period two price and the expected period three price. At the end of this section I will, rather loosely, discuss how both these probabilities and other results of the paper depend on the form of the price process - measured by β .

The expected market price given that the owner chooses to sell the dwelling must exceed the unconditional expectation in the distribution of the market price. Analogously, the expected payoff of letting given that this action is chosen must exceed the unconditional expectation.

$$E(P_2 | P_2 > W(r_2)) \geq E(P_2) \quad (10a)$$

$$E(V(h_1, h_2, s_3 | P_2 < W(r_2))) \geq E(V(h_1, h_2, s_3)) \quad (10b)$$

If both $\pi_2(s)$ and $\pi_2(h)$ are positive, the weak inequality symbols in (10a) and (10b) can be replaced by strong inequalities.

The results we have seen so far can be used to derive the expected value of still being in possession of the dwelling in the beginning of period 2 ($E(U_2)$). This is equivalent to the concept 'expected continuation value', see Pindyck (1991). My solution technique where the value is calculated at each node is somewhat similar to the 'extended decision tree' approach used by Capozza and Sick (1991) in their analysis of the value of long-term leases of land.

$$E(U_2) = \pi_2(s) E(P_2 | P_2 > W(r_2)) + \pi_2(h) E(V(h_1, h_2, s_3 | P_2 < W(r_2))) \quad (11)$$

The results from the discussion of what is happening at node two in the decision tree make it possible to return to the principal question of the paper, i.e. what is the lowest net rent after tax that will induce the owner of an extra dwelling to let it rather than selling? The solution of this problem is given in equation (12):

$$r_1^* = P_1 - E(U_2)/(1 + \varphi) \quad (12)$$

As in the certainty case the after-tax net reservation rent can be transformed to a gross rent paid by the tenants:

$$g_1^* = c_r + r_1^*/(1 - \tau) \quad (13)$$

In order to simplify, the operating costs of rented dwellings are treated as non-stochastic. Letting operating costs be stochastic will not alter the qualitative conclusions.

2.3 Comparison of reservation rents under certainty and uncertainty

Equations (3) and (12) can be used to describe the difference, D , between the two reservation rents derived in the preceding sections. This difference will be termed the 'discounted option value'. Assumption (A-1) will be kept throughout the comparison. The reservation rent r_1^* is calculated using information on the entire distribution of the stochastic variables, \hat{r}_1 refers to the certainty case. These two cases are compared under the assumption that expected prices and rents under uncertainty are equal to the 'expectations' held in the certainty case.

$$\begin{aligned} D &= \hat{r}_1 - r_1^* \\ &= (E(U_2) - E(P_2))/(1 + \varphi) \end{aligned} \quad (14)$$

The discounted option value might be interpreted as the expected value of the option to choose whether to sell or let in the light of new information at the start of period 2. This value must be positive. Equation (15) confirms this. Note that, because of the stochastic independence

between r_2 and P_2 , $E(P_2) = \int_{-\infty}^{\infty} P_2 f(P_2) dP_2$.

$$\begin{aligned}
D(1 + \varphi) &= \int_{-\infty}^{\infty} \left\{ \int_{-\infty}^{W(r_2)} W(r_2) f(P_2) dP_2 + \int_{W(r_2)}^{\infty} P_2 f(P_2) dP_2 - \int_{-\infty}^{\infty} P_2 f(P_2) dP_2 \right\} g(r_2) dr_2 \\
&= \int_{-\infty}^{\infty} \left\{ \int_{-\infty}^{W(r_2)} [W(r_2) - P_2] f(P_2) dP_2 + \int_{W(r_2)}^{\infty} [P_2 - P_2] f(P_2) dP_2 \right\} g(r_2) dr_2 \quad (15) \\
&= \int_{-\infty}^{\infty} \int_{-\infty}^{W(r_2)} [W(r_2) - P_2] f(P_2) dP_2 g(r_2) dr_2
\end{aligned}$$

Clearly $D(1 + \varphi)$ is positive, in view of the limits of integration of the inner integral. This explains why the net reservation rent before tax is lower under uncertainty than in the certainty case. An owner of an extra dwelling can, if she lets the dwelling, use the rental market as a kind of insurance against low market prices in period two. The option value, or the value of this insurance, consequently depends on the shape of the price distribution below the expected payoff of letting strategy. I argued that using three rather than two periods did not add anything substantial to the analysis of reservation rents of a landlord acting in a certain environment. When uncertainty and the value of waiting for new information is incorporated into the analyses it is seen that the use of more than two periods in the analyses is crucial for the results obtained.

It should be emphasised that in the certainty case I found that the set of rental contracts profitable for both landlords and renters was likely to be empty. The discussion of reservation rents in a model where future prices and rents are probability distributions shows that the owners' valuation of future flexibility might be a source of mutual advantageous contracts. Given the actual size of the rental sector in both Norway and other countries, it is clearly satisfactory to find such a source of mutual advantageous contracts.

Qualitatively, all of the results in section 2 hold for any β within the interval $(0 \leq \beta \leq (1+k))$. To demonstrate this and to show the effects of changes the value of β , two different stochastic

processes are compared, one white noise with a trend (WNT) in which $\beta=0$ and the other a 'pure random walk' (RW) with $\beta=(1+k)>0$. For any price realisation P_2 below $E(P_2)$ the pay-off of the letting strategy will be lower under RW than under WNT. The reason for this is of course that the owner under RW cannot escape from an unexpectedly low P_2 by letting. The low period two price lowers the expected price of period three. This again leads to higher probabilities of a sale for all low prices ($P_2 < E(P_2)$) under RW than under WNT. Thus, when the parameter β has a value equal to its upper limit, the owner cannot use the rental market as an insurance against low prices. At low realisations of P_2 the ex post value of the tenure flexibility is lower under RW than under WNT. This does not imply that the value of the real option to change tenure of a dwelling is decreasing in β . To demonstrate this RW and WNT under high realised values of P_2 is compared.

The term 'high realisation of the period two price' refers to a realisation in excess of its expectation. Under WNT the owner will be inclined to sell when facing high prices. If she lets to a high market rent she will expect to lose the good price of the dwelling. For high prices the selling probability will be lower under RW than under WNT. Under RW one does not have to cash in the good price today as one expects it to be there also in the next period, because there is not expected to be any reversion downwards to the trend. Tenure flexibility allows the owner to take advantage of high rents in a period without expecting to lose on the selling price. That is, the ex post value of the real option is, for high P_2 , higher under RW than under WNT.

To draw firm conclusions on how selling probabilities and the option value depends on the value of β , when aggregated over the whole distribution of P_2 , it would be necessary to make additional assumptions on the characteristics of the probability distributions. Such an analysis is beyond the scope of this paper.

3. Reservation rents and uncertainty

One of the main results of this paper is that reservation rents will be lower when the potential landlord perceives future prices as uncertain compared with a situation when future prices are known with certainty. I will now discuss how a transition from one distribution of future prices to another that exhibits more uncertainty affects the value of ownership of a dwelling that can

be sold. It is first necessary to define what is meant by more uncertainty. More uncertainty, or increased variability, can be understood as an increase in the probabilities of both high and low realisations of the price with its expectation being unchanged. Rothschild and Stiglitz (1971) provide an intuitively appealing way of making this statement more concise, which also leads to an easy way of showing what happens to the reservation rents as uncertainty is increased.

A low realisation is a period two price that leads the owner to postpone the sale, while a high realisation is a price that would lead the owner to sell. Thus the owner collects the upside of the increased uncertainty of the period two price and protects herself against the downside by letting. This increases the continuation value and consequently the value of the real option. In periods of large uncertainty about future prices of owner-occupied housing one should expect low rents and/or a high supply of rental housing.⁸

The results of this section can be interpreted in the light of results from an econometric time-series study of home ownership rates in the US by Rosen et al (1984). A demand function for homeownership was estimated under the assumption that housing supply is perfectly elastic. Rosen et al found that uncertainty had a strong negative effect on homeownership rates. This was interpreted as due to the choices of risk averse demanders of housing services. My study shows that one should expect a positive correlation between the supply of rental housing and the expected volatility of house prices. These two explanations are by no means competing statements, they should rather be regarded as different parts of the same picture.

4. A Numerical Example

The theoretical analysis of the determination of reservation rents presented above will now be illustrated through a numerical example. It must be stressed that the parameters of the example are not intended to describe the Norwegian housing market. A numerical example such as this cannot replace a thorough empirical analysis. To make the exposition as clear as possible, a three-period time frame has been used in the presentation of the theoretical framework. The numerical results reported are calculated for a ten-year planning horizon⁹.

The net reservation rent under uncertainty is found as the difference between the period 1 price of the housing unit and the discounted expected continuation value of period two, see equation

(12). However, the continuation value of period two depends on the continuation value of period 3, and so on. The numerical simulation routine starts from the end of the 'time-line' by calculating a continuation value and an expected market rent for the period before the terminal period. By using these values the expected continuation value and market rent of the period before that is calculated. This procedure is continued until the continuation value of period 2 is found. Each of these steps involves evaluation of the probabilities of letting and selling being optimal and the expected pay-off of each of these strategies. The resulting period 1 net reservation rent is transformed to a gross reservation rent using equation (13).

In this example, the reservation rent of a potential landlord who owns a dwelling that can be sold at a price of NOK¹⁰ 500,000 at the beginning of period one is calculated. The annual operating costs c_t and c_0 (including 'normal' maintenance) are set to NOK 12,500 in the first year, and are expected to increase at the same rate as inflation, which is assumed to be 3%. The nominal interest rate is set constant to 8.5% throughout the ten years. Marginal tax rates on capital income in Norway are equal to 28%, and this is also assumed to be constant over time. Thus, a constant after-tax discount rate equal to 6.12% is used.

Expected prices of housing in the future

The numerical results are heavily influenced by the way it is assumed that the landlord forms her expectations on future market rents and dwelling prices. The first period-price P_1 is assumed to be observable. For the subsequent periods, a landlord's price expectations are probability distributions rather than points. For convenience it is assumed that the probability distributions of prices are normal.

$$P_t \sim N(\mu_t, \sigma^2) \quad t=2,3,\dots,T \quad (16)$$

The expectation of the distribution is assumed to grow at a constant rate:

$$\mu_t = (1+k)\mu_{t-1} \quad t=2,3,\dots,T \quad (17)$$

The standard deviation in the distribution of the expected price, σ , is assumed to be constant over time. Equations (16) and (17) describe the expectations of future prices held by the landlord at the beginning of period 1. Furthermore, the potential landlord does not expect her

expectations to change over time. This implies that when she in the beginning believes that the expectation of the period 6 price is $P_1(1+k)^5$, she still believes this at the beginning of period 5¹¹. Prices observed in periods 2, 3, 4, and 5 are thus not expected to affect the expectations for period 6 prices. This is a result of the specific stochastic process used in this example. Expected house prices are assumed to evolve along a known trend, but are allowed to fluctuate randomly around this deterministic trend. In such a stochastic process realised prices prior to period t does not contain information relevant for expected prices of period t . In the terminology of equation (7) I am setting $\beta=0$.

The expectation mechanism used in this paper might be given a theoretical justification. The trend can be considered as a (known) trend in construction cost. A long-run equilibrium price of housing will equal total construction cost. The expectation mechanism here can then be stated as a joint hypothesis that potential landlords believe that the market in period will be in a long-run equilibrium and that future market prices will fluctuate unsystematically around a known path of long-run equilibrium prices. The parameters describing the stochastic process that (is expected to) generates market prices of the dwelling considered here are:

$$\mu_1 = 500,000 \text{ NOK}$$

$$\sigma = 30,000 \text{ NOK}$$

$$k = 0.04$$

The ratio of imputed rental income to the market value of a housing unit, a , depends on three factors: the assessed value of the unit which on average is about 30% of the market values, a deduction in the assessed value of NOK 50,000. These two factors give the base of the assessment of imputed rental income. Imputed taxable rental income is 2.5% of the described base. These three factors taken together give an a -value of 0.5%.

Expected future rents

Expected future rents are calculated using the same line of reasoning as when the reservation rents were calculated, i.e. expected after-tax return on rental housing capital equals the normal after-tax return. With the white noise price process (i.e. $\beta=0$) rents too are white noise with an

expected growth from one period to the next of k . The standard deviation of the expected market rents is set at 30% of the market rent. The effect of major changes in this assumption on the reservation rent of the first period is negligible.

Results

Under these conditions the monthly gross reservation rent, g_1^* , is NOK 1,910. Hence, the annual gross reservation rent is equal to the sum of operating costs and 2.1% of the value of the dwelling. In comparison, it can be noted that under the same set of assumptions the monthly gross reservation rent in the certainty case (in other words calculated using equation (4)) is as high as NOK 2,808. The annual gross rent in this case is 4.2% of the value of the dwelling plus operating costs. The monthly user cost of a similar dwelling calculated using equation (5) is NOK 1,929 (the yearly user cost is operating costs plus 2.2% of the value of the dwelling).

To illustrate the inter-dependency between reservation rents and the variability of expected future prices, simulations of reservation rent with high variability in the expected future prices ($\sigma = \text{NOK } 50,000$) and low variability ($\sigma = \text{NOK } 10,000$) have also been made. Increasing σ from 30,000 to 50,000 decreases the reservation rent by slightly more than 45%, whilst reducing σ from 30,000 to 10,000 increases the reservation rent by almost 40%.

The reservation rent in the absence of uncertainty, where the value of the tenure-flexibility option associated with a rental dwelling equals zero, is 45% higher than the user cost. The reservation rent is lower than the corresponding user cost under the uncertainty specified in the example of this section. This is a clear illustration of my claim that when the potential landlord's decision problem is considered within a stochastic and dynamic framework, it is possible to find a rent that simultaneously makes renting a sensible decision for a household and letting a rational action by the landlord. The demonstration that uncertainty in future market prices of dwellings might produce a non-empty set of mutual advantageous contracts between renters and landlords is the main contribution of this paper.

5. Concluding Remarks

This paper has shown that even if it is assumed that all agents are risk neutral, one gets both qualitatively and quantitatively different conclusions on potential landlords' decisions using a dynamic-stochastic framework than when the decisions are considered within a certain two-period framework. The most important conclusion is that even if there is a tax advantage associated with owner-occupation, uniform marginal tax rates, uniform expectations and no credit rationing, mutually advantageous contracts between a landlord and tenant are possible.

I have focused on the decision made by a single agent who chooses either to sell or let a dwelling. To get a more complete (but still partial) description of the supply of rental housing, the distribution of potential landlords will have to be described. Furthermore, the results of the optimisation of a single landlord facing an uncertain environment cannot be interpreted as any complete description of an equilibrium. Still I claim that the mechanisms analysed in this paper are an essential feature of equilibria in rental markets and of the inter-dependencies between the rental and other markets.

A major weakness in the analysis is that the action set of the potential landlord has been restricted to include only two possible actions - sell or let. It would have been preferable to include the possibility of keeping the dwelling vacant for one or more periods. Such an extension could be very important, particularly if the probability distribution of the operating cost of a dwelling that is hired out differs significantly from that of a vacant dwelling.

An interesting way to extend the analysis of this paper would be to formulate a simultaneous model of the rental market and the owner occupation market where the supply of both rental housing and owner-occupied dwellings are affected by such considerations as those examined in this paper. Households' demand for housing could also be described in the same terms, for the households who want to buy an owner occupied dwelling the rental market would then be a place to stay while they search for the right dwelling at an advantageous price. In such a framework the cost of a household's purchase of an owner-occupied dwelling can be understood as consisting of the sum of the price of the dwelling and the cost of killing the option to enter the owner-occupied segment of the housing market at a later date. This way of treating the demand for owner-occupied housing may provide new insight into the

determinants of tenure choice.

An equilibrium model of a housing market with different tenures and tenure flexibility could also give us important insight into mechanisms that may stabilise or destabilise both regional and national housing markets.

Notes

¹ I have not been able to find any literature on tenure flexibility, or in other words on the tenure choice on the supply side of the housing market. There is however a well developed theoretical and empirical literature on tenure choice on the demand side of the housing market. See (amongst others) Börsch-Supan (1986) and Henderson and Ioannides (1983).

² Kreps (1990) describes Bellman's principle in the following way: *If a strategy is optimal for each point in time at that point in time, given that an optimal strategy will be used thereafter, then the strategy is optimal.*

³ That is, capital gains on dwellings that have been used by the owner at least 53 weeks during the last two years are not taxed.

⁴ Under the Norwegian tax rules, equation (1) applies to all dwellings whose capital gain is taxed. An example may clarify the meaning of this. A household bought a dwelling in 1980 and owner-occupied it up to 1995 when they moved. Had they sold it immediately they would not have had to pay capital gains tax. Had they let the dwelling for more than a year between moving out and selling they would have had to pay capital gains taxes. The base of this tax would be the nominal difference between the 1980 purchase price and the selling price, rather than the capital gains accrued through the renting period. The Norwegian tax system makes no inflation adjustment.

⁵ The interest rate on loans and bank deposits is, as a simplification, throughout the paper assumed to be equal. Consequently, the analysis applies for both mortgage and equity financed rental dwellings.

⁶ That is, the cost of keeping a rental dwelling at a given quality is expected to be higher than the corresponding cost for a similar owner-occupied dwelling. Sweeney (1974) showed that quality deterioration is expected to be faster in rental than in owner-occupied dwellings, because of lower maintenance intensity.

⁷ This assumption is primarily made for convenience. Without this assumption the algebra in the paper would get quite messy.

⁸ A formal proof of this proposition, using the tools of Rothschild and Stiglitz (1971), is available from the author upon request.

⁹ To perform the calculation a simulation routine in the statistical package SAS has been developed.

¹⁰ NOK 7.75 is approximately equal to 1US\$.

¹¹ It should be noted that the variables that enter our analysis of the formation of the first period reservation rent are not the expectations held in later periods, but the expectations that the agent is expecting to hold in future periods.

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Cost Dispersion, Re-entry Costs and Rental Housing Markets

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Abstract

This paper analyses the tenure distribution of the housing stock in a competitive housing market where landlords maximise expected profit and consumers minimise the cost of their housing consumption. The housing stock is assumed to be tenure flexible. An owner of a rental housing unit can either sell it at the prevailing market price or let it. In the presence of positive re-entry costs a sale will reduce possible future rental profitability.

Within a stochastic framework it is shown that the return on rental housing consists of rental income and the value of the opportunity to utilise information revealed to the owner in the future. This paper demonstrates that this opportunity to utilise future information can be regarded as a real option. When the value of this tenure flexibility option is accounted for one sees that equilibrium rents can be lower than the user cost of a comparable dwelling. This conclusion is showed to hold even when tax advantages of owner-occupied housing and the value of the consumers' real option to change tenure are taken into account.

Keywords: Rental Housing, Tenure Choice, Real Options, User Costs, Entry/exit

0. Introduction

Units of housing capital can be used by owner-occupiers or tenants. There is no physical reason for some units to be rental units and others to be owner-occupied. Furthermore, there is no reason why a housing unit should stay over time within one particular tenure. This phenomenon may be termed the tenure flexibility of the housing stock (Nordvik, 2000). The option of converting rental housing to owner-occupied housing yields a positively valued real (put) option. One part of the return on rental housing is the possibility of exercising the put option. In econometric work on housing choices where rental housing is assumed to be priced according to a no-arbitrage condition the value of this option is ignored. This implies that if such option values are empirically important, many econometric models of tenure choice are based on misspecified alternative costs.

The paper develops a simple model of a housing market. Rents are determined so that a marginal supplier earns zero profit, while intra-marginal suppliers earn positive profit. A stochastic price process produces uncertainty on whether a marginal supplier in a particular period will become an intra-marginal supplier next period. This uncertainty produces together with positive re-entry costs and cost heterogeneity among landlords a positively valued tenure flexibility option in equilibrium also for a marginal supplier.

Even though there is a tax advantage associated with owner-occupation, it remains a fact that private rental housing amounts to a quite large share of the housing markets in most countries. Explanations of this phenomenon have been sought in interpersonal differences in marginal tax rates, (Swan, 1984), and in the fact that transaction costs for owner-occupiers are significantly larger than for renters. This last argument is shown to be stronger the shorter the expected spell in a dwelling is (Rosenthal, 1988 and Henderson and Ioannides, 1989). There also exists some evidence that liquidity constraints bias housing demand towards rental housing (Haurin, 1991). Meyer and Wieand (1996) showed in an equilibrium model of a housing market where housing units are tenure flexible that there might exist mutually advantageous contracts between risk averse landlords and consumers if the ability to diversify risk differs between landlords and consumers. The basic idea is that an owner-occupied dwelling is such a large part of the portfolio of most consumers that owner-occupation prevents them from diversifying.

All these types of explanations are probably parts in a complete description of rental housing markets. Hence, this paper is not searching for explanations of the presence of rental housing markets that replace the reasons analysed in the literature referred above. Rather, in analysing some combined effects of re-entry costs and tenure flexibility of the housing stock, I identify and explore some mechanisms that together with the above mentioned literature contributes to the understanding of private rental housing markets.

The basic question underlying this paper is whether the possibility to exercise a tenure flexibility option may affect the return on private rental housing, and whether this has any effect on market rents. As will become evident, I give affirmative answers on both questions. My research strategy was to formulate a simple model that enabled me to focus on tenure flexibility and hence to abstract from most other difficult aspects of housing markets in general and tenure choice in particular. This research strategy could be viewed as a formulation of an 'analytic experiment'. Quite a lot of work remains in incorporating the mechanisms of this paper into theoretic models of housing markets that has a closer resemblance to real world housing markets. And of course, even more work is needed before these mechanisms can be an integrated part of empirical work on tenure choice. However, the mechanisms analysed in this paper gives quite strong arguments against ignoring supply-side effects when interpreting empirically estimated tenure choice equations.

Section 1 presents a stochastic process for asset prices of housing capital and some of the simplifying assumptions on which the model is built. Supply decisions of potential landlords are described in Section 2, while Section 3 explores tenure choices of cost minimising consumers. Equilibrium in the model is analysed in Section 4. Concluding remarks are given in Section 5.

1. Background

As already noted, the markets studied in this paper are in many respects quite simple compared to real world housing markets. The most important deviations are presented in this Section. Housing units are assumed to be homogeneous, and consumers do not have preferences over tenure. Markets of both rental and owner-occupied housing are assumed to be competitive in so far as neither consumers nor landlords have power to set prices. All agents in the market are sharing the same expectations over future house prices. All agents on

both the sides of the market are assumed to be risk-neutral. Furthermore, both consumers and landlords face the same after-tax interest rate ϕ on a perfect capital market. None of these assumptions are intended to be empirical claims of the working of housing markets, they are a description of the environment under which the analytic experiment of the paper is performed.

At any point in time t the asset price P_t is observed before any action is taken. The price of period $t+1$ is assumed to be a realisation of a stochastic variable with a known expectation $E(P_{t+1})$. The distribution of the period $t+1$ price is affected by the realisation of P_t . As I throughout the paper deals with the choices made by consumers and landlords after P_t is revealed I treat P_t as a predetermined non-stochastic variable. Consequently $E(P_{t+1})$ and the density $f(P_{t+1})$ is not written as conditional on P_t .

At $t+1$ when the realisation of P_{t+1} is revealed agents revise their expectation of the central moment of the distribution of the price of period $t+2$. This expected $t+2$ price given information on the realisation of the period $t+1$ price is denoted $E(P_{t+2}|P_{t+1})$. Thus, there may be some serial correlation in the price process. Poterba (1984) showed in a no-arbitrage setting that demand shocks leads to short-run over-shooting in house prices. In the longer run house prices adjust to a new long-run asset market equilibrium price. The driving force of this effect is that housing supply (or the size of the housing stock) can not be adjusted instantaneously to changing demand. This mechanism will lead to a mean reverting structure in time series of house prices. Equation (1) gives one particular specification of a price process that exhibits the desired mean-reversion property and at the same time is quite simple. The process is simple in so far as the 'mean reversion component' of the expected price of a period is specified as being proportional to the forecasting error of the preceding period.

$$(1) \quad E(P_{t+2} | P_{t+1}) = (1 + k)E(P_{t+1}) + \beta(P_{t+1} - E(P_{t+1}))$$

A $\beta > 0$ will emerge as long as forecasting errors are results of demand shocks that, at least to some extent, affects demand also in future periods, and there is some inertia in the adjustment of housing supply.

In addition to the theoretical arguments for house prices being mean reverting, estimated error correction models of house prices also support this hypothesis. A majority of these models finds that the growth of house prices correlates significantly and negatively with the fore-

casting error of the preceding period. Hort (1998) reviews some of these results. A negative correlation implies that the value of the parameter β is less than $(1+k)$. Further discussions of properties of a process like (1), for different values of β , are given in Nordvik (2000).

The information that can be inferred from a price realisation varies with the value of the parameter β . A parameter value equal to zero implies that a price realisation P_{t+1} does not give any information relevant for a revision of expected future prices. However, in this case the price realisation leads to a one-to-one revision of the difference between the $(t+1)$ and the discounted $(t+2)$ price. Later in the paper this difference will be showed to play an important role. At a β -value equal to $(1+k)$ the price process will be a random walk with a trend. In this case P_{t+1} can really be said to contain information on $E(P_{t+2})$ as it is the only information needed to make a prediction. Consequently there is no inertia in the price process and realisations of P_{t+1} will not contain any information relevant for a revision of the expected difference between the $(t+1)$ and the discounted $(t+2)$ price.

In the same way as house prices the period t rent (r_t) is observed at the start of period t . Both demanders and suppliers are assumed to have perfect foresight in so far as they know which period $t+1$ rent (r_{t+1}) each realisation P_{t+1} will yield. The theme of this paper is how a tenure flexible housing stock is divided between landlords and owner-occupiers for any given market prices. Therefore I will not close the model by going into how these prices are arrived at. One possibility is to think of the asset prices of housing capital as determined by a stochastically generated number of new consumers.

2. Supply of Rental Housing

Supply of rental housing is in this paper essentially treated in the same way as in the partial supply analysis of Nordvik (2000). Landlords compete with owner-occupiers and must sell or buy housing units at the prevailing market price. The planning horizon of landlords, who are maximising the net present value of their stream of income, is taken to be three periods long. That is, at every period, t , no landlords are considering hiring out their housing unit in period $t+2$. The assumption of a finite planning horizon is made because it makes the calculus less messy, as it implies, as shown in Nordvik (2000), that the optimisation of the landlords can be described by a straightforward application of Bellmans principle.

In the three-period economy analysed in this paper I will start by analysing the let decisions in period $t+1$. Two strategies are open to a potential landlord, either to let or to sell (eventually not to buy). Those who get an expected pay-off from the letting strategy at least as high as the market price of the housing unit will let. The period t decisions are a little bit more complex. For letting to be profitable the expected pay-off from the letting strategy must be at least as high as the sum of the market price of the housing unit and the value of the possibility (or option) to re-enter the rental market next period. It should be noted that the purpose of the paper is to analyse how letting decisions are affected by the fact that housing units in the future can be moved from one tenure to another. Hence, the period $t+1$ decisions are analysed here only because it is a building block in the analysis of the period t decisions.

Each landlord is characterised by a cost of being in the rental market, (c_t^i, c_{t+1}^i) . The cost of being in the rental market is continuously distributed on the interval (c_t^-, c_t^+) according to the density $h_t(c_t)$. These densities are known by all potential landlords (and also by demanders). The main component of this cost is operating costs. One can also think of these costs to be affected by capital gains taxation. Most countries tax (nominal) capital gains on realisation rather than on an accrual basis. Housing units that have been rented for a long time can consequently have a quite large tax credit. The value of this pushes down the cost of staying a landlord, that is c_t^i . Different buying dates of the rental stock provides under this interpretation an explanation of the spread in the distribution of the landlord costs.

If landlord i withdraws from the rental market by selling her unit in period t , she can of course re-enter the rental market by buying a unit when she observes a new house price at the start of period $t+1$. However, her period $t+1$ operating costs when re-entering the rental market $c_{t+1}^{re,i}$ may be higher than they would have been had she not left the market in period t . If δ_{t+1}^i is the cost disadvantage of leaving and re-entering the market, the operating cost upon re-entering can be written as $c_{t+1}^{re,i} = c_{t+1}^i + \delta_{t+1}^i$. A positive shift in the operating costs when re-entering the rental market can be traced back to many different sources. The shift can be caused by transaction costs or by reduced efficiency in running rental housing during the time the landlord are 'out of business'. Finally, and may be most important, when a dwelling is sold the tax credits must be paid. When re-entering the rental market a landlord starts off with zero tax credit. These causes and their relative importance will not be further explored in this paper.

The profitability of hiring out depends of course on both the developments of rents and house prices. A landlord who buys or keeps a housing unit in t will in this period collect the market rent r_t . After the market price of next period is revealed she will chose whether to let or sell the dwelling. She will let if:

$$(2) \quad P_{t+1} < (r_{t+1} - c_{t+1}^i) (1-\tau) + (1+\varphi)^{-1} E(P_{t+2} | P_{t+1})$$

τ is the tax rate employed on net rents that the landlord is facing and r_{t+1} is the pre-tax rent. The tax rate is assumed to be equal for all potential landlords. One can think of (2) as a 'landlord participation constraint'. If (2) applies for a potential landlord she will be an 'active landlord'; otherwise she will step out of the rental market by selling the housing unit. In short the landlord participation constraint will be termed the participation constraint in the rest of the paper.

A marginal supplier is a landlord who earns zero profit (in excess of the normal rate of return). The operating cost of the marginal supplier, c_{t+1}^M , is defined by (3):

$$(3) \quad r_{t+1} = c_{t+1}^M + \{P_{t+1} - (1+\varphi)^{-1} E(P_{t+2} | P_{t+1})\} (1-\tau)^{-1}$$

By inserting (3) into (2) and rearranging, one sees that landlord i will hire out in period $t+1$ if she is more cost efficient than the marginal supplier is. Hence, the participation constraint reduces to $c_{t+1}^M - c_{t+1}^i > 0$. By definition c_{t+1}^M is a function of the price realisation of period $t+1$. Equation (3b) offers another way of expressing the competitive period $t+1$ rent, where the expected price process (1) is inserted.

$$(3b) \quad r_{t+1} = c_{t+1}^M + \frac{P_{t+1}(1+\varphi-\beta) + E(P_{t+1})(1+k-\beta)}{(1+\varphi)(1-\tau)}$$

As P_{t+1} increases, letting (and renting) becomes relatively less attractive. A positive shift in P_{t+1} will thus reduce the number of potential landlords who actually chooses to let. The most inefficient landlords (i.e. with the highest operating costs) will leave the rental market first. Thus, the operating costs of the marginal supplier of rental housing will be decreasing in P_{t+1} .

For any specific landlord i an indifference price D_{t+1}^i , at which she is indifferent between letting and selling, can be defined. This particular value D_{t+1}^i is the unique solution to the equation $c_{t+1}^M(D_{t+1}^i) - c_{t+1}^i = 0$. If the price is higher than D_{t+1}^i she sells, if it is lower she lets. This definition of D_{t+1}^i can be used to write an expression for landlord i 's expected value of letting a dwelling in t $\Pi^i(r_t)$:

$$(4) \quad \begin{aligned} \Pi^i(r_t) = & (r_t - c_t^i)(1 - \tau) + (1 + \varphi)^{-1} \int_{-\infty}^{D_{t+1}^i} [(r_{t+1} - c_{t+1}^i)(1 - \tau) + (1 + \varphi)^{-1} E(P_{t+2} | P_{t+1})] f(P_{t+1}) dP_{t+1} \\ & + (1 + \varphi)^{-1} \int_{D_{t+1}^i}^{\infty} P_{t+1} f(P_{t+1}) dP_{t+1} \end{aligned}$$

Then $0 = \int_{-\infty}^{D_{t+1}^i} P_{t+1} f(P_{t+1}) dP_{t+1} - \int_{-\infty}^{D_{t+1}^i} P_{t+1} f(P_{t+1}) dP_{t+1}$ is added to (4) and the equilibrium rent from (3) is inserted and one gets after some rearranging (4b).

$$(4b) \quad \begin{aligned} \Pi^i(r_t) = & (r_t - c_t^i)(1 - \tau) + (1 + \varphi)^{-1} \int_{-\infty}^{D_{t+1}^i} (c_{t+1}^M - c_{t+1}^i)(1 - \tau) f(P_{t+1}) dP_{t+1} \\ & + (1 + \varphi)^{-1} \int_{-\infty}^{\infty} P_{t+1} f(P_{t+1}) dP_{t+1} \end{aligned}$$

The expected value of selling in period t (S_t^i) equals the sum of the market price and the value of the option of re-entering the market by buying and letting in period $t+1$. A landlord i who sold in t will re-enter the market in $t+1$ at prices below Q_{t+1}^i , this indifference price is defined by (5).

$$(5) \quad Q_{t+1}^i = (r_{t+1} - (c_{t+1}^i + \delta_{t+1}^i))(1 - \tau) + (1 - \varphi)^{-1} E(P_{t+1})$$

By comparing (2) and (5) one sees that as long as the cost disadvantage of leaving and re-entering the market is positive the price that leaves an individual who has stopped letting

indifferent between re-entering and staying out is strictly lower than the indifference price of an active landlord. Using (5) and inserting from (3) one sees that it will be profitable to re-enter the supply side of the rental market as long as $c_{t+1}^M(P_{t+1}) > c_{t+1}^i + \delta_{t+1}^i$.

The expected value of selling the dwelling in period t (S_t^i) is:

$$(6) \quad S_t^i = P_t + (1 + \varphi)^{-1} (1 - \tau) \int_{-\infty}^{Q_{t+1}^i} [c_{t+1}^M(P_{t+1}) - c_{t+1}^i - \delta_{t+1}^i] f(P_{t+1}) dP_{t+1}$$

It should be noted that S_t^i is the expected value of selling calculated after the period t house price and rent is revealed to the potential landlord.

Like in period $t+1$ there is also a marginal supplier in period t , i.e. an owner whose expected pay-off from letting equals the expected pay-off from selling. Hence, her cost c_t^μ can implicitly be read out of a rearranging of the condition $\Pi^\mu(r_t) = S_t^\mu$. The relation between the operating costs of a marginal supplier and the market rent must therefore be as in (7):

$$(7) \quad r_t = c_t^\mu + \frac{P_t - (1 + \varphi)^{-1} E(P_{t+1})}{(1 - \tau)} - (1 + \varphi)^{-1} \left\{ \int_{-\infty}^{Q_{t+1}^\mu} \delta_{t+1}^\mu f(P_{t+1}) dP_{t+1} + \int_{Q_{t+1}^\mu}^{D_{t+1}^\mu} (c_{t+1}^M - c_{t+1}^\mu) f(P_{t+1}) dP_{t+1} \right\}$$

By definition the profit of the marginal supplier equals zero. Landlords with costs below those of the marginal supplier (these can be termed intra-marginal suppliers), earn a positive profit. Extra-marginal suppliers of rental housing earn zero profit by withdrawing from, or not entering, the rental market. One consequence of the stochastic nature of the price process, and consequently of rental demand, is that the reservation rent of the marginal supplier is pushed downwards by the expected value of being intra-marginal in next period.

The value of the specific tenure flexibility option in equation (7) has two components. For any realisation of the period $t+1$ house price below Q_{t+1}^μ , the marginal supplier μ will be an active landlord (i.e. she will let) even if she sold in the preceding period. Did she sell, she will earn a positive profit by buying a unit and let it. However, for such low price realisations the profit made by a re-entering landlord will, because of the positive re-entering costs, be lower than

the profit made by a landlord who stayed in the market. This is captured by the first component in the option expression in (7). At prices in between the two indifference prices the marginal supplier in period t earns a positive profit because she is more cost efficient than the marginal supplier in period $t+1$, is. For all prices in this interval the excess profit will be lower than the re-entering cost δ_{t+1}^{μ} .

Hence, the economic explanation of the existence of a positively valued real option connected to ownership to rental housing unit can in the particular model of this paper be traced back to three causes. Firstly, it is the stochastic nature of house prices. Secondly, it is the heterogeneity of landlords with regard to their operating costs. Thirdly, the fact that there is some kind of irreversibility in the choice of selling the dwelling. By this I am referring to the fact that there is a cost disadvantage associated with re-entering of the market. It should be noted that if the re-entering cost disadvantage δ_{t+1}^i , for all potential landlords, equals zero the two indifference prices will coincide, i.e. $Q_{t+1}^i = D_{t+1}^i$, and the option in (7) vanishes.

Equilibrium rents developed in other theoretical work on rental housing markets and tenure choice differs from my expression. The equilibrium rent described by others equals the first two terms of the right hand side of (7).¹ If there is some cost disadvantage associated with re-entry on the supply side of a rental housing market, ignorance of the (real option) value of optimal utilisation of information arriving later leads to a systematic overestimation of no-arbitrage, or equilibrium, rents.

Aggregate supply of rental housing in period t , is of course equal to the size of the set of potential landlords who has an operating cost below the operating cost of a marginal supplier c_t^{μ} . Furthermore it might be noted that aggregate supply is decreasing in the period t house price.

One minor technical point is worth noting. The expression (7) was derived under the condition that the ordering of the c_t^i 's is the same as the ordering of the c_{t+1}^i 's. This condition ensures that no landlord with a $c_t^i > c_t^{\mu}$ is able to make zero profit on a rent below what is given in (7). Had this condition not been fulfilled it is possible that some landlords with higher period t costs than the cost of the marginal supplier, had been able to make zero profit at a lower rent because of them having a high value of the real option.

3. Tenure Choice of Consumers

Consumers live for two periods. In short I term consumers in the first period of their life as young, consumers in their second period are termed old. The analysis of tenure choice within a single period must consequently deal with three different types of consumers. The three types are old tenants, old owner-occupiers and young consumers entering the housing market. As already noted housing units are treated as being homogenous. All consumers choose one housing unit and have access to a perfect capital market. No one has preferences over tenure. Housing choice under these conditions is a choice of tenure and a consumer chooses the tenure that gives him the lowest net present value of the housing costs.

First period housing choices of young consumers will affect the costs of housing consumption of the second period. The dependency between first period housing choice and second period cost works through two different channels. Firstly, if part of a consumer's wealth is held in the form of owner-occupied housing, he is of course exposed to changes in the asset price of housing. Secondly, if a consumer should want to change tenure at the start of the second period he would face moving costs. An implication of this is that first period choices must be regarded as the first steps of a dynamic plan for the consumers' housing consumption. At first instant it seems like a young household who is about to enter the housing market has four possible strategies, or combinations of renting (R) and owner-occupying (O) over its two period long lifecycle:

(R, R), (R, O), (O, R) or (O, O)

I will claim that it makes more sense to reduce this set of possible plans to two. That is: rent (or buy) a housing unit for the present period, and do whatever is advantageous at the start of next period. 'Whatever is advantageous at the start of next period' depends on the realisation of the stochastic market price, which will be revealed at the start of next period. Later in the paper it will be argued that it really makes a difference whether one thinks of the choice set as consisting of two or four strategies. This Section will give a thorough discussion of the costs of each of the two tenures. Some of the results of this discussion may be interesting in its own right. However, the main purpose is to shed light on the determinants of cost differences

between tenures. This is so because I assume that the sign of this difference determines tenure choice.

Before turning to the costs under each of the strategies, the phrase 'Whatever is advantageous at the start of next period' must be discussed a little bit closer. In the last period a consumer chooses the tenure yielding the lowest discounted housing expenses. Before turning to a more formal discussion of the choices, some symbols will have to be defined (all subscripts refer to period):

- m_{t+1} is the cost of moving into a rental housing unit
- M_{t+1} is the cost of moving into an owner-occupied housing unit
- o_t^i is household i 's operating costs
- $f(P_{t+1})$ is the density of the period $t+1$ price

Did the household owner-occupy in its first period, they will continue as owner-occupiers if:

$$(8) \quad r_{t+1} + m_{t+1} - P_{t+1} > o_{t+1}^i - (1+\phi)^{-1} E(P_{t+2}|P_{t+1})$$

If the inequality is reversed the household will move on to a rental unit. By replacing the 'larger than' in (8) with equality, equation (8b) which defines the price at which a sitting owner-occupier, i , will be tenure indifferent in the last period (V_{t+1}^i), is obtained.

$$(8b) \quad r_{t+1} + m_{t+1} - V_{t+1}^i = o_{t+1}^i - (1+\phi)^{-1} E(P_{t+2}|P_{t+1})$$

In interpreting (8) and (8b) it should be remembered that the rent r_{t+1} , depends on the price realisation P_{t+1} and the expected period $t+2$ price $E(P_{t+2}|P_{t+1})$.

If the indifference price V_{t+1}^i exists for a particular consumer i , it will also exist for all consumers with higher operating costs.² At prices above (below) the indifference price consumer i will prefer to continue as owner-occupier (switching over to tenancy). To see this, think about a price equal to the indifference price plus some small amount Δ . This increases the cost of ownership for both owner-occupiers and landlords by the same amount. For a tenant to compensate the landlord for this increased cost, a rent increase has to cover both Δ

and the tax increase for the landlord. In other words: for renting to be a sensible choice for a consumer he must have an inefficiency in operating a housing unit which is larger than the tax disadvantage of renting. When prices increase this tax disadvantage increases while the inefficiency is left unaffected. Hence, the attractiveness of renting is decreasing in the price of housing capital.

The discussion of period $t+1$ choices of sitting owner-occupiers is done because optimal reactions towards information arriving in $t+1$ is embedded within the cost of choosing owner occupation in t . The expected discounted cost of choosing an owner-occupied dwelling in the first period t , $B^i(O_t)$, can be written as (9):

$$(9) \quad B^i(O_t) = M_t + \{P_t + o_t\} + (1 + \varphi)^{-1} \left\{ \int_{V_{t+1}'}^{\infty} [o_{t+1} - (1 + \varphi)^{-1} E(P_{t+2})] f(P_{t+1}) dP_{t+1} \right\} \\ - (1 + \varphi)^{-1} \left\{ \int_{-\infty}^{V_{t+1}'} [r_{t+1} + m_{t+1} - P_{t+1}] f(P_{t+1}) dP_{t+1} \right\}$$

Some straightforward manipulations allow me to rewrite this as (9b).

$$(9b) \quad B^i(O_t) = M_t + \{(P_t - (1 + \varphi)^{-1} E(P_{t+1})) + o_t\} \\ + (1 + \varphi)^{-1} \left\{ \int_{-\infty}^{\infty} [o_{t+1} + P_{t+1} - (1 + \varphi)^{-1} E(P_{t+2} | P_{t+1})] f(P_{t+1}) dP_{t+1} \right\} \\ - (1 + \varphi)^{-1} \left\{ \int_{-\infty}^{V_{t+1}'} [(o_{t+1} - (1 + \varphi)^{-1} E(P_{t+2} | P_{t+1})) - (r_{t+1} + m_{t+1} - P_{t+1})] f(P_{t+1}) dP_{t+1} \right\}$$

One may note that the first two bracketed terms of (9b) equal the user cost of housing capital, respectively for period t and $t+1$, as it is usually expressed (see Smith et. al., 1988 and Poterba, 1984). The last term of (9b), which is not present in traditional expressions of the user costs, is the value of the real option to move over to a rental dwelling later on. The value of this option is always positive. Thus, traditional measures of the user costs of owner-occupiers are biased upwards! At least this statement is valid as long as the user cost concept is intended to capture the cost of owner-occupancy of one period. If the user cost is meant to be a measure of the housing costs of households who have entered owner-occupation and stay

within this tenure throughout its life, then my critique is irrelevant. As inspection of (9b) reveals, the positive bias is due to a neglect of the value of stepping out of owner-occupation whenever it seems advantageous.

A similar expression of the discounted stream of housing expenses given that the household is renting in period t , $B^i(R_t)$, and plan to revise its tenure choice at the start of period $(t+1)$ when new price information is revealed, is given in (10). Also this is written as the discounted sum of expected rental costs over the two periods minus the value of being able to switch over to be an owner-occupier in period $t+1$ if that is advantageous.

$$(10) \quad B^i(R_t) = m_t + r_t + (1 + \varphi)^{-1} \int_{-\infty}^{\infty} r_{t+1} f(P_{t+1}) dP_{t+1} \\ - (1 + \varphi)^{-1} \int_{W_{t+1}^i}^{\infty} [r_{t+1} - (M_{t+1} + o_{t+1}^i + P_{t+1} - (1 + \varphi)^{-1} E(P_{t+2} | P_{t+1}))] f(P_{t+1}) dP_{t+1}$$

The indifference price of a sitting tenant $W_{(t+1)}^i$ is a house price such that a period t renter i , is switching over to owner-occupation for all P_{t+1} higher than $W_{(t+1)}^i$ and continues renting for all P_{t+1} lower than $W_{(t+1)}^i$. In other words: it is defined equivalently to how V_{t+1}^i was defined as the solution to (8).

The discussions of the expected net present value of the two strategies rent and buy should have made it clear why one should not treat the consumers' housing choice as a choice between four different strategies. If one does not consider the opportunities to react optimally towards new information, i.e. towards price realisations in $t+1$, then the real prices of respectively renting and owning will be misspecified.

As already noted, tenure choice in my model is very simple, and also intuitively appealing. The consumer is simply choosing the (expectedly) most inexpensive way of buying the housing services he needs. Thus, if the difference $B^i(R_t) - B^i(O_t)$ is positive (negative) then he buys (rents) a dwelling in period t .

When turning to aggregation of the tenure choices of households, some of the assumptions made in Section 1 should be kept in mind. Everybody is assumed to make their tenure choices by comparison of expected discounted costs. More specifically no one becomes a renter because they prefer renting, because of risk-aversion or because they are unable to finance a home purchase. In addition everybody are facing the same tax rates and every member of a generation employs the same after tax discount rate.

However, I assume that the households differ by the operating costs they will experience as owner-occupiers. Operating costs are distributed with a density $g_t(o_t)$ on an interval (o_t^-, o_t^+) . Differences in operating costs can originate in different consumers imposing different need for maintenance on a dwelling, and its sources may be differences in the efficiency of operating a housing unit. My model treats differences in operating costs as stemming from the latter source. The operating cost of a landlord is thus assumed not to depend on any of the characteristics of a particular tenant. If households differ in the operating costs they impose upon a rental dwelling there will be an adverse selection of households into the rental sector. It may be that there would not exist any rental market in equilibrium under adverse selection (see Akerlof, 1970).

Defining o_t^* as a solution to $B^i(R_t) - B^i(O_t) = 0$, every young household with an $o_t^i > o_t^*$ will be tenants and every household with an $o_t^i < o_t^*$ will be owner-occupiers. Thus, the young generation's demand for rental housing can be written as (11):

$$(11) \quad n_{t=0}^{YR} = \int_{o_t^*}^{o_t^+} g_t(o) do$$

The structure of the tenure choice of the old consumers in period t is of course the same as the structure of the present young generation's (at t) tenure choice of period $t+1$. This implies that the higher the period t price is, the higher is the old generation's demand for owner-occupancy and consequently, the lower is the rental demand.

The rental demand of respectively old owner-occupiers and renters is termed $n_{t=1}^{EOR}$ and $n_{t=1}^{ERR}$. Aggregate demand for rental housing at period t is thus given by (12).

$$(12) \quad n_{t=1}^R = n_{t=1}^{YR} + n_{t=1}^{ERR} + n_{t=1}^{EOR}$$

If the ranking of the old consumers according to their operating costs in period t is the same as the ranking was in period $t-1$, then will $n^{EOR}_t > 0$ only if all old renters still prefer to rent in period t . This result is obvious because the old owner-occupiers face both higher costs in rental housing than old renters, because of the moving costs, and, by assumption, lower costs in owner occupied housing.

4. Tenure Distribution in Equilibrium

If there exists a rental market in period t in the model of this paper, the landlords must not be better off withdrawing from the market and the equilibrium rent must consequently be as given in (7). This section discusses conditions under which there will exist a rental market in my model. The analytical strategy is to start from the assumption that the participation constraint is fulfilled for some landlords and investigate conditions that must be fulfilled for some consumers to choose to rent their housing unit. Because of the problems caused by the use of a terminal period, the discussion in this Section is focused upon the equilibrium tenure distribution of period t , i.e. two periods before the terminal period.

First the young generation is considered. At the end some short comments on the demand from the old generation are given. The main strategy of the paper is however to show that there might exist a rental market in my model. For this purpose it suffices to show conditions under which the young generation's demand for rental housing is strictly positive. Equilibrium rents of periods t and $(t+1)$, as given in (3) and (7), are inserted into an expression for the cost-difference $B^i(R_t) - B^i(O_t)$. Equation (13) is a slightly rearranged version of the cost difference in equilibrium. If there exists values of o_t^i inside the interval (o_t^-, o_t^+) which yields a negative cost difference, then there will exist young tenants in equilibrium.

$$\begin{aligned}
& B^i(R_t) - B^i(O_t) = (m_t - M_t) \\
& + ((c_t^m - o_t^i) + \frac{\tau}{(1-\tau)} \{P_t - (1+\varphi)^{-1} E(P_{t+1})\}) \\
& - \frac{1}{(1+\varphi)} \left\{ \int_{-\infty}^{Q_{t+1}^m} \delta_{t+1}^m f(P_{t+1}) dP_{t+1} + \int_{Q_{t+1}^m}^{D_{t+1}^m} [c_{t+1}^M - c_{t+1}^m] f(P_{t+1}) dP_{t+1} \right\} \\
(13) \quad & + (1+\varphi)^{-1} \int_{-\infty}^{\infty} \left[((c_{t+1}^M - o_{t+1}^i) + \frac{\tau}{(1-\tau)} \{P_{t+1} - (1+\varphi)^{-1} E(P_{t+2} | P_{t+1})\}) \right] f(P_{t+1}) dP_{t+1} \\
& + (1+\varphi)^{-1} \int_{W_{t+1}^i}^{\infty} \left[M_{t+1} - (c_{t+1}^M - o_{t+1}^i) - \frac{\tau}{(1-\tau)} \{P_{t+1} - (1+\varphi)^{-1} E(P_{t+2} | P_{t+1})\} \right] f(P_{t+1}) dP_{t+1} \\
& - (1+\varphi)^{-1} \int_{-\infty}^{V_{t+1}^i} \left[m_{t+1} + (c_{t+1}^M - o_{t+1}^i) + \frac{\tau}{(1-\tau)} \{P_{t+1} - (1+\varphi)^{-1} E(P_{t+2} | P_{t+1})\} \right] f(P_{t+1}) dP_{t+1}
\end{aligned}$$

It is not a straightforward exercise to interpret the equation determining tenure choice in equilibrium in its form (13). I will therefore show how the cost difference can be interpreted in the special case where moving costs equal zero. This is done in order to focus on effects of tenure flexibility at the supply side of the rental housing market. The first fact to be noted is that both indifference prices of a consumer will coincide when moving costs equal zero, i.e. $W_{t+1}^i = V_{t+1}^i$. The cost difference between choosing tenancy and owner-occupation at t is then considerably simplified as it reduces to (14). The main reason for the tenure equation being so much simpler when moving costs equal zero is that all lock-in effects on the demand side disappears.³

$$\begin{aligned}
(14) \quad & B^i(R_t) - B^i(O_t) = (c_t^m - o_t^i) + \frac{\tau}{(1-\tau)} \{P_t - (1+\varphi)^{-1} E(P_{t+1})\} \\
& - \frac{1}{(1+\varphi)} \left\{ \int_{-\infty}^{Q_{t+1}^m} \delta_{t+1}^m f(P_{t+1}) dP_{t+1} + \int_{Q_{t+1}^m}^{D_{t+1}^m} (c_{t+1}^M - c_{t+1}^m) f(P_{t+1}) dP_{t+1} \right\}
\end{aligned}$$

The last term, the 'the real option value of tenure flexibility', is by necessity positive and when it appears with a minus in (14) it contributes towards a reduction of the cost advantage of owner-occupancy over tenancy. As is assumed in this model, and indeed observed in most countries, there is a tax advantage of owner-occupancy over tenancy. This is captured by the second term in (14) and contributes towards an increase in the cost advantage of owner-occupancy. Without specifying the probability distributions of period $t+1$ price and operating costs more it is not possible to conclude on the sign of the sum of the two last terms.

The surprising result that can be read out of equation (14) is that one, in equilibrium, can find cost minimising consumers renting from landlords who are less efficient in operating a housing unit than the consumer would have been as an owner-occupier. Hence even though there is a tax advantage associated with owner-occupancy one can not on theoretical basis rule out the possibility that a landlord will offer a contract that is accepted by a tenant. The reason of this is that the positively valued tenure flexibility option pushes the reservation rent downwards.

Next question to be addressed is how positive moving costs affects the conclusion that mutually advantageous rental contracts can exist even between a consumer-landlord pair where the consumer is most efficient in operating a housing unit. The discussion of this will be done under the assumption that for all t the cost of moving into owner-occupancy (M_t) is higher than the corresponding cost on rental dwellings (m_t). The total effect of such tenure-asymmetric moving costs can be described as consisting of three types of partial effects:

- a) The cost difference in favour of owning is pushed downwards by the immediate effect that moving into an owner-occupied dwelling is higher than the cost of moving into tenancy.
- b) The cost of choosing tenancy in the first period increases because the direct cost of moving over to owner-occupancy next period increases. In addition the interval on the price distribution at which a sitting tenant is locked in by his historical tenure choice is increased, i.e. the cost of moving over to owner-occupancy constrains the possibility to take advantage of lower housing costs in owner-occupancy as compared to tenancy. The total effect is that the cost difference is pushed upwards.
- c) An effect similar to b) applies to the cost of owner-occupancy. It is increased because of the increased cost of moving over to tenancy. The total effect is that the cost difference is pushed downwards.

The question of how the cost difference of a particular consumer is affected by the introduction of tenure-asymmetric moving costs, or what is the sign of the sum of the three effects above, can not be given unless more specified functional forms is used. As it is assumed that operating costs is continuously distributed this non-result concerning the effects of tenure-asymmetric moving costs also applies to the size of the rental sector in equilibrium. This inability to draw conclusions on how the existence of moving costs affects rental demand

in equilibrium stands in contrast to results in Rosenthal (1988) among others. The difference arises because the model of this paper abstracts from many features of real world rental housing markets. An example is that length of stay in my model is determined by realisations of the stochastic asset price of housing capital and not by demographics and job opportunities.

As shown in the discussion of tenure choice of consumers, the tenure choice of the old consumers resembles that of the young consumers. It resembles, but it is somewhat simpler as old consumers do not have to take account of how present tenure choice affects the choice of next period. On the other hand the choices of the old generation are strongly affected by their historic choices.

The ambition of this section was to demonstrate that there could exist a rental market in which cost minimising consumers are renting from less efficient landlords even though there is a tax advantage associated with owner-occupancy. I therefore refrain from spelling out characteristics of the equilibrium tenure distribution in more detail. Before turning to some concluding remarks, one crucial feature of the model should be stressed. At the equilibrium distribution no tenant would be better off by bidding up the asset price of housing units. Similarly, no 'inactive', or extra-marginal, landlords can earn positive profit by bidding up the asset price.

5. Concluding remarks

The analytic experiment performed in this paper has given two results. The first is that the equilibrium rent in a competitive market can be written as a sum of three components. These are the operating costs of a marginal supplier, the alternative cost of capital held as rental housing (corrected for expected appreciation of house values) and the negative of a positively valued real option. Earlier work on rental housing markets has only identified the first two of these three components. Hence, no-arbitrage rents have been over-estimated. The ignored component, i.e. the real option value, captures the expected value of becoming an intra-marginal supplier in next period, and hence to earn an extra-normal profit in this period. The second result is that when equilibrium rents is pushed down by a tenure flexibility option one might, in equilibrium, find inefficient landlords letting to efficient owner-occupiers. The value of the tenure flexibility can hence be large enough to overcome both the tax advantages

associated with owner-occupation and an owner-occupier's cost efficiency in operating a housing unit. The second 'result' is a direct consequence of the first one.

These results are identified within a theoretical model that in one sense is not closed. It is not closed in so far as it does not explain how equilibrium asset prices are determined. This was done because my ambition was to show how tenure distribution in equilibrium is determined, and in order to keep the model as simple as possible. However, as the central results of the paper apply for all prices, I do not see this as being any major weakness of the paper!

As argued above, my paper establishes theoretical results not identified for rental housing markets before. What remains are to find out whether this point is empirical relevant for real world rental housing markets or not and if relevant: what is the quantitative significance of it. Can the value of tenure flexibility option be estimated and can it be established how it affects rents in real world rental housing markets? No attempt to address this empirical question will be made here. However, it may be noted that Crook and Kemp (1996) find some evidence, which can be used as indications of equilibrium rents being pushed down by a real option value. In a nationally representative sample of lettings from Britain, 1993, they find that *'the discounted net rental stream and expected capital gain from letting residential property is still significantly less than the price owner occupiers are prepared to pay for properties'* op cit. p. 59. Here one should also note that the size of the private rental sector had been growing in the years prior to 1993, indicating that the 'low' return was not a temporary phenomenon occurring while the size of the private rental stock was adjusting downwards.

The model employed in this paper is quite simple. Further research is needed to show whether the results are robust to changes in the simple model. One important feature would be to allow for imperfect competition. In reality, housing units are highly heterogeneous, yielding thin housing markets in which landlords have some sort of market power (see Arnott, 1989).

It is also possible that option values are under-estimated by the model I have been employing. The only source of stochastics in the return of rental housing in the model is a stochastic process for the asset price of housing capital. In addition to this it also possible that there is a stochastic element in aggregate rental demand which is independent of the house prices. Such stochastics in the rental demand is probably important empirically. It can, among other things, be a result of variations in credit availability among 'marginal home-buyers', stochastic

elements in the processes behind formation of new households (moving out from parents) and immigration to the housing market.

User costs of owner occupied housing are also showed to be pushed down by the value of an option to step out of owner-occupation at a desirable point in time. Using this result and the corresponding results for housing costs for tenant may extend our knowledge of 'the path of tenure choices' of newly formed households. This finding is however not thoroughly discussed in the paper.

¹ This applies to among others Henderson and Ioannides (1983) and Rosenthal (1988).

² It may be noted that the results in this paper is depending on the existence of some V_{t+1}^i 's, but not on this indifference price existing for all i .

³ A sketch of an interpretation of the equilibrium tenure choice equation is given in appendix 1.

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Appendix 1

This appendix shows how the tenure choice equation can be decomposed when moving costs are positive. The decomposition is done so that each of the components can be given a partial economic interpretation. Then a brief discussion of how each of these components contribute to the cost difference is given.

First it should be noted that the indifference price a consumer i will hold as a sitting tenant is greater than (but not necessarily strictly greater than) the indifference price i will hold as a sitting owner-occupier. To be used in the discussion still another 'indifference price' is defined. Let Ω_{t+1}^i be a price so that a consumer will not regret her period t tenure choice no matter what her tenure choice were! Such no regret will only occur at the price realisation where the user cost and rent are equal, and is defined by equation (§1).

$$(\S 1) \quad (c_{t+1}^M(\Omega_{t+1}^i) - o_{t+1}^i) + \frac{\tau}{(1-\tau)} \{ \Omega_{t+1}^i - (1+\varphi)^{-1} E(P_{t+2} | \Omega_{t+1}^i) \} = 0$$

An alternative, and equivalent, way of introducing Ω_{t+1}^i had been to say that it is the indifference price in a hypothetical situation where both moving costs equal zero. Indifference prices of sitting tenants and owner-occupiers would in this hypothetical situation be identical. The purpose of introducing this variable will become evident as it is employed in the discussion of (§2).

$$\begin{aligned}
& B'(R_t) - B'(O_t) = (m_t - M_t) \\
& + (c_t^\mu - o_t^i) + \frac{\tau}{(1-\tau)} \{P_t - (1+\varphi)^{-1} E(P_{t+1})\} \\
& - \frac{1}{(1+\varphi)} \left\{ \int_{-\infty}^{Q_{t+1}^\mu} \delta_{t+1}^\mu f(P_{t+1}) dP_{t+1} \int_{Q_{t+1}^\mu}^{D_{t+1}^\mu} (c_{t+1}^M - c_{t+1}^\mu) f(P_{t+1}) dP_{t+1} \right\} \\
& + (1+\varphi)^{-1} \int_{V_{t+1}^i}^{\Omega_{t+1}^i} (c_{t+1}^M - o_{t+1}^i) + \frac{\tau}{(1-\tau)} \{P_{t+1} - (1+\varphi)^{-1} E(P_{t+2} | P_{t+1})\} f(P_{t+1}) dP_{t+1} \\
& + (1+\varphi)^{-1} \int_{\Omega_{t+1}^i}^{W_{t+1}^i} (c_{t+1}^M - o_{t+1}^i) + \frac{\tau}{(1-\tau)} \{P_{t+1} - (1+\varphi)^{-1} E(P_{t+2} | P_{t+1})\} f(P_{t+1}) dP_{t+1} \\
& + (1+\varphi)^{-1} \int_{W_{t+1}^i}^{\infty} M_{t+1} f(P_{t+1}) dP_{t+1} \\
(\S 2) \quad & - (1+\varphi)^{-1} \int_{-\infty}^{V_{t+1}^i} m_{t+1} f(P_{t+1}) dP_{t+1}
\end{aligned}$$

Each of these eight components can be interpreted as in the list below. For most of the component I am also indicating which sign it is expected to have.

- i) The first component measures the higher moving costs when moving into owner-occupation at the start of t.
- ii) The second component is a measure of the period t inefficiency of the marginal landlord as compared to the particular consumer i.
- iii) The third component is the tax disadvantage of renting over owner-occupancy, in period t.
- iv) The fourth component is the discounted after-tax value for the marginal supplier of period t of being able to collect a gain because of her being more efficient than the marginal supplier of period t+1. Is she less efficient than the marginal supplier in t+1, she just sells of the housing unit. This is what I in this paper term the value of the tenure flexibility option of a landlord.

- v) Is a kind of expected regret of choosing owner-occupancy, measured in money terms. To be more concise, at price realisations above V_{t+1}^i and below Ω_{t+1}^i there is a regret cost associated with the choice of owner-occupancy in period t . At all prices below Ω_{t+1}^i tenancy will be less expensive than owner-occupancy, but as long as the price is above V_{t+1}^i the cost advantage of rental housing is smaller than the cost of stepping over to tenancy. This component is a part of the cost of owner-occupancy and is thus negative in (13).
- vi) This component resembles component v), it is expected regret of choosing tenancy, measured in money terms. As this is a component in the cost of choosing tenancy in period t , it is pushing up the cost disadvantage of renting.
- vii) Is the discounted cost of moving over to owner-occupancy at price realisations above the indifference price of sitting tenants, weighted by the probability of such moves. This of course increases the cost difference between tenancy and owner-occupation.
- viii) Is the discounted cost of moving over to tenancy at price realisations below the indifference price of sitting owner-occupiers, weighted by the probability of such moves. This of course decreases the cost difference between tenancy and owner-occupation.

Utilisation of the Stock of Owner Occupied Single Family Houses- an Econometric Analysis^{#*}

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Abstract

In many 'single-family' houses the owner has the option to let a part of the house to another party or to use the entire house for her own purposes. This paper uses a stochastic utility framework to provide a theoretical analysis of this dichotomous choice. The paper also shows how an empirical model that is consistent with the theoretical model can be formulated and estimated using suitable parameterisation. Within the empirical analysis I test, and reject, the hypothesis of locally linear utility functions that are frequently used in models of discrete housing choices. Furthermore, the estimated model is used to show how the tax treatment of owner-occupiers affects the utilisation of the stock of single family houses.

0. Introduction

In semantic terms the topic of this paper is quite peculiar. The subject considered is the rental activity in 'the second unit' of owner-occupied single family houses. Part of the floor space in a large share of single family houses can either be utilised by the owner and her family or it can be let. The part of the single-family house that can be let will be referred to as 'secondary dwellings'. Both a theoretical and an econometric analysis of the decision facing an owner on how to 'utilise a single family-house with an additional dwelling, is presented. This analysis provides insight into both the demand and the supply side of the housing market. On the supply side the analysis help us understanding a segment of the rental market that is important in Norway.

Provided there is a market for rental secondary dwellings, the owners must chose whether to demand the entire floor space of their house for their own purposes or to let part of it. The analysis of the demand of homeowners for their own floor space provides an interesting source of estimates of price and income elasticities of consumption of housing services. Amundsen (1985) and Nordvik (1997) have shown that demand functions estimated using cross-sectional data might be biased as a result of the costs associated with changes in housing consumption. An interesting feature of estimating price and income elasticities from data on utilisation of single family-houses is that the costs of changing housing consumption by changing the utilisation of a single-family house is negligible compared to the cost associated with moving. The option of letting a part of a single-family dwelling therefore represents one way of adjusting the mix between housing and other types of consumption without having to move.

Some basic facts confirm the importance of secondary dwellings in the Norwegian housing market. Between 25 and 30% of all rented dwellings in Norway is part of a single-family house in which the owner-household currently lives. Only one in ten of these are a single-room dwelling. About 9% of all owner-occupied single-family houses contain an additional renting household. Close to three in ten of the owner-occupiers living in a single-family house are currently not letting, but state that it is possible to divide the house into one main and one secondary unit, without undertaking any physical conversion activities. In this context a secondary dwelling is defined as a housing unit with its own entrance.¹

The high frequency of subletting of secondary units should be interpreted in light of some characteristic features of the Norwegian housing market. The owner-occupied single-family house is a quite dominant type of housing in Norway. A little bit more than 40% of all Norwegian households live in their own single-family house. Among household headed by a person whose age is 35-60 years more than 60% are owner-occupiers in a single-family house. Inclusion of secondary dwellings in single-family houses has been encouraged through The State Housing Bank of Norway. The bank gives loans for residential construction as long as lot and construction costs are kept below a ceiling. The ceiling of lot costs for a single-family house is increased by 50% if a secondary unit is included. Imputed rental income for owner-occupiers is taxed in Norway. However the imputed rental is set at a very low level, this will be further described in Section 5. If an owner-occupier let less than 50% of her housing unit she will not have to pay any taxes in excess of the tax on imputed rental income. Hence, taxation of an owner-occupier is not affected by letting of a secondary dwelling!

Renting of secondary dwellings in single-family houses is a subject that hardly is mentioned in the literature on housing economics. One exception is Poulton (1995). He states that about 5% of all dwellings in Vancouver are such secondary dwellings. Furthermore, this kind of dwellings is also found in a significant number of single family-house in other parts of North America.

Part 1 presents a brief sketch of the choice-theoretic basis of the paper. Part 2 develops an econometric model that is consistent with the choice-theoretic basis. Data sources is described and discussed in Part 3, and an estimated model is presented in Part 4. In Part 5, I present a policy experiment, which shows how the utilisation of the stock of single-family houses would alter if tax advantages associated with owner-occupied housing were to be removed. Some concluding remarks are presented in Part 6.

1. Choices of one single owner of a single family house

This paper only deals with the decisions of owners of 'single family houses', that can be divided into one main and one secondary flat, who already are, and intend to remain in possession of their housing unit². Owners have two possible courses of action: to stay in the main flat and let the secondary flat or to use both the flats for their own residential purposes. In reality this choice is nested within the choice of setting up or buying a single-family house in which it is possible to let a

secondary dwelling. This paper, however, is confined to an analysis of the choices made at the lowest level of the decision tree. The choice is modelled as a comparison of the utility that each of these two actions yields. An additive utility function with three arguments will be used:

$$U = u(C_0 + rH) + v(q'_m + (1-H)q'_s) + d(l) \quad (1)$$

- Where:
- C_0 is the household's consumption of 'other consumption goods' if the secondary flat is not let.
 - r is the market rent, net of any renting expenses, of the secondary flat
 - H is a dummy, which equals unity if the secondary unit is let, and zero otherwise.
 - q'_m is the number of units of housing services that the main dwelling yields to the household.
 - q'_s is the number of units of housing services that the secondary dwelling yields to the household.
 - l is an index describing the household who is renting the secondary flat. $l=0$ is conventionally defined as no tenant.

Of course the use of an additive utility function is a simplification. Furthermore, utility levels will be employed in the analysis. The utility function is therefore a cardinal utility function. The final component $d(l)$ expresses the fact that an owner might have preferences over tenants. There are two reasons for owners of house containing their own residential unit to care for who a tenant is. These two reasons can be attributed to two different roles an owner will have in relation to her tenant.

- i) Firstly, tenants may (be thought to) vary in terms of the need for maintenance and repairs they cause on a dwelling.
- ii) Secondly, owners of houses that consists of one main and one secondary flat are choosing a very close neighbour when they choose a tenant.

All landlords have to take the first consideration into account when choosing a tenant. The second one implies that an owner of a two-dwelling house is likely to be even more careful than other landlords in choosing tenant. It could also be inferred that an owner of a two-dwelling house might

be more reluctant to let. This last point is only valid when the utility attached to a specific tenant is negative. It is reasonable to assume that the opportunity to help relatives and/or friends to find a dwelling to some 'landlords' yields positive utility.

The way a house can be split up into a main and a secondary dwelling is assumed to be physically determined. For a household in a given house the letting decision is hence a choice of whether or not to let a given part of the house. This captures one of the main characteristics of the part of the stock single-family houses that is constructed with one main housing unit and one potential secondary unit. An alternative to this 'fixed splitting possibility' assumption had been to assume that single-family houses are perfectly divisible.³ Of course any of these two assumptions are simplifications. I see the 'fixed splitting possibility' assumption as being far closer to reality than an assumption of perfect divisibility.

My approach to the choice of the owners is very simple; the market rent, income and taxes are regarded as exogenously given and the only choice to be done by the owner is whether to let or not. I make no attempt to analyse any possible actions taken by the owner to find a renter who would cause minimal disutility (or highest utility) to the owner. Furthermore, I do not consider a situation where the owner waits for a satisfying tenant to turn up.

Passive search for satisfying tenants could have been modelled as demanders of rental housing showing up at one specific rental dwelling according to a specified stochastic process. Arnott (1989) used such a way of modelling the search process of a landlord. Read (1988) models active search behaviour of landlords with vacant units. Search in Reads model is active as landlords are assumed to be able to affect the arrival rate of tenants at their vacant unit through the effort they put into advertising. Neither of these two articles considers a situation where landlords have preferences over tenants. These two models represent sensible starting points in a modelling of search over a heterogeneous set of tenants.

The outcome of the individual optimisation will not be considered in detail. However, it should be noted that the outcome of the optimisation could be described as a vector of reservation rents. It is the preferences over heterogeneous tenants that produces a solution in the form of a vector of reservation rents rather than a single reservation rent. There is a reservation rent for each distinct type of potential tenant. Another way of describing the outcome of the optimisation is to state that for each given market rent the set of potential tenants is divided into two subsets. One subset

consists of tenants who would be considered satisfactory, whilst the other subset consists of those who would not receive an offer from the owner.

2. An econometric model

The ambition of this paper is to provide and use tools for empirical analyses of the supply side of an important segment of the rental market. The description of the structure of individual choices given in Part 1 is of course an important building block in this attempt. An appropriate way to aggregate individual choices is to employ the 'stochastic utility' framework applied by Anas (1980) and others.

Owners are assumed to be relatively homogenous in that they have some common components in their utility function. In addition to the common components I allow for household specific components to be part of the utility. The chosen parametric 'sub'-utility function of 'consumption of other goods and services' is specified in (2):

$$u(C) = \frac{a_1}{b} C^b \quad (2)$$

Necessary conditions for the reasonable assumption of positive and decreasing marginal utility of 'other consumption', to be valid are: $a_1 > 0$ and $b < 1$.

The formulation (2) allows marginal utility of other consumption to vary, while the common practise of using a measure of income minus housing cost in choice models constrains marginal utility to be constant. This approach which may be denoted 'the common practise' implies a (locally) constant marginal utility of other consumption. Use of such locally linear utility functions can be found in the seminal articles of Anas and Arnott (1991) and Börsch-Supan (1986). One of the considerations in my choice of utility function was that it should be possible to obtain a linear utility function by imposing suitable constraints on the parameters. Tests of these constraints can then be interpreted as a test of the validity of using linear utility functions when modelling housing choices.

The utility of housing services is assumed to have two components, one common and one household-specific. The household-specific component is intended to capture what Anas and Arnott

(1991) termed 'idiosyncratic taste dispersion'. The utility of housing services for household i can therefore be written as (3).

$$v_i(q_i) = v^*(q_i) + \varepsilon_{iq} \quad (3)$$

where the ε_{iq} 's from the analyst's point of view, can be regarded as realisations of a stochastic variable with a common distribution. In ordinary housing choice models, where each household chooses one and only one dwelling from a specified finite choice-set there is no need for specifying the v^* -functions. The choice sets in this paper consist of two elements for each owner. To put it simple one can say that the two elements in the choice set are 'a high' and 'a low' housing consumption. The selection of a low consumption is the decision to let the secondary flat.

Housing services (q) is not an observable variable. When turning to the empirical work, floor space of a dwelling (q) will be used as a proxy. In the problem presented in this paper, the fact that dwellings vary in size must be taken into account when specifying the v^* functions. A decision to let 50 m² of a house with a total floor area of 105 m² is different from a decision to let 50 m² of a house of 250 m². The common component in the utility of dwelling size is assumed to have the same form as the utility of other consumption goods:

$$v^*(q_i) = \frac{1 - a_1}{\beta} q_i^\beta \quad (3')$$

The parameters of the sub-utility function $v^*(\cdot)$ is of course subject to the same types of constraints as the utility of 'other consumption' function.

The tenant specific component of the utility function, given in (4), is also assumed to be a sum of a common component and a household specific-component:

$$(4) \quad d_i(l) = d^*(l) + \mu_{il}$$

In the same way as the ε_{iq} 's, the μ_{ij} 's can be considered as realisations of a stochastic variable with a common distribution. In this version of the model, I assume that the type of a tenant is not observable. The choice of whether to let or not is thus a choice of whether to take in a random realisation from the distribution of possible tenants. The common component of the (ex ante) utility of taking in a tenant or not can be treated as constants (d_L and d_0). The utility of letting and not letting is specified as (5a) and (5b):

$$U_i(\text{letting}) = U(H=1) = \frac{a_1}{b} (C_0 + r)^b + \frac{1-a_1}{\beta} (q_m)^\beta + \varepsilon_{iqm} + d_L + \mu_{iL} \quad (5a)$$

$$U_i(\text{not letting}) = U(H=0) = \frac{a_1}{b} (C_0)^b + \frac{1-a_1}{\beta} (q_m + q_s)^\beta + \varepsilon_{iqs} + d_0 + \mu_{i0} \quad (5b)$$

As the utility function includes a number of stochastic components one can not from inspection of the utility functions draw any conclusions on whether a specific household i will choose to let one part of their 'single family house'. However, the stochastic nature of the utility functions can be used to construct an aggregate econometric model.

When the decision to let is a result of a utility maximisation, the probability that a household chooses to let can be written as the probability that $U(H=1) > U(H=0)$, or in short $U_H > U_0$.

$$\begin{aligned} P(U_H > U_0) &= P\{ u(C_0+r)+v^*(q_m) + d_L + \varepsilon_{iqm} + \mu_{iL} > \\ &\quad u(C_0)+v^*(q_m+q_s) + d_0 + \varepsilon_{iqs} + \mu_{i0} \} \\ &= P\{ (\varepsilon_{iqs} + \mu_{i0}) - (\varepsilon_{iqm} + \mu_{iL}) < \\ &\quad u(C_0+r)+v^*(q_m) + d_L - u(C_0) - v^*(q_m+q_s) - d_0 \} \end{aligned} \quad (6)$$

If the $(\varepsilon_{iqs} + \mu_{i0})$'s follow a Weibull-distribution, the differences between the household specific terms will follow a logistic distribution. A convenient result of this assumption is that the letting probability will have a form that makes it possible to estimate the parameters of the sub-utility

functions. The resulting logit equations can also be used to show how income and rent levels and the size of main and secondary flats affect the probability of letting a secondary flat.

$$P(U_H > U_0) = \frac{\exp(u(C_0+r)+v*(q_m) + d_L)}{\exp(u(C_0+r)+v*(q_m) + d_L) + \exp(u(C_0)+v*(q_m+q_s) + d_0)} \quad (7)$$

The parameters of (7) can be estimated using maximum likelihood methods. Ben-Akiva and Lerman (1985, p 79-87) show how the ML-problem should be formulated and how it is solved when the utility functions are linear. Solutions when utility functions are non-linear can in principle be solved the same way. A major difference is however that the log-likelihood function is more messy when utility functions are not linear in the parameters.⁴

3. Data

Data derived from a postal survey of owners of single family houses can be used to estimate the parameters of the model presented above. This survey contains information on the characteristics of houses and households for 699 single-family houses. 60% of these owners state that it is possible to let a secondary dwelling within their house, 23% are currently letting a secondary dwelling, while the secondary dwelling is currently used as part of the main dwelling in 37% of the houses. The data set includes information on floor space of main and secondary dwellings. Furthermore, rents are reported for those units that are hired out. Owners of secondary dwellings that are not being let were asked what rent they would have received had they been letting. Of course, such owners may misjudge the market rent of their unit. Whether they misjudge the rent or not is however unimportant in my analysis as the rent they believe they will receive is the price of the floor space of the secondary dwelling they use when choosing whether or not to let. Information on pre-tax income (reported in the questionnaire), family size and type has also been taken from the survey. There is a low frequency of missing values in the data set. Rents are reported by all the letters and by as much as 96% of those who use a secondary dwelling as a part of their own home, only 5% of the respondents refused to give information on income.

A fundamental assumption behind the econometric model developed in Part 2 is that the owners are homogenous in that their utility functions have common components. This assumption is more

appropriate within rather than between demographic groups. Thus, the problem is to find a way to compromise between the desire to estimate the model on a large data set and the desire to estimate the model on a relatively homogenous group of households. For this reason both Börsch-Supan and Pitkin (1988) and Börsch-Supan (1986) emphasise a reasonable stratification along demographic dimensions as a crucial factor for the quality of empirical models of (discrete) housing choices.

The parameters of the theoretical model are estimated on a sample consisting of two-parent families with between one and three children. This estimation strategy leaves me with 191 observations. A total of 100 of these are households who use the potential secondary dwelling as a part of their own home. The remaining 91 are hiring out the secondary dwelling.

C_0 is the gross income of the household minus taxes and the costs associated with owning the single-family houses. The data from the survey includes information on pre-tax income. These and other data are used to calculate C_0 for each of the households. Taxes paid by each household are calculated through a routine representing a slightly simplified version of the Norwegian tax system.

'The costs associated with being owner of the actual single family house' is measured in a way that has more in common with a 'housing expenses-concept' than a cost concept. Our housing expense-concept consists of interest and amortisation on loans defined as 'loans for housing purposes' and a calculated operating cost. The estimated operating cost, included energy, of single-family houses where the secondary dwelling is not let is taken from the Norwegian housing market model BUMOD. On average, these estimated operating costs amounts to 2.2% of the value of the houses. The decision to let part of a single-family house is taken in the light of the available economic resources in the current situation. A liquidity-based housing expense concept is therefore more likely to contribute to the explanation of the decisions made by the households than a cost concept that may appear theoretically more attractive.

There are two premises that suggest that the use of a housing expense concept is more appropriate than a user-cost approach; both of these premises are connected to the illiquidity of housing capital. The first of these premises is the fact that the option of selling the house has been assumed away, whilst the second premise is that households may meet constraints in the credit markets. Both human capital and future appreciation may be considered as insufficient security for a household that wants to take out a loan in order to reallocate consumption over its life-span. However,

throughout this paper the preferability of using a housing expense rather than a user-cost approach will remain an untested assumption.

For a household that is letting the secondary dwelling, the gross rent received increase its potential consumption. In addition, letting will reduce energy costs as the tenant pays the energy costs of the secondary flat. As shown in the introductory remarks, if a household chooses to let a secondary flat within its single-family house the tax of the return on their housing capital⁵ is not affected. The maintenance costs for a secondary flat that is included within the main dwelling and those for a rented secondary flat is assumed to be equal. This assumption is clearly questionable. A pragmatic reason for ignoring differences in costs of maintenance is that no data that enables me to take account of any possible differences is available.

4. Results

This section presents estimates of a model of the decision of whether to let a secondary dwelling or not. Some properties of the estimated model are illustrated by figures that show how the probability of letting varies with rent and income. It is also shown how one on the basis of the estimated model can calculate demand elasticities of a part of the housing demand where housing consumption can be varied without incurring moving costs. A particular advantage of modelling housing choices as the outcome of a stochastic utility maximisation is that the parameters of the theoretical model can be estimated directly. Estimates of coefficients of the model from equation (7) are shown in Table 1.

Table 1 - ML-estimates of the parameters of the utility function

	Parameters	Standard errors
$-(d_L - d_0)$	3.38	0.814
a_1	1.003	0.007
b	0.45	0.083
β	1.42	0.442
$-\text{Log } \mathcal{L}$	114.69	

There is no single criterion for evaluating the goodness of fit of an estimated logit model. The estimated model will therefore be discussed in the light of three different types of criteria. Firstly,

the model is tested against some nested models. The model's ability to predict the data set, on which it was estimated, is evaluated. Finally I discuss sign, magnitude and precision of the estimated coefficients.

The first step in evaluating the statistical appropriateness of the model is to compute the log-likelihood functions, at their maximum, of a number of other models that are nested within the model estimated and presented in Table 1. A model nested within the 'unrestricted (or full) model' is a model that is obtained by imposing linear restrictions upon the unrestricted model. Using the log-likelihood of these one can form a test static with a known distribution (see Ben-Akiva and Lerman, 1985 p.28).

In the theoretical discussion in Part 2, I argued that it is preferable not to use utility functions that by necessity violates the traditional assumptions of properties of utility functions, despite the fact that this will result in estimation procedures becoming more complex. As linear utility functions are frequently used in models of housing choice, the utility function in this paper is tested against a linear specification. A linear utility function can be obtained by imposing certain restrictions on the utility function that is used in this paper ($b=1$ and $\beta=1$). A likelihood-ratio test of these restrictions shows that the hypothesis of the utility function being linear is rejected at a significance level of 1%. Hence, both theoretical considerations and our data indicate that the use of linear utility functions is an inappropriate simplification.⁶

A second method of illustrating the quality of the estimated model is to assess how well it predicts the choices in the sample, on which the model is estimated. Two different measures of within sample prediction are presented. Firstly, a rather coarse procedure that predicts that only those households who have an estimated probability in excess of 0.5 are letting their secondary dwelling is used. Thereafter it is shown how the average estimated probability of letting differs between those who in fact are letting and those who are not.

Table 2 - Single predictions of the model

	P(H=1) > 0.5	P(H=1) < 0.5	Sum	Average P(H=1)
Letting	53	38	91	0.558
Not letting	30	70	100	0.394
Sum	83	108	191	0.472

The results shown in Table 2 are encouraging. The model is discriminating quite well between those who are letting and those who are not.

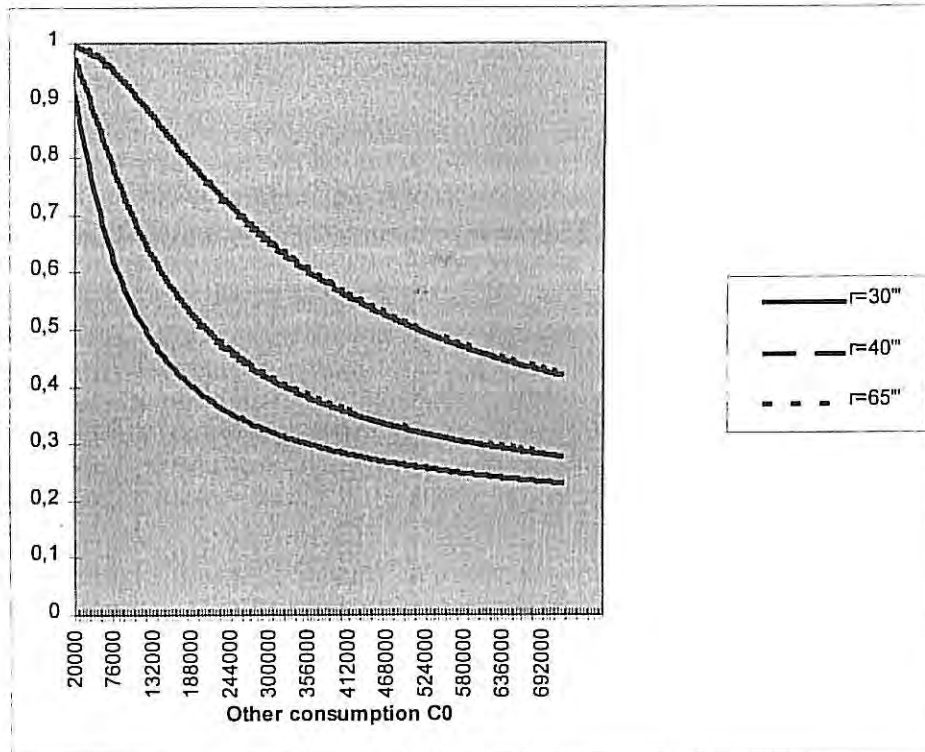
All coefficients of the estimated model are significantly different from zero, most of them are also in line with theoretical based expectations. The disutility of taking in a tenant in the secondary housing unit as compared to using the house purely as a single-family house {i.e. $-(d_L - d_0)$ } is significantly positive. Magnitude and sign of a_1 and b implies positive decreasing marginal utility of other consumption. The estimated parameters of the sub-utility of consumption of floor area do not, exhibit such desirable properties. When a_1 and β are considered together it is seen that they imply a negative marginal utility of floor area.

My interpretation of the undesirable sign of the marginal utility of housing services is that floor space probably is not a good proxy. The negative effect of taking in a tenant may in the estimated model be captured by the constant term. In effect the estimated model indicates that whether one chooses to take a tenant into the house or not affects utility very much stronger than marginal variations of floor space. The partial effect of taking in a tenant is clearly negative. Even though the coefficients determining the sign of the marginal utility are not sharply determined and the importance of the 'tenant present'-effect, it remains a fact that a negative marginal utility of course really is an undesirable characteristic of an empirical model.

The parameters of the model as they are presented in table 1 are not immediate interpretable. To focus on the economic content of the model, I will therefore show how the predicted probabilities for letting a secondary dwelling vary with income and rent levels. Figure 1 shows how the probability of letting a secondary dwelling changes as income after taxes and housing expenses

changes. In the calculations of the probabilities the size of the secondary dwelling is held constant equal to 55 m² and the yearly rent equal to 40 000 NOK (1 US\$ equals 7.5 NOK). The effect of income after taxes and housing expenses on the probability of letting is depending on rent level. This effect is also apparent in Figure 1.

Figure 1 - Hiring out probabilities and income after taxes and housing expenses



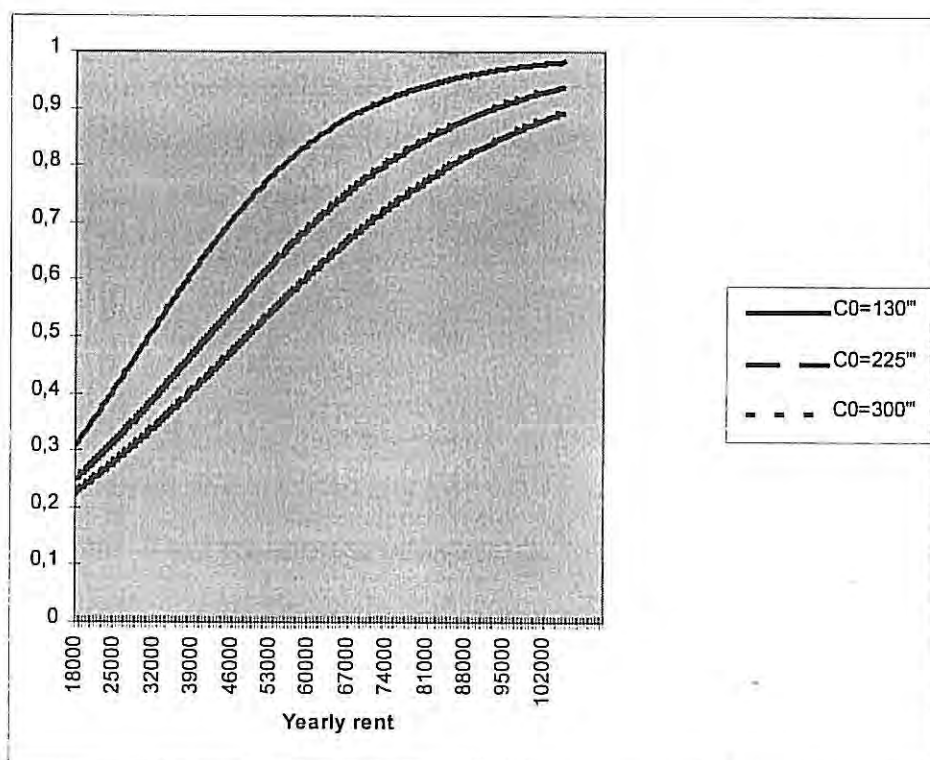
The figure reveals that the propensity to let decreases markedly with increasing income. Furthermore, it can also be seen from the figure that at low income levels the dependency between the propensity to let and the level of 'other consumption' when the secondary flat is not let increases as the rent decreases.

Under the current tax system in Norway the rent paid by a tenant is a net increase in the owners' after tax income. An increase in the rent level therefore increases the potential consumption of other goods and services for a household that chooses to let a secondary dwelling, in a one-to-one scale. Figure 2 illustrates the magnitude of the effect variations in rent have on the probability of letting;

calculations are made for single family houses where the main dwelling is 130 square meters and the secondary dwelling 55 m².

The figure reveals that changes in rent levels have a very strong effect of on the probability of letting. It is also interesting to note the difference between those with a high and those with a low 'after tax and housing expenses' income. As mentioned in the discussion of Figure 1, those on low incomes are markedly more responsive to changes in the rent levels than those with a higher income. Despite the fact that high-income families has a lower probability of letting secondary dwellings, their decisions also seem to be sensitive to variations in the market rents.

Figure 2 - Hiring out probabilities and rents



In a model using linear utility functions the probability of letting will only depend on the difference in size of the dwelling (y_m as compared to (y_m+y_s)) and the potential consumption of other goods and services ($C_{0+r} - C_0$). This property of the linear utility function will yield completely different pictures than those shown in Figures 1 and 2. Provided that rent and size of a secondary dwelling remain constant, the probability of letting will also remain constant, i.e. the probability of letting a secondary dwelling is independent of the level of consumption of other goods and services a household can maintain without letting. These unattractive properties of the linear utility model are

a direct result of functional forms that forces marginal utilities to be constant. I consider these results, together with the statistical rejection of the restrictions yielding the linear model, as conclusive arguments against use of such linear sub-utility functions.

Income and price elasticities of housing demand can also be calculated on the basis of the estimated model. The model has so far been interpreted as a description of the decision to let, and the interdependencies between the probability of letting and exogenous variables have been explored. The decision not to let a secondary flat is of course 'dual' to the let decision. Furthermore, the decision not to let can be regarded as the owners being demanders of extra floor space within their own single-family house. The price of this extra floor space is the sum of foregone income (rent) and extra operating costs (energy) associated with the decision not to let.

In order to obtain numerical estimates of income and price elasticities, the data set on which the model is estimated is used as a base of a simulation model, i.e. the estimated utility function is added to each of the observations. This approach is used to calculate probabilities of using the secondary dwelling as part of the owners' own home, for each of the observed households. The next step is to assess how these probabilities change as rent and income vary. Income elasticities are calculated with respect to current pre-tax income.

The changes are reported in the form of elasticities in Table 3. In order to show how elasticities vary between individual households, households have been sorted according to their propensity to let the secondary flat. Together with the mean elasticity, elasticities are reported for the 1th and 9th decile, the median and the upper and lower quartile of the distribution of the propensity to use the secondary flat as a part of the family home.

Table 3 - Price and income elasticities

	Price elasticity	Income elasticity
Mean	- 0.77	0.39
9 th decile	- 2.52	1.49
Upper quartile	- 1.13	0.67
Median	- 0.72	0.48
Lower quartile	- 0.53	0.32
1 th decile	- 0.27	0.26

The absolute value of average price and income elasticities in my analysis are in line with what Rothenberg et al (1991 p.20) report as '*a consensus that, overall, housing demand elasticities with respect to price, current and permanent income are significantly less than one in absolute value*'. Furthermore, both price and income responsiveness, as measured by the elasticities, correlate very strong with the propensity to include a secondary dwelling in the owner's own home. This again correlates strongly with income. Thus, the housing demand of high-income families responds less to variations of prices and income than the demand of those with low income. Visual inspection of Figures 1 and 2 also indicated this to be the case. Also in this respect my study gives results that is in line with the majority of demand studies. Rothenberg et al (1991, p.20) state that there is convincing evidence that demand elasticities vary significantly with, among other things, income.

5.Utilisation the stock of single family housing stock under alternative tax regimes

Changes in the taxation of the return of housing capital will affect the utilisation of the housing stock. This section presents expected consequences on the utilisation of the stock of single-family houses, of two alternative tax reforms. The first reform is taxation of imputed rental income in line with taxation of return on other assets. The second reform is to retain the tax advantage for owner-occupiers, but to tax net rental income⁷ from secondary dwellings at the same rates as net rents from other forms of rental housing. In Norway, as in other countries, we have an ongoing debate on the desirability of reducing the tax-advantages associated with owner-occupied housing. The analysis in

this section can contribute to such discussions by showing the effect such reductions can have on one segment of the rental market. An additional purpose of the analysis is that it shows how a simulation model can be constructed on basis on the parameter estimates from Table 1 and the sample on which the model is estimated.

The basic idea behind the simulation model is that the sample on which the model was estimated is interpreted as a representative sample. Each household in the sample is given the estimated utility function, and each observation is interpreted as a household type. The estimated probabilities of letting are taken as the expected rental activity of households of this type. By 'household type' I am here thinking of the combinations of household members, income and characteristics of houses that each observation, on which the model is estimated on, represents. My estimate of the short-run first-order effect of the tax reforms is the effect on the average probability of letting.

In short the present tax system can be described as a system where the return of the owner-occupiers housing capital is taxed at a flat rate of 28%. This return, or imputed income (II), is calculated as described in (8):

$$II = \text{Max}\{0, (AV - 51.2)\} * 0.025 + \text{Max}\{0, (AV - 450)\} * 0.025 \quad (8)$$

AV is the assessed value of the dwelling. Both II and AV are measured in thousands of NOK. The assessment of the taxable return of housing capital is favourable compared to the assessment of the taxable return on most other components of wealth. There are three particular advantages. The assessed value is low compared to the real (market) value. An informed guess is that on average the assessed value is equal to 33% of the market value. The bottom deduction of a little bit more than NOK 50,000 represents a small tax advantage. The assessed rate of return is set to 2.5%. Well below the market rate of return. In the calculations the market rate of return is set to 5.5%

The tax reform I analyse first is a removal of all these three advantages of the present system. Thus the tax system (8) is replaced by (9) (Where V is the market value of the dwelling), and new letting probabilities are calculated.

$$II = V * 0.055 \quad (9)$$

The estimated effect of this tax reform is a 4 % increase of the supply of secondary rental dwellings from the stock of owner-occupied single-family houses. Some will see such an increase of supply as a step towards a more effective utilisation of the housing stock.

The next question to be posed is: what is the short run first-order effect if the favourable tax treatment of return of owner-occupied housing is kept, but net rental income is taxed at a flat rate of 28%. Net rental income is defined as rental income in excess of the operating costs of the rental unit. Such a reform would, for a given level of rent, decrease the effect on other consumption that letting a secondary dwelling would enable and would therefore also decrease the attractiveness of such activities. The simulations confirmed this expectation. The quite heavy increase of taxes on net rental income from secondary dwellings decreased the supply of such rental dwellings by nearly 17 %! However, it should be remember that this result is produced under the (improbable) assumption that no part of the heavy tax increase is passed on to the tenants in a new equilibrium.

In interpreting the effects that are presented in this section, the meaning of the phrase short-run first-order effects should be remembered. First it implies that only the supply side of a market is analysed. Interaction with the demand side will in most cases reduce the magnitude of the effects. The second point to note is that utilisation of a given stock of owner-occupied single-family houses owned by a given set of households is considered. Thus, no account is taken of how prices of single family houses might be changed as a result of changes in income and the tax system.

6. Concluding remarks

This paper has provided a framework for understanding of the supply of a particular type of rental housing that is not, as far as I am aware, treated in the economic literature. Even though this type of rental dwellings 'is hardly known in the economic literature' it is known in the market, in Norway it makes up 20-25% of the entire rental sector. Poulton (1995) presents some evidence to indicate that letting of secondary dwellings in single family houses is also an important part of the rental market in a number of other sparsely populated regions with a high proportion of single family houses.

The theoretical analysis is formulated in a way that provides direct guidelines for empirical estimation of supply functions. This framework is used to estimate an empirical model of the behaviour of two-parent families in possession of single-family houses with a secondary dwelling.

The estimations and a number of specification tests give confidence in the estimated model. An important feature of the model is that it includes both a variable that captures how the potential consumption of 'other goods and services' and quantity of housing services (measured by floor size) varies between the two options that is open to the owner-occupiers.

By interpreting the estimated model as a demand model an income elasticity of 0.39 is found. Even more important is it that the estimated model shows that income elasticities are varying quite strongly between households. The upper quartile in the distribution of income elasticities is estimated as being twice as high as the lower quartile. Much of the same structure is found when price elasticities are evaluated. An implication of this is that aggregate, or average, measures of price and income elasticities might be insufficient when evaluating effects of policy measures.

The simulations of effects of reforms in the taxation of the return on housing capital show that the design of a tax system really should be expected to affect the utilisation of the stock of owner-occupied housing. Full taxation of net rents is expected to depress the supply of this particular type of rental housing quite strongly.

Finally I would like to draw attention to the functional form of the utility functions that are used. This form allows for testing of and confirmation to standard assumptions of utility functions. Furthermore, it is shown that the probability of letting a secondary dwelling in my model is strongly dependent of the absolute level of income, i.e. consumption of 'other goods and services'. The linear utility functions which are frequently used in models of housing choices, results in choice probabilities that are only depending on the difference of such measures in different alternatives.

¹ These figures are taken from the National Housing Survey of 1995.

² This might introduce some kind of sample selection bias in the empirical analyses. This problem will not be dealt with in this version of the paper.

³ If this assumption had been used the letting choice should have been analysed as a 'two-step' choice. First an owner must decide how large part of her house she would want to let given that she wants to let. Then the utility of this optimal letting-strategy should be compared to the utility under a no-letting-strategy.

⁴ A somewhat technical point is worth noting. All but one of the parameters of the utility functions is identifiable through a ML-estimation. The exception is that d_L and d_0 is not identifiable. The difference between them is however identifiable. I have chosen to normalise d_0 to zero.

⁵ For an additional dwelling to be regarded as a 'secondary flat' by the tax authorities it must be smaller in size than the main dwelling.

⁶ It can be noted that the joint hypothesis that all coefficients of the utility function except the constant term equal zero is rejected at any sensible level of significance. Skipping one of the arguments in the utility function, housing services or 'other consumption', leads to a significantly worse fit of the estimated model.

⁷ Net rental income equals rent minus the operations costs of the rental unit.

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Moving Costs and the Dynamics of Housing Demand[#]

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Abstract

It is well established that moving costs makes households adjust their housing consumption far less frequent than they would have done if relocation was costless. This paper adds to our understanding of the dynamics of housing demand by constructing a life-cycle model of housing demand on which several numerical experiments are performed. Among other things it is shown how the sign of price elasticities may be indeterminate because of changes in moving careers induced by price changes. The paper also demonstrates that planned (endogenous) moving activity and stochastic forced moves should be analysed within a common analytical framework. One simple version of such a common analytical framework is presented and discussed.

JEL-classification: R21, D21

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1. Introduction

In the presence of moving costs households will not instantaneously adjust housing consumption to changes in prices, preferences or household composition. Knowledge of this of course affects housing choices made when a move takes place. Through an analysis of theoretic structures and some simulations on a calibrated model I will show how demand of housing services at one point in time should be interpreted as a part of an intertemporal plan. Hence, this paper analyses housing demand as a dynamic plan, which depends on an exogenously given time-path of moving costs and prices, of housing consumption over the life-cycle. One new result is that planned moving activity of a household may change with the probability of forced moves.

The paper is related to two different traditions in the economics of intra-urban mobility. My baseline model is a discrete time version of the model in Amundsen (1985). Hence, my work is a part of the dynamic movement plan approach. Another tradition in economic studies of mobility is the 'disequilibrium'-approach. In order to illustrate the connections to this I will briefly discuss the articles of Venti and Wise (1984) and Loikkanen (1988).

At the start of Venti and Wise (1984) it is stated that *'The basic idea of our model,..., is that families move if the advantages of moving outweigh the transaction costs associated with moving'*. Later on when a disequilibrium term is introduced it is inferred that this equals zero just after a move has taken place. This will be true only if the household is planning to stay for only one period in the dwelling into which it moves. The nature of the equilibrium concept employed by Venti and Wise and others in this tradition is thus somewhat myopic. Even though Venti and Wise offer an econometric framework that facilitates simultaneous analyses of housing demand and moving decisions that take account of moving costs, they fail to take the consequence of housing demand at one point in time being a part of a dynamic plan. Indeed Amundsen (1985), Goodman (1995) and Muth (1974) show that a disequilibrium measure can be at its largest just after a move has taken place. This is supported by the empirical results of Edin and Englund (1991).

Loikkanen (1988) gives a search theoretic analysis of housing demand in which the decision to move can be split up in two steps. First, large discrepancies between actual and desired housing consumption lead a household to start searching for a new dwelling. Second, the household receives an offer of a suitable dwelling (a dwelling with characteristics inside the acceptance set). A move is the result of households passing through these two steps. Also Loikkanen bases his econometric models on a current, or a myopic, disequilibrium concept.

The empirical mobility analyses based on 'the (myopic) disequilibrium approach' have produced important insights but it has failed to take full account of the dynamics of housing demand. On the other hand, analyses that deal explicitly with the dynamics, such as Amundsen (1985), Goodman (1995) and this paper, are not yet able to produce a sound basis for empirical analyses. These papers have to rely on simulations on calibrated models in order to give quantitative indications of the dependencies within the models.

My paper differs from the others in two important ways: Firstly I show how a stochastic process that can generate forced moves can be integrated into a model of endogenously determined moving activity. Secondly I show, through simulations, how a dynamic plan can be revised as exogenous variables changes. I find that the demand reaction towards such changes depends crucially on the date the changes are announced.

Section 2 gives the central theoretical framework of the paper. In section 3 it is showed how stochastic forced moves can be integrated into a model of endogenous (or voluntary) moving activity and which effects it will have. Simulations on a calibrated version of the baseline model are given in part 4. The last section concludes.

2. Baseline model

In order to focus on aspects I regard as important, the 'Baseline model', presented in this Section, is kept quite simple. This means that important aspects of the reality most consumers face, is not taken into account. The most important simplifying assumptions, around which the model is built, are given below.

- i) a perfect capital market in which the market interest rate equals the consumer's discount rate. Thus, there are no liquidity constraints.
- ii) Housing consumption is measured by a uni-dimensional measure of housing services with a known price.
- iii) Time paths of moving costs, prices, interest rates and lifetime wealth are known with certainty.
- iv) The planning horizon over which the consumption of housing services and other consumption is allocated is finite equal to T. Furthermore there are no bequest motives.

The consumer behaves as if he solves the following maximisation problem:

$$(1) \quad \begin{aligned} & \text{Max} \quad U = \sum_{t=1}^T (1 + \rho)^{-(t-1)} u(x_t, h_t, \Gamma_t) \\ & \{x_t, h_t\} \end{aligned}$$

Subject to

$$\sum_{t=1}^T (1 + \rho)^{-(t-1)} [x_t + r_t h_t + \mu_t] \leq W$$

- ρ is the constant interest rate, which is equal to the consumer's discount rate
- x_t is the consumption of the composite good 'other goods and services' in period t.
- h_t is the consumption of housing services in period t
- r_t is the period t price of housing services
- W is the life-time wealth measured as a net present value
- Γ_t is a (set of) parameter(s) that describes the consumers type
- μ_t is a potential moving cost

By consumers type one can think of whether there is children in the household¹, or whether the taste for housing relative to other goods changes over time. In periods in which the household is not moving μ_t will equal zero, when the household is moving at the start of the period μ_t will equal the exogenously given moving cost m_t .

Characteristics of the solution to this dynamic optimisation could have been gathered by solving it by backward induction. The last step of the backward induction will be to maximise the sum of the period one utility and an indirect utility function, containing the effects of

optimal choices in period 2 to T. Because of the discontinuities caused by the presence of moving costs, the indirect utility function will, however, not be very well behaved.

As the baseline model of this paper treats a situation without any uncertainty, using the methods of dynamic programming will not yield any new insights. I therefore proceed in the same way as Goodman (1995) and Amundsen (1985) by postulating a moving career and show how the optimal consumption bundle within this career can be described. To facilitate comparisons of consumption bundles in one period and multiple period stays I will describe the consumption bundles under a career in which the consumer chooses a dwelling at the start of period one, and lives in it for one period. At the start of period two she chooses to move and stay in the period two dwelling throughout the planning horizon. The consumption vector $\{x_1, \dots, x_T, h_1, h_2\}$ that yields maximum utility is found where the Lagrangian in (2) has a stationary point.

$$(2) \quad L = u(x_1, h_1, \Gamma_1) + \sum_{t=2}^T (1 + \rho)^{-(t-1)} u(x_t, h_2, \Gamma_t) \\ - \lambda \{x_1 + r_1 h_1 + m_1 + (1 + \rho)^{-(t-1)} m_2 + \sum_{t=2}^T (1 + \rho)^{-(t-1)} [x_t + r_t h_2] - W\}$$

Some rearranging gives the following first-order conditions:

$$\frac{\partial u(x_t, h_t, \Gamma_t)}{\partial x_t} = \lambda = \frac{\partial u(x_t, h_t, \Gamma_t)}{\partial x_t} \quad t = 2, 3, \dots, T$$

$$MRS_t = r_t$$

(3)

$$\sum_{t=2}^T (1 + \rho)^{-(t-1)} \{MRS_t - r_t\} = 0$$

$$x_1 + r_1 h_1 + m_1 + (1 + \rho)^{-(t-1)} m_2 + \sum_{t=2}^T (1 + \rho)^{-(t-1)} [x_t + r_t h_2] = W$$

MRS_t is the period t marginal rate of substitution between housing and other consumption:

$$MRS_t \equiv \frac{\partial u}{\partial h_t} / \frac{\partial u}{\partial x_t}$$

The first equation of (3) shows that the path of other consumption is adjusted so that the marginal utility is equalised both within and between stays. This result depends naturally crucially on my assumption of perfect capital markets and a subjective discount rate equal to the interest rate. Goodman (1995) and Artle and Variya (1978) show that with imperfect access to capital markets the (constrained) optima may imply inter-period variation in the marginal utilities of other consumption. To arrive at conclusions on the form of the time path of 'other consumption' one will have to make more specific assumptions on the time path of Γ_t and prices r_t and on the cross derivatives of the intra-period utility functions, see proposition 2 in Amundsen (1985)².

In a one-period stay housing consumption is chosen so that MRS equals the relative price of housing consumption (the price of the bundle of other consumption goods is set equal to unity). This is exactly what one may denote the traditional first-best allocation rule. For multi-period stays this first-best allocation rule does not apply. From the third equation of (3) one sees that the housing consumption within a stay is chosen so that the discounted average difference between MRS and the relative price of housing services is equal to zero. Within a stay housing is chosen so that discounted over- and under-consumption are equalised.

If for one moment one assumes that the form of the inter-period utility function and the price path yield an increasing housing consumption, one can within my model show a result that also emerged in Muth (1974). Positive moving costs will induce the consumer to choose a stay in which over-consumption is at its largest immediately after a move. Hence, there is really no reason to believe that recent movers are in equilibrium. This theoretical point is important, as it has been common to argue that demand equations preferably should be estimated on samples consisting of recent movers. For a review, see Edin and Englund (1991).

Some of the empirical results in Edin and Englund (1991) indeed support the results of Muth (1974). They first estimated a 'standard housing demand equation' on a cross section of owner-occupiers. Then they checked whether the squared residuals correlated with duration of the consumers' incomplete stays. Duration was found to have a significant negative effect on the squared residuals. This result is consistent with results in my model, but certainly not with a 'recent mover hypotheses'.

It still remains to show how the consumer chooses between the different moving careers. Let f_1, f_2, \dots, f_F be the possible moving careers and $X(f)$ and $H(f)$ be the optimal paths of other consumption and housing under moving career f . The consumer will choose the moving career that yields the highest utility (U^*).

$$(4) U^* = \max\{ U(X(f_1), H(f_1)), U(X(f_2), H(f_2)), \dots, U(X(f_F), H(f_F))\}$$

Thus, the choice of moving career is in this paper modelled as a comparison of utility levels of different careers. The need for such a comparison arises because of the discontinuities of the set of consumption bundles, which is a result of the positive moving costs. It is not possible to give any general comparative statics of the structure of the solution of (4). Such comparative statics will at least involve so many expressions and conditions that they will hardly be informative, this is due to the switches of moving careers that may take place as the ordering of the utility levels changes when exogenous variables vary. To illustrate the structure of the solutions results from some numerical experiments are given in section 4.

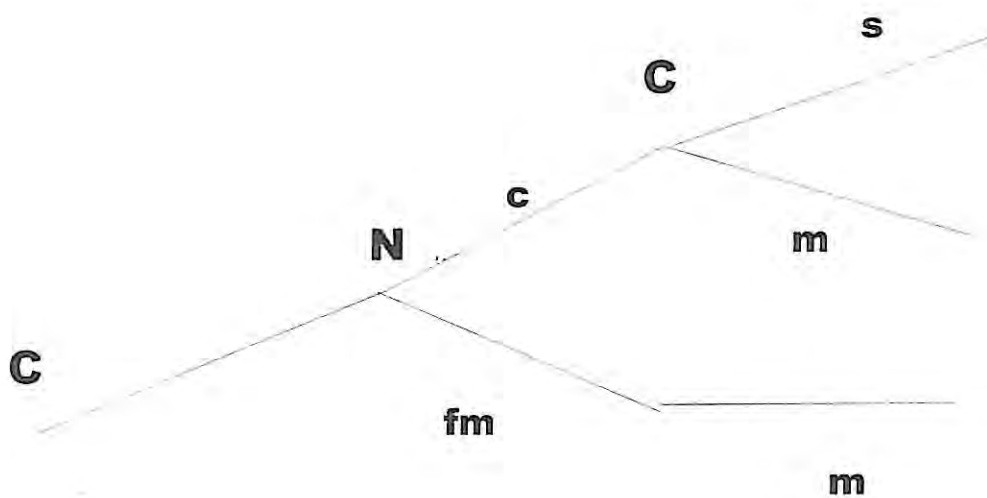
3. Induced moves

Some moves form a part of a planned moving career and should thus be treated as endogenous in the utility maximisation of a consumer. This type of moves is described in my baseline model. In addition to this one has moves that are triggered by unforeseen events. Muth (1974) analyses the choice of housing quantity throughout a stay when a stochastic process may generate exogenous moves and length of a stay thus is a stochastic variable. One central conclusion that may be read out of his analysis is that the willingness to accept over- or under-consumption early in a planned stay is decreasing in the probability that an exogenous

move should take place. Using a two-period model I shall here show how a planned housing (and moving) career is affected by the presence of stochastic exogenous moves.

As an introduction to this analysis a decision tree may illustrate the decision process:

Figure 1



The large letters describe who is taking the decisions at the node. The consumer (C) takes her decision at the beginning of the first period when she chooses how much housing to consume in this period. Next period is started by 'nature' (N) deciding whether the consumer is allowed to choose a stay or a move. After the decision of the nature the consumer ends her series of decisions by choosing among the available alternatives.

In the baseline model where everything were certain, the consumer made a plan in the form of a time series of moving and staying decisions. In the situation analysed here and illustrated in figure 1 the picture is somewhat different. The strategy 'stay' must be replaced by another strategy, which might be denoted 'attempted stay'. The consumer starts off in the first period and chooses a plan conditioned on her reacting optimally on information arriving later. Thus, the techniques of dynamic programming will be suitable for the analyses of the optimisation

of the consumer. That is, I start by analysing the choices of the second (and last) period in two different cases. These two cases correspond to the possible realisations of the nature's draw, which is 'forced move' and 'do as you want'. For each of these cases an indirect utility function is defined, and both these two indirect utility functions enter the period one optimisation.

If the consumer is forced to move at the start of the second period, she maximises utility by choosing the consumption pair $\{x_2, h_2\}$ so that:

$$(5) \quad u(x_2, h_2, \Gamma_2) - \lambda_{fm}(x_2 + r_2 h_2 + m_2 - W^*)$$

is at a stationary point. W^* is the period two value of the part of the initial wealth that is not consumed through period 1.

$$W^* = (1 + \rho)\{W - m_1 - x_1 - r_1 h_1\}$$

This optimisation yields standard first order conditions:

$$(6-1) \quad MRS_2 = r_2$$

$$(6-2) \quad x_2 + r_2 h_2 = W^* - m_2$$

The solution to (6-1) and (6-2) is denoted x^{fm}_2 and h^{fm}_2 . Inserting them in the utility function gives the indirect utility function $V^{fm}(h_1, W^*)$, whose arguments in the language of Kreps (1990) are the links between the past, the present and the future of my model. The derivatives of the indirect utility function are:

$$(6-3) \quad \frac{\partial V^{fm}}{\partial h_1} = 0$$

$$\frac{\partial V^{fm}}{\partial W^*} = \lambda_{fm}$$

The first part of (6-3) is of course due to the fact that variations of the first period housing consumption is not (partially) affecting period two utility as long as you are not allowed to stay in the same dwelling.

Because of the discontinuities imposed by moving costs, I will have to look at the optimisation in the case where nature chooses 'do as you please' in two steps. First I characterise the optimal consumption pair given that a stay (s) is chosen and then when a move is chosen (cm). Given that a stay is chosen, the period two optimisation reduces to spend all remaining money on 'other consumption'.

$$(7-1) \quad h_2 = h_1$$

$$(7-2) \quad x_2 = W^* - r_2 h_1$$

Given that a move is chosen the first-order conditions for utility maximum will, in form, be equal to the conditions under 'forced move'. However, they are not identical as the amount saved for period two consumption differs in the two strategies attempted stay and chosen move. I will return to this point when the planned housing career under this framework is discussed. The indirect utility function in the case when the consumer is allowed to choose in the second period $V^C(\cdot)$ is:

$$(8) \quad V^C(h_1, W^*) = \max\{u(W^* - r_2 h_1, h_1, \Gamma_2), u(x_2^{cm}, h_2^{cm}, \Gamma_2)\} = \max(v^s, v^{cm})$$

The two arguments of the $\max\{\}$ -expression are indirect utility functions. The initial wealth and the historical period one choices give the maximum attainable utility under 'stay' (v^s). The optimal quanta when a move is chosen are denoted x_2^{cm} and h_2^{cm} , and v^{cm} is the corresponding utility.

The derivatives of $V^C(\cdot)$ depend on which of the two arguments of the $\max\{\}$ -expression is largest. If $v^s > v^{cm}$ then:

$$(9-1) \quad \frac{\partial V^C}{\partial h_1} = \frac{\partial u(x_2, h_1, \Gamma_2)}{\partial h_1} - \frac{\partial u(x_2, h_1, \Gamma_2)}{\partial x_2} r_2$$

$$\frac{\partial V^C}{\partial W^*} = \lambda_s$$

If $v^s < v^{cm}$ then:

$$(9-2) \quad \frac{\partial V^C}{\partial h_1} = 0$$

$$\frac{\partial V^C}{\partial W^*} = \lambda_{cm}$$

(9-1) and (9-2) are obtained from optimisations similar to (5). The variables λ_s and λ_{cm} are consequently the value of the Lagrange-multipliers in optimum. They can also be interpreted as the marginal utility of period two income.

At the start of period one the consumer must choose a consumption pair $\{h_1, x_1\}$. This choice must be done before it is known whether the strategy stay is available in period 2. I assume that the choice is done so that the sum of the period one utility and the discounted expected utility of period two is maximised, within the limits set by the budget constraint. This is attained at the stationary point of (10).

$$(10) \quad u(x_1, h_1) + (1 + \rho)^{-1} [PV^{fm}(h_1, W^*) + (1 - P)V^C(h_1, W^*)] \\ - \psi(x_1 + r_1 h_1 + m_1 + (1 + \rho)^{-1} W^* - W)$$

P is the exogenous probability of being forced to move and ψ is a Lagrange multiplier. The form of $V^C(h_1, W^*)$ differs depending on whether the stay-utility exceeds the chosen-move-utility or not. I will therefore start by characterising a planned housing career where the utility of a move in the second period exceeds the potential stay-utility. The results of this analysis are standard.

$$(11-1) \quad \frac{\partial u_1}{\partial x_1} = \psi$$

$$(11-2) \quad MRS_1 = r_1$$

$$(11-3) \quad P\lambda_{fm} + (1-P)\lambda_{cm} = \psi$$

$$(11-4) \quad x_1 + r_1 h_1 + m_1 + (1+\rho)^{-1} W^* = W$$

A household who has planned to move anyhow will not be affected by a message, which says you have to move. This implies that $\lambda_{cm} = \lambda_{fm}$. (11-3) then implies that the marginal utility of money spent in period 1 should equal marginal utility of money spent in period 2. Under this voluntary move scenario the marginal utility of money spent on housing in the first period is equalised to the common marginal utility of other consumption in both the first and the second period. A similar result holds for the housing consumption of period 2. These results hold for any P.

In the case in which the household will prefer a stay in period two some more interesting, and maybe even surprising, results emerge. The first-order condition for utility maximum, in which some of the characteristics of the indirect utility function $V(\cdot)$ is inserted is given in the equations (12):

$$(12) \quad \begin{aligned} \frac{\partial u_1}{\partial x_1} &= \psi \\ \{MRS_1 - r_1\} &= -(1+\rho)^{-1}(1-P)\lambda_s \{MRS_2 - r_2\} \\ P\lambda_{fm} + (1-P)\lambda_s &= \psi \\ x_1 + r_1 h_1 + m_1 + (1+\rho)^{-1} W^* &= W \end{aligned}$$

Using (12) to discuss planned housing careers containing planned stays, in the presence of an exogenous stochastic process that may produce forced moves, it is convenient to start with the third equation of (12). Equation (12) applies only when the household prefers not to move if this alternative is available, that is only if $v^s > v^{cm}$. Under the plausible assumption that marginal utility of income is decreasing in the utility level - λ_{fm} is greater than λ_s . Period one consumption of other goods is chosen so that its marginal utility equals the expected marginal utility over the two possible states of the second period.

This result can be used to show how variations of the probability of being forced to move affects the period one consumption of other goods and services of a household who does not intend to move if it is allowed to stay. As the probability of being forced to move is given a positive shift, the weight attached to the marginal utility under 'forced move' also increases. This increases ψ , which in turn leads to a decreased period one consumption of other goods. The economic rationale behind this is that 'forced move' is an undesirable event. When the probability of this event increases, period one consumption is decreased in order to be better prepared to meet the moving cost which might be imposed on the household in next period.

In the discussion of equation (3) I showed that without any exogenous moving processes (that is: $P=0$) housing will be chosen so that over-consumption in some periods is balanced against under-consumption in other periods. The question is so if (and how) this conclusion is affected by the presence of exogenous stochastic moves. Inspection of the second equation of (12) reveals two differences. First, the mismatch of the first period is weighted by ψ . As seen in the preceding paragraph, ψ is increasing in P . This pushes the size of the 'first-best' housing consumption downwards. One can say this result is generated by the same mechanism that pushed down the period one consumption of other goods and services. Total consumption expenses in period one is decreased in order to increase the utility level if a move should be imposed upon the household in period two.

The second effect on first period housing consumption is that the first period over-consumption (under-) is balanced against the product of the probability that stay-strategy is available in the last period and under-consumption (over) in the last period. Thus the

consumer is less willing to take a first period mismatch of the housing consumption the more likely it is that she is not able to avoid paying moving costs in the second period.

Within the two-period model analysed here it is possible that a consumer who plans to stay in the same dwelling in both periods when P is low, will plan to move if the probability of being forced to move, P , is high. A sufficient condition for the existence of a P -value (P^0) so that a consumer who chooses the strategy 'attempted stay' for $P < P^0$, and chooses to move for $P > P^0$ is that for $P=1$ condition (C1) is fulfilled.

$$(C1) \quad u(x_2^{cm} + m_2 + r_2(h_2^{cm} - h_1^{cm}), h_1^{cm}) < u(x_2^{cm}, h_2^{cm})$$

The period one mismatch in housing consumption is reduced towards zero as P approaches one. For $P=1$ the consumption vector in the first period equals that under chosen move. Under C1 consumers who have chosen the period 1 housing and 'other consumption' under the constraint that a stay was not available will not stay even if they receive a message at the start of period 2 saying that a stay is possible in period 2.

If one starts at $P=1$ and reduces P by some small amount the utility of attempted stay will be reduced. There are two reasons for this result. Firstly, C1 ensures that for P 's close to one the 'ex post' utility of a stay is lower than the chosen move utility. Secondly, as P is reduced from unity, the consumer deviates from the period one consumption vector under chosen move. Consequently the ex post utility under 'forced move' is lower for low values of P than for high values. Hence, under C1 there exists P -values also below 1 where the utility of the move strategy is lower than the utility of an 'attempted stay'-strategy, even though attempted stay yields higher utility at some lower values of P .

This paper will not proceed the analysis by characterising the P -value where the utility ordering of the strategies is changed. The ambition of this part of the paper is rather to establish that high probabilities of being forced to move may induce the consumers to increase their planned moving activity. In appendix 1 it is shown, in a simple numerical example, how the ranking of the utility under the strategies 'attempted stay' and 'chosen move' may change as P is varied.

The intuition behind this result is easy to grasp. The gain from a stay is of course that one does not have to pay moving costs, the price of this gain is some misfit in the time path of housing consumption. A stochastic process that may generate forced moves can in this situation lead to households paying the price through a misfit without them collecting the gain. It is no surprise that increased possibility of not gaining from a strategy reduces the propensity to paying the price of it.

Amundsen (1985) expressed his aim to be to '*make a contribution to the micro-economics of the part of intra-urban mobility that is explained by long-term planning*'. My results indeed show that to understand *the part of intra-urban mobility that is explained by long-term planning*, one should analyse planned moving activity within a framework that allows for unplanned moves. The analysis of this section should not be regarded as any completion of an integrated model of induced and planned moves, but rather as a start of such a work.

4. Some simulations

Formulation and calibration of a model

In the presentation of the baseline model I argued that comparative statics would yield so messy expression that they hardly will be informative. This section therefore illustrates some central features of the model through simulations on a calibrated version of the baseline model. Additive logarithmic utility functions are used:

$$(13) \quad U = \sum_{t=1}^T (1 + \rho)^{-t+1} (\alpha_t \ln(h_t - b_t) + (1 - \alpha_t) \ln(x_t - \beta_t))$$

α_t , β_t and b_t are parameters of the utility function.

Equation (13) yields, in the absence of moving costs, the 'linear expenditure system'. In the presence of moving costs the demand functions still resemble those of the linear expenditure system.

Simulations based on the utility function above are done under an eight period long planning horizon. In my simulation I think of each period as consisting of five years. The results of the simulations can thus be thought of as an example of a planned housing career from the age of twenty up to sixty years. No attempt has been made to do the calibration so that the simulation model resembles the Norwegian housing market or describes typical housing careers. Hence, the simulations should be interpreted as no more than a numerical example that illustrates structural interdependencies.

An annual discount rate of 4% yields a period discount rate of 21.7%. In the standard simulations it is assumed that both the real price of housing services and moving costs grow at an annual rate of 1.5%, corresponding to a growth rate from one period to the next approximately equal to 7.7%. The price of housing services is set to 10 and moving costs to 40 in the first period. Life time wealth is set equal to 10.000. This implies that discounted housing expenses over the life time equals a little bit more than 20% of life time wealth.

Both Goodman (1995) and Amundsen (1985) use such simulations on a calibrated model as part of their discussion of the dynamics of housing demand in the presence of moving costs. Both stress the fact that planned moves may be triggered by foreseen changes in the composition of the household or by (foreseen) changes in the preference for housing. My simulations differ from both in so far as I let the parameters of the utility function vary over time.³ It may seem rather peculiar to formulate a specified time-path of the parameters of the utility function. In my view it is not more peculiar to describe a path where the parameters changes than a path where they are constant over the life cycle.

The parameter b and the β_i 's that are sometimes interpreted as some kind of minimum consumption, are given the values 8 and 400. The α -parameters that may be interpreted as excess-consumption-expenses-shares are set to the quite low value 0.18 in the first period. In each period they are increased by 0.07 up to the fourth period where they equal 0.39. This value is kept also in the fifth period. In period six α equals 0.32, finally in period seven and eight it is set to 0.25.

Table 1 shows the planned housing career under the standard assumptions spelled out in the text. The third column is included in order to facilitate comparison with some kind of first-best solution and contain housing demand when moving costs equal zero. The wealth effect is removed by letting the wealth that generates the demand of column three equal initial wealth minus the net present value of the moving costs associated with the optimal plan.

Table 1 - Simulated path of housing consumption, reference path

Period	Reference path with moving costs	'First-best' demand
1	51.0	39.3
2	51.0	48.4
3	51.0	56.0
4	51.0	62.3
5	51.0	58.4
6	51.0	46.4
7	35.0	35.9
8	35.0	33.9

Even though I have chosen quite low moving costs, the optimal number of moves, in addition to the first compulsory move in period one, is only equal to one. The simulation results also reveals that given the prices and parameters I am using in the simulations the discrepancies between first-best demand and the simulated demand is substantial. Over-consumption in the first period is 30% of first-best demand, and under-consumption in period 5 is almost 20%.

Some structures are revealed when wealth and moving costs are varied. The number of moves is, not very surprising, decreasing in the size of the moving-costs. It is increasing in income. Absolute variation of first-best housing demand is larger the larger life-time wealth is. This implies that the mismatch cost of not adjusting housing consumption between two periods is increasing in lifetime wealth.

Harrington (1989) analyses the dynamics of housing demand in a framework without any explicit treatment of moving costs. The central idea in Harrington's article is that the time-path of housing and other consumption is affected by changes in the price in one specific period through two different channels. Firstly, one has the direct price effect that pushes down housing consumption in the specific period. This is denoted an intertemporal substitution

effect by Harrington. Secondly, one has a wealth effect. That is, the real value of a lifetime income decreases as the price of one of the components of the consumption vector is increased. This decrease pushes down the consumption of housing services in all periods.⁴

In my model where adjustment of housing consumption to variations in the price of housing services might be chosen away because of the moving costs associated with adjustment, one may have a third effect. That is that the moving careers might be changed. This is illustrated in table 2 where the effect of a 50% price increase in period 6 is given. In the table elasticities will be reported in three cases: zero moving costs, moving costs equal to 10 and as in the standard case, moving costs equal to 40. As the price elasticities in table 2 are the sum of three different effects, I will denote them gross price elasticities.

Table 2 - Gross price elasticities when the period 6 price is increased

	m(1)=0	m(1)=10	m(1)=40
El _{r(6)} h(1)	-0,004	-0,004	0,019
El _{r(6)} h(2)	-0,005	-0,004	0,019
El _{r(6)} h(3)	-0,005	-0,004	0,019
El _{r(6)} h(4)	-0,005	-0,004	0,019
El _{r(6)} h(5)	-0,005	-0,004	0,019
El _{r(6)} h(6)	-0,556	-0,525	-0,657
El _{r(6)} h(7)	-0,004	-0,039	-0,041
El _{r(6)} h(8)	-0,004	-0,039	-0,041

Over the interval over which I have calculated them the absolute value of the direct price elasticities is between 0.5 and 0.7. The exact figure depends on the magnitude of the moving costs. There does not seem to be any systematic tendencies in the dependencies between moving costs and the intra-period price elasticity. The source of the variations in the intra-period price elasticity lies in the effect the price increase has on the planned moving career. To see this I will discuss the relation between the elasticities in the cases where m(1) equals respectively zero and ten.

Before the price increase period 6 was a one period stay when moving costs equalled 10. Housing consumption in this single period-stay were 33% above housing consumption in the following stay. The price increase did then push 'first-best' consumption in the sixth period slightly below the consumption in the last two periods. The difference between the period six

first-best consumption and the consumption of the last periods is so small that the consumer is better off by moving into a dwelling at the start of period six that she stays in for the last three periods. As long as first-best consumption in period seven and eight is higher than in period six, consumption is chosen so that there will be some over-consumption of housing in period six. This over-consumption is the reason of the, in absolute terms, lower price elasticity in period six when moving costs equal 10. As period six is included in the last stay, this pushes down the housing consumption through this stay. This is reflected in the relative high absolute value of the elasticity period eight housing consumption with respect to the price of housing services in period 6. These elasticities are about ten times as large as the 'pure wealth effects' that can be seen in the elasticities of housing consumption in the periods prior to period six. The difference is due to the described effects on the planned moving career, that is the cancellation of one move.

When turning to the simulations where the initial moving costs is set equal to 40, one interesting result emerges. The elasticity of period one to five housing consumption is positive. Thus, in response to a price increase in period six housing consumption is increased in the preceding periods. This is due to the fact that prior to the price increase period six was part of a stay in which the housing consumption was pushed down by the overconsumption in period six. The price increase leads the consumer to move one period earlier, and this increases the consumption of housing services in the preceding stay. One can say that in this case a positive housing career-effect is dominating the 'conventional' negative wealth effect.

The effects illustrated in table 2 are not very important as they are gathered from a loosely calibrated model. The important insight is that the effect of a price change is composed of three different effects, of which the moving career-effect is even capable of changing the sign of some of the price effects on housing consumption.

Timing of shocks

In this part I will see how the reaction to changes of prices depends on when the consumer is informed about the changes. I denote these changes shocks as I perform the analysis under the assumption that prior to a change the consumer has not in any way prepared herself to such

changes. In further work it is natural to extend this analysis to see how demand profiles is affected if the consumers expectations on future prices are probability distributions rather than point expectations.

In order to illustrate how the reaction to price changes depends on when the consumers is informed of the change, I will show how the response to an increased period six price of housing services varies with the date of announcement. Table 3 shows how the price elasticity is varying with the date of the announcement of the price increase, these figures are reported for two different levels of the initial moving costs.

Table 3 - Gross price elasticities when a period-6 price increase is reported at different dates

Message-date	m1=10	m1=40
1	-0,525	-0,657
2	-0,526	-0,653
3	-0,526	-0,653
4	-0,529	-0,653
5	-0,531	-0,653
6	-0,534	-0,653

Intuition tells that the later an increase of a price is announced, the larger intertemporal distortions one should expect. These distortions are due to the consumer spending too much of her resources early in her life span before the price increase is announced. This again implies that the reduction of the period six consumption of housing services is expected to be larger the later it is announced. Even though the variation of the price elasticities is quite small, this intuition is supported by the elasticities calculated for initial moving costs of 10. For initial moving costs of 40 however, the picture is different. Here one see that the absolute value of the price elasticity is largest for price increases reported in first period before any part of the initial plan is realised!⁵ This somewhat peculiar result originates in the effects on the moving career. As already shown, a price increase in period six announced at the start of period one leads to an earlier move into the last of the two stays, this increases the housing consumption in the first stay. When the price increase is announced after the move into the first stay the

consumer prefers to stay in this dwelling for five periods and avoid new moving costs, even though the stay one consumption is lower than what would have been preferred had the prices been known in advance. Loosely speaking, the resources that is not spent on housing early in the life span is then divided on housing consumption in the last stay and other consumption after the announcement. The later the announcement is made the less is spent on other consumption and the more is spent on housing in the last stay.

This last result is again a clear illustration of the fact that once moving costs is introduced some intuitive and standard results might be changed. It does also illustrate the problems of giving easily interpretable comparative statics on housing demand in a dynamic framework with moving costs.

Welfare effects of a stamp duty

An important part of the monetary moving costs for owner-occupiers is the stamp duty. This tax is in Norway paid by the buyer and amounts to 2.5% of the home price. Loosely estimated the stamp duty accounts for 75% of the monetary moving costs. For a proper analysis of the welfare effects of the stamp duty one would of course need utility functions whose parameters are determined through an empirically based calibrating. These utility functions should then be incorporated in an equilibrium model where house prices are endogenously determined.

However, I will in this paper give a numerical illustration of how to calculate welfare effects. This illustration is meant to serve two purposes. Firstly, it is meant to indicate how dynamic moving career models such as the one in this paper can be used for welfare analysis of the stamp duty. Secondly it is meant to show that it is by no means reasonable to regard a stamp duty as a fiscal tax without any negative distortive effects.

In the numerical illustration I assume that the price of housing capital is not affected by a removal of the stamp duty. This leaves the prices of housing services independent of any changes of the stamp duty. The welfare effect of the removal of the stamp duty is defined as the size of the cash payment needed to make the consumer considered in my example,

indifferent between a package consisting of the prevailing stamp duty and a cash payment and a removal of the stamp duty. Hence, the welfare measure employed here is a measure of the compensating variation.

The effects on housing consumption and welfare of a removal of the stamp duty under these assumptions are reported in table 4.

Table 4 - The effect of a complete removal of the stamp duty

	standard	Removal of stamp duty
h1	51,0	43.7
h2	51,0	43.7
h3	51,0	59.0
h4	51,0	59.0
h5	51,0	59.0
h6	51,0	46.6
h7	34,9	35.0
h8	34,9	35.0
CV		59

CV is the welfare-gain of a removal of the stamp duty for the consumer considered in the simulation. The removal of the stamp duties leads the household I am looking at here to increase its number of moves from one to three. This increase of the moving activity is due to the fact that the reduction of the moving costs allows the consumer to reduce intertemporal mismatch in her housing consumption at a 'lower price'.

The interpretation of table 4 can be turned 'upside down' by using it to answer the question of how large is the cost imposed on the private sector when the government is collecting a tax income of 44 through a stamp duty. The welfare loss amounts to 59. Hence, the dead-weight loss in my example is about 34% of the tax income. This is in the same range as the dead-weight loss frequently found for other taxes.

The number reported here is by no means an estimate of the dead-weight loss. The somewhat arbitrarily chosen form of the utility function and its parameters heavily influences it. Furthermore, the number of moves is in the model constrained to be an integer. This implies

that the effect of the stamp duty, for a single consumer, will be discontinuous in the size of the stamp duty and other moving costs. In a more complete analysis of the welfare effects one should not base the calculations on a representative agent, but on a (continuous) distribution of consumers. This would level out the discontinuities. I do however, take the result of the numerical exercise as a strong indication that a stamp duty by no means can be regarded as any lump-sum tax, as the tax leads to adjustments of the consumption vector in excess of pure income effects.

5. Conclusions

The most interesting theoretical result in my paper arises when a stochastic process that may generate forced moves is introduced into the model of endogenous moving activity. I find that as the probability of being forced to move increases the willingness to accept an early mismatch in housing consumption, in order to avoid moving costs, decreases. This effect can be so strong that an increase of the probability of a forced move make the consumer change her strategy from 'attempted stay' to be a mover.

The paper gives a discrete time version of the model of endogenous moving activity resulting from a dynamic plan of housing demand developed by Amundsen (1985). My model is somewhat more flexible as I explicitly allow prices and parameters of the utility function to vary over time. However, this larger flexibility does not give qualitatively new theoretical results. The central result both here and in Amundsen (1985) is that in the presence of moving costs households will move less frequently than without moving costs and that within a stay the household will not equate instantaneous marginal substitution rates to instantaneous price ratios. Instead average discounted marginal substitution rates is equated to average discounted price ratios.

The larger flexibility of my approach does however facilitate a richer set of simulations. Within the framework of the model I replicate Harrington (1989) who decomposed demand reaction to changes in the price of housing services into a wealth effect and an intertemporal substitution effect. When moving costs are introduced one gets still another effect, which I denote the moving career effect. That is, as prices in one period changes both the number of planned moves and the moving dates may change. This moving career effect might be positive

and it might be negative. Indeed it is shown in table 2 that a positive moving career effect can dominate the negative wealth effect of a price increase.

Even though the model of this paper captures many aspects that are important in understanding the dynamics of housing demand it is built on many simplifying assumptions. In further work some of this should be relaxed. The most important of this is firstly to distinguish between different tenures. Moving costs in rental dwelling is probably lower than in owner-occupied housing, at the same time does the tax benefits produce a price of housing services that is lower in owner-occupied housing. This is of course important in an understanding of housing careers. Secondly, real world consumers face liquidity constraints that seriously affect the set of available housing careers, also this should be included in the analysis.

¹ The terms consumer and household will used synonymously throughout the paper.

² One may note that there is misprint in the text of proposition 2 in Amundsen (1985). The inequalities of part a and b should be reversed. In the proof of the proposition correct inequalities is used.

³ In one of the simulations in Ekman and Englund (1997) one parameter of the utility function is allowed to vary.

⁴ Due to a wrong sign (of the $\theta(t)$'s) in equation (10) it seems like the wealth effect of increased price of housing services is positive in Harrington (1989). This again leads to some peculiarities in his '*Interpretation of price parameters*'.

⁵ If four or more decimals had been included in the last column of table 4 one would have seen that the decline of the absolute value of the price elasticity is monotone in announcement date!

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Appendix 1

In the main text of the paper it is argued that it is possible that a consumer that chooses the strategy attempted stay for some P , may chose that strategy chosen move for some higher P 's. I.e. that a threat of not being allowed to stay in the chosen housing unit for more than one period, can increase the planned moving activity. This appendix demonstrates this to be the case in a simple numerical example.

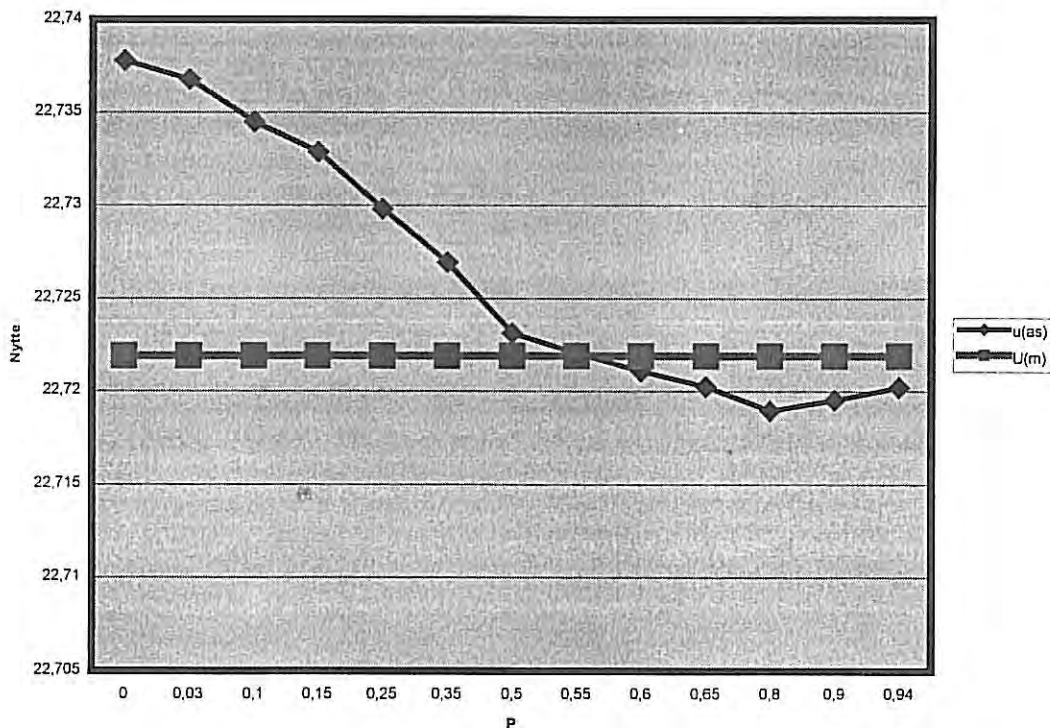
The example ignores discounting and uses a simple version of the utility function of equation (13):

$$(A1) \quad U = \ln(h_1) + \ln(x_1) + \ln(h_2) + \ln(x_2)$$

Lifetime wealth of the consumer is set to 2200, moving costs equal to 20 in both periods. The price of housing services is set to 4 and 3 in respectively period 1 and 2.

Figure A1 shows how the utility under the attempted stay strategy ($u(as)$) varies with P . The utility of chosen move ($U(m)$) is on the other hand not affected by P .

Figure A1 - Utility and the forced move-probability



This figure demonstrate the it really is possible that the utility of the attempted stay strategy may be higher than the utility under the move strategy for some values of P and lower for other (and higher) values of P .

Tenure Choice and Residential Mobility

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Abstract

Planned housing market behaviour of households is strongly affected by presence and magnitude of moving costs. The size of non-monetary or as it is sometimes termed: emotional, moving costs is depending of the composition of a household. This paper presents and estimates an econometric model of the joint decisions of tenure and (planned) residential mobility. The estimated model is used as a framework for tests of various hypotheses of determinants of housing market behaviour. Within the simultaneous two-equation model of this paper it is found that sex and age of household head variables affect planned lengths of stay they have no direct effect on tenure choice. It is also shown that expected residential mobility shifts downwards as children of a family starts their schooling.

1. Introduction

It is well known that moving costs leads to inertia in the dynamic adjustment of housing consumption to changes in the determinants of housing demand. Furthermore, when a household chooses a housing unit it is aware of the costs associated with consumption adjustments. Hence, households take this into account when choosing their housing unit, and buy or rent a housing unit that is expected to serve the needs of the household fairly well over a period of time.

Under such circumstances housing consumption at any particular point in time should be regarded as part of a dynamic plan for housing consumption. In other words, housing demand should be regarded as part of a planned housing career. Arguments in favour of this and its consequences of this are put forward in the next section 'The Economics of Planned Housing Careers'. In this section it is showed that tenure and planned lengths of stay are simultaneously determined dimensions of the choice of a planned housing career.

This paper develops and estimates an econometric model of tenure choice and planned future stay in the present dwelling of a household. Ideally, models of this type should be estimated on a panel. However, as such data is not available, a cross-section has been used instead. Most of the results conform to what is usually found in models of this type. My model differs from other papers in that it contains more detailed description of the household composition. This has been done for two main reasons: firstly, moving costs may affect planned housing careers and housing market behaviour strongly; and secondly, non-monetary moving costs probably differ between different types of household members. I hope to capture some of these effects, by using the variables describing household composition. Hence, demographic explanatory variables in mobility and tenure models are capturing the effect of moving costs. The estimated model is used as a framework for several tests regarding the determinants of the dynamics of housing market behaviour.

In Section 2 of the paper it is argued that the dynamic stochastic decision problem of choosing and revising an optimal housing career is so complex, involves so many discontinuities and has so many dimensions that one should be reluctant to interpret empirical models as complete structural forms. Rather, empirical models should be interpreted as econometric

experiments and as a framework for statistical testing of specific hypotheses of determinants of the dynamics of housing market behaviour. A number of such tests are undertaken in this paper. I would claim that some of the test results should have consequences for formulation of empirical housing market models in general, and more specifically, in formulation of models of tenure choice.

The empirical analysis reveals some very interesting results. Presence of school children in a family reduces expected residential mobility. In most single-equation models, age and sex of household head affect tenure choice. In the two-equation model presented in this paper it is found that even though these two explanatory variables affect planned lengths of stay they have no direct effect on tenure choice.

Section 2 of the paper provides a brief overview of theoretic structures and literature on what, in this paper, is termed the economics of planned housing careers. Section 3 discusses the econometric models, and data is presented in Section 4. In Section 5 model estimates are given and their properties are discussed. Concluding remarks are presented in Section 6.

2. The Economics of Planned Housing Careers

One basic assumption in this paper is that households' housing choices are the outcome of a utility maximisation. In the absence of moving costs this implies that housing consumption is chosen so that at any given point in time, the marginal rate of substitution is equal to the ratio of the prices of housing and other consumption. Tenure choice, in such a situation, will partly be determined by the relative price of housing services in each of the tenures and partly by a household's ability to finance the purchase of owner-occupied housing. Planned length of stay in a dwelling will affect neither the quantity nor the tenure decision, as no consumer is locked in by former choices and no one expects to be locked in in the future by present decisions.

The reason for this is that as long as moving costs equal zero, any mismatch between actual and desired housing consumption leads the household to move on to a more suitable housing unit.

In isolation, the conclusions above are not very interesting. Households do face positive moving costs. These consist of both monetary transaction costs, search costs, costs associated with the physical act of moving and non-monetary costs associated with relocating. As shown

by Amundsen (1985) and Englund (1986): when taking account of moving costs, housing demand, at any point in time, should be regarded as a part of a dynamic plan of a housing career. The theoretic literature on the dynamics of housing demand is reviewed in Nordvik (1999)¹.

The main results which are found in the literature on the dynamics of housing demand is that housing demand is not determined by a single marginal condition. Ignoring tenure choice, an optimal housing career must fulfil two conditions.

- i) Within each stay the average discounted marginal rate of substitution should be equal to the discounted average price ratio.
- ii) In addition to i) the chosen number of planned moves and their timing should yield higher utility than the highest attainable utility (i.e. the utility when condition i is fulfilled) under any other possible combination of moves and moving dates.

The latter condition implies that the analytic description of an optimal housing career consists of a global comparison of utility levels over a discontinuous set of housing careers that satisfy the marginal condition i). These discontinuities arise because of the moving costs. In a discrete time setting the number of possible combinations of moves and stays equal $T(T-1)$, where T is the length of the planning horizon of a consumer. When taking account of the two alternative tenure choices, the size of the set of possible housing careers increases dramatically to $(T(T-1))^2$.

A brief description of an algorithm needed to find an optimal housing career illustrates the complexity of the situation facing both households about to choose a housing career and analysts trying to describe the choices. Firstly, optimal levels of both housing consumption and the profile of other consumption must be calculated under each of the $(T(T-1))^2$ possible housing careers. The one with the highest utility level is then chosen.

The complexities can be further illustrated by considering the effects changes of 'exogenous' factors have on demand profiles or planned housing careers. Given the reasonable assumption

¹ In this review, there is a discussion of the similarities and dissimilarities of the 'planned housing career' approach applied in this paper and the disequilibrium approach of studies of residential mobility. This important – and interesting – topic will not be discussed further in this paper.

of housing being a normal good, an increase in permanent income will lead to increased housing consumption in any given stay. However, the growth of income may alter the ranking of housing careers. The gross effect of a positive shift in permanent income may be that housing demand in some periods decrease! Examples of combinations of coefficients of the utility function that yield such counter-intuitive 'gross effects' are given in Nordvik (1999). I do not regard these counter-intuitive results as mere theoretical peculiarities. Rather, I regard them as plausible structures that correspond to observable phenomena.

The complexities caused by the discontinuous set of housing careers produce severe problems for applied analysis of the demand side of the housing market. If moving costs and the discontinuities they produce are ignored, it will be difficult to give sound interpretations of estimated demand and tenure choice equations (see Edin and Englund, 1991). On the other hand, when the discontinuities and moving costs are taken account of, an applied analyst faces another difficulty. The theoretical analysis of the dynamics of housing demand in the presence of moving costs is very open. Hence, theory does not give an analyst many constraints around which an empirical model may be constructed.

In their analysis of 'Dynamic Aspects of Consumer Decisions in Housing Markets', Henderson and Ioannides (1989) note that it is hardly possible to formulate a closed form model of housing market behaviour that is at the same time theoretically plausible and empirically estimable. Rather, they formulated their strategy to be to '*...design a number of econometric experiments by expressing essential features of the ... maximization problem, such as the simultaneity of various decisions and their dynamic structure*'. This will also form the empirical strategy of this paper.

In spite of these problems, the first main theme of this paper is to show how one, within a dynamic housing career framework, can carry out an empirical investigation of the determinants of the simultaneous choice of tenure and planned length of stay. As both choice of tenure and planned length of stay are dimensions of the choice of a dynamic plan of the housing consumption, their simultaneity can be inferred directly from the discussion of optimally chosen housing careers. Intuitively, it is obvious that tenure choice depends on planned length of stay as the (expected) price ratio of rented to owner-occupied housing is increasing in planned length of stay, Rosenthal (1988).

The idea of analysing planned length of stay and tenure choice as a sequence of decisions, have been utilised by Rosenthal (1988) among others. Henderson and Ioannides (1989) allow tenure to affect planned length of stay insofar as they estimate separate planned length of stay equations for owner-occupiers and tenants. As well as random variations, such differences in estimated planned length-of-stay equations can be traced back to two different causes. Firstly, differences can be caused by selection mechanisms and can thus be consistent with length of stay and tenure being sequential choices. Secondly, there may be a structural causal link via which tenure affects planned length of stay.

Quite a lot of households plan to become owner-occupiers sooner or later. The tendency to settle down in the present dwelling, rather than looking forward to the next stay, is consequently stronger in an owner-occupied than in a rented unit. Reasons for a preference for owner-occupied housing can, among other things, be tax advantages associated with owner-occupancy, security of tenure being stronger in owner-occupancy and property rights giving more freedom as to the choice of physical conversions of a housing unit. These forces can produce a structural causal link via which tenure affects planned length of stay.

Muth (1974) showed that households facing a high probability of being forced to move in the near future are less inclined to give weight to future preferences when choosing a housing unit, than households facing low probabilities of being forced to move are. Hence, lowering the probability of being forced to move will, *ceteris paribus*, increase the planned length of stay. As long as the probability of being forced to moved is larger in rental than in owner-occupied housing it follows that any given household will be expected to have a lower expected stay as tenants than as owner-occupiers. Hence, Muth's argument provides a mechanism by means of which planned length of stay is directly affected by tenure.

At least in Norway the hypotheses that a majority of households want to end their housing career as owner-occupiers has strong empirical support. In the 1995 Survey of Housing Conditions, only 11% of the households state that they prefer rented housing. Almost half of these prefer a rental dwelling suitable for the elderly. The corresponding figure among tenants is 30%, also in this group half of those who prefer a rented dwelling want a rented dwelling suitable for the elderly. If only households with heads aged 25 to 60 years is considered only around 4% prefer a rented unit. I take these figures as a strong indication that the very fact that a household is renting will in itself reduce planned length of stay.

The number of moves in a planned housing career is decreasing in the size of the moving costs (Amundsen, 1985). This implies that the average length of planned stays is increasing in moving costs.² The size of the moving costs of a household depends on household composition. Pure transaction costs such as taxes and brokers fees are, for a given housing unit, probably independent of household composition. Approximately this will also hold for the physical moving cost. Non-monetary (sometimes termed emotional) moving costs on the other hand, are strongly affected household composition. The non-monetary/emotional component of the moving cost of a household can be said to be a sum of these cost for each of the household members. The elements of this sum are probably not independent of one another. The effect on planned housing careers of the non-monetary moving costs of each of the household members depends on how individual preferences of household members are aggregated to a 'utility function' of the household. Throughout the paper it will be assumed that such an aggregate utility function of a household exists.

The second main theme of the paper is to gain insight into the role of non-monetary moving costs of children. This investigation is based upon a hypothesis of how the non-monetary moving costs of children depend on their age. The hypothesis consists of two parts:

- i) Non-monetary moving costs of children starts from a fairly low level (probably around zero) at the birth, and is increasing thereafter. When a child reaches a certain age it will be strongly increasing in age.
- ii) At a certain point in time there will be a positive shift in the moving cost of a child. This takes place when the child has become established in the area on a social level. I assume that this takes place at around the same time as the child starts school.

If this hypothesis holds and if children's moving costs affect the preferences of a household, age and presence of children in a household will affect planned housing careers. The greater the number of children in the household, the longer the planned lengths of stay should be expected to be. As far as the youngest children are concerned, this effect is expected to be quite weak. Moreover, as the children in the household approach school age, there is expected

² Amundsen (1985) showed this in continuous time where the number of moves were not constrained to be an integer. In a discrete time framework where the number of moves are constrained to be an integer, the number of moves will be an increasing 'step function' of the size of moving costs.

to be a positive increase in the planned length of stay of the household. As argued above, most Norwegian households plan to enter owner-occupied housing at some point during their lifespan. If this step is taken prior to the children of the household starting school, high moving costs are avoided. Hence, the likelihood of households living in rented housing is expected to shift negatively as the children reach the age of five or six.

Assume that my hypothesis on the time path of the individual non-monetary moving costs of children is correct and the tendencies indicated above are not found in data. This can be taken as an indication that the preferences of the children do not carry much weight in the aggregate utility function of households.

The question of how children of a household influence the household's mobility plans and behaviour in the housing market in general has been attracting little attention from housing economists. The quite rudimentary description of children in demand, tenure and length of stay equations may have resulted in some important structures not being revealed.

Kan (1999) points out that the effects of demographic explanatory variables in empirical models of mobility behaviour can be traced back to their effect on moving costs. He finds that there is a significant decrease in the probability that a household plan to move '*within the next couple of years*' as the age of the head of the household increases. The larger the household is the less likely it is that the household plans to move: this effect is also significantly different from zero. This is clearly compatible with moving costs being increasing in number of family members. It may be noted that Kan in his analysis constrains the effect on moving costs of the household of presence of children at different ages and adults to be identical. Within the empirical analysis of this paper this is a testable hypothesis, rather than an assumption.

In Henderson and Ioannides (1989), the pattern found in the expected length of stay equations, estimated jointly with a tenure choice equation, differs somewhat from Kan's results. Neither family size nor marital status significantly affects expected length of stay in either rental or owner-occupied housing. However, both being married and a large family increases expected length of stay as these characteristics have a significantly depressing effect on the probability of renting. This increases expected length of stay as expected stays of tenants are clearly shorter than those of owner-occupiers.

Haurin and Chung (1998) estimate a hazard model of households' length of stay. They distinguish between an expected path for the demographic variables and deviations from this expected path. Age of head increases expected length of stay significantly, while male-headed households have significantly shorter expected stays. Marriage, measured by the probability of being married, increases expected stay quite strongly. Haurin and Chung's hazard function is linear in predicted number of children. Somewhat surprisingly they find that the coefficient of 'predicted number of children' is negative, but not significantly different from zero. Unexpected changes in the number of children in the household significantly shorten expected stays. Hence, in the results of Haurin and Chung it is difficult to see moving costs of children affecting the expected mobility behaviour of households.

Loikkanen (1992) uses a quite large set of dummies describing the households in his analysis of tenure choice and the demand for housing. His study allows for cross-effects by using dummies that combine the number of adults, number of children and age of the head. Inspection of the estimated probit equation for tenure choice clearly indicates that number of children affects the propensity to owner-occupy in a non-linear fashion.

3. Econometric model

The discussion of Section 2 showed that the decisions on tenure and planned length of stay or mobility should be regarded as simultaneous, and as part of a dynamic plan. To describe these dynamic plans empirically, ideally a panel of households should be used. However, as I do not have access to suitable panel data, I will base my estimations on a cross-section, which is further described in the next section.

When I proceed by estimating a model on a cross-section, it is necessary to consider which conditions have to be met for the cross-section estimates to be of interest, and how they should be interpreted. Edin and Englund (1991) have raised a similar question. In their analysis, they argue that the potential bias of the coefficients of well-specified models estimated on cross-sections is probably not quantitatively serious. Even though a panel would have been preferable, it should be born in mind that cross-sections also contain information on the dynamics behind the plans made by households and their behaviour in the housing market. Hence even though the data used are taken from a cross-section they can reflect both historic information and (rationally formed) expectations over paths of future values of the relevant

variables. Such information should be utilised when a cross-section is used to estimate housing demand. Henderson and Ioannides (1989) on the other hand consider the use of panel data as crucial for an empirically based understanding of the dynamics of housing choices.

Another thing to be learned from the discussion of Section 2 is that a theoretic discussion of the dynamics of housing demand does not give any single answer to the question of how an econometric model should be specified. The paper presents and estimates one model described in Section 3.1, of tenure choice and planned length of future stay. Alternative specifications are also loosely discussed. One problem is that individual information on planned mobility is not continuously observed. This will be the subject of further discussion in section 4.

3.1 Tenure choice and planned length of stay

Any single household will choose tenure according to the sign of the difference between the utility in each of the tenures owner-occupation, Ω_O and renting, Ω_R . Hence, my econometric specification does not explicitly deal with the possibility of liquidity constraints affecting tenure choice. It should be noted that in the 1995 Norwegian Survey of Housing Conditions more than 95% of the renters state that for them, renting was not a response to problems of financing a home purchase. The indirect utility function of a household i is given in (1).

$$(1) \quad \Omega_{ij} = v_j(X_i, D_i, F_i) + \varepsilon_{ij} \quad j=O, R$$

where:

- $v(\cdot)$ is a common component of the utility functions of all households.
- X_i is a vector of explanatory variables
- D_i is a vector of demographic characteristics of household i that among other things proxy for moving costs.
- F_i is the expected future stay in the present dwelling.
- ε_{ij} is a household specific component, which is unobservable. From an analytical point of view these components are regarded as realisations of stochastic variables with a known common distribution.

The components of each of the vectors of explanatory variables will be further described in the next section on data. The probability of household i being found renting is:

$$(2) \quad P_i(\text{rent}) = P(\Omega_{iR} > \Omega_{iO}) = P(v_R(X_i, D_i, F_i) - v_O(X_i, D_i, F_i) > \varepsilon_{iO} - \varepsilon_{iR})$$

Assume that the individual components are independently normally distributed among households, with expectation equal to zero and a variance that does not vary between households. The parameters of the utility difference function can then be estimated using a standard probit procedure. Equivalently, tenure choice can be described by introducing a latent variable R_i^* . If this latent 'tendency to rent' is positive the household will choose to rent. The latent variable is a linear function of the arguments of the indirect utility function:

$$(2b) \quad R_i^* = aX_i + dD_i + bF_i + v_i$$

Assuming that the residual v_i is standard normal distributed, the coefficients a , d and f can be estimated by the standard probit procedure.

The length of the expected future stay in the present dwelling is specified as a linear function of a set of explanatory variables where the latent 'tendency to rent', R_i^* , is included. The variance of expected future stay is assumed to be increasing in its level so that the variance approaches zero as the level approaches zero. These assumptions ensure that confidence and prediction intervals of any positive expected future stay do not include negative stays. A statistical model that satisfies these conditions is the lognormal regression model:

$$(3) \quad F_i = \alpha X_i + \delta D_i + \beta R_i^* + \gamma S_i + u_i$$

Where S_i is the length of incomplete spell in the present housing unit and α , δ , β and γ are vectors of coefficients that are to be estimated. The parameters of the lognormal regression equation (3) can be directly estimated using ML-methods.

Equation (2b) and (3) are a simultaneous system and hence single-equation ML-estimation of the two equations is inappropriate. The system is therefore estimated using a two-stage procedure proposed by Maddala (1983). In the first step R_i^* and F_i is estimated as a function of all the explanatory variables in the system except R_i^* and F_i . Then, in the final step, the predicted values of the simultaneous determined variables are inserted into equation (2b) and (3), and each of them is re-estimated. This two-stage procedure, when applied to a cross-section, ignores possible fixed, or individual specific, effects on the planned future stay. Future research on tenure choice and residential mobility, based on panel data, should test for the importance of fixed effects.

The coefficient estimates from the second step are consistent estimates of the structural parameters. However, the standard errors estimated in the second step are not correct. In the user's manual for LIMDEP 7.0 it is noted that correction of the asymptotic covariance matrix of the structural parameters of simultaneous equation models of mixtures of continuous and dichotomous variables can be both a complex and a complicated task. In this paper this problem is handled by not handling it!

The estimated model is primarily used as a framework for tests of various hypotheses of the determinants of the dynamics of housing market behaviour. These tests are based on comparisons of the values of the loglikelihood functions. Hence the standard errors of single coefficients are not used in the main interpretation of the results of the estimations. This is my pragmatic argument for not putting any effort into correction of the standard errors.

4. Data

The data is from the 1995 Norwegian Survey of Housing Conditions. This contains a broad range of information about households, their income and their housing condition. The observations of the sample cover all parts of Norway. Both answers from a questionnaire and information from official registers are included. I focus on tenure and mobility decisions of relatively young adults. That is to say, I analyse the choices of households with heads aged between 20 and 45. Using only those observations without 'missing' values on any of the relevant variables and in which a household head or his/her partner has been interviewed leaves me with 2,128 observations. Of these 622 (or close to 30%) are tenants.

In the questionnaire, the households were asked to respond to the question '*For how long will Your household stay in Your present dwelling?*'. The respondents were asked only about their moving plans. Consequently it is not possible to distinguish between planned inter- and intra-urban mobility. The answers to this question are used to construct the mobility and planned future stay variable used in the empirical analysis. Rather than giving an 'exact' answer to the question the respondents were asked to choose among a number of categories. These categories and their distribution are given in table 1.

Table 1 - Moving and staying plans among renters and owners, head 20-45 years old (percent)

	Owners	Renters	All
Immediate moving plans	6.8	31.9	14.2
Will move within the next three years	9.6	33.5	16.6
Not within the next three years/No plans	56.4	30.9	49.0
Stay here the rest of our life	27.1	3.7	20.2
Number of observations	1,504	621	2,125

Table 1 reveals that tenants have moving plans to a larger extent than owner-occupiers do. Duration of present incomplete spell also differs significantly between the two tenures. Mean duration of incomplete spell among the owners is 15.8 years, with a standard deviation of 12.8 years. The corresponding figures for tenants are a mean of 4.8 years with a standard deviation of 8.5. Around 8% of the owner-occupiers and 39.6% of the tenants, moved into their present housing unit within the last year.

Planned future stay in present dwelling is essentially a continuous variable even though it is unfortunately categorically observed in my data set. Therefore, I have translated the data over to a continuous scale. Of course it is not ideal to put information into a data set by using such a translation procedure. The results from the analysis of the 'translated' data should therefore be interpreted together with the results obtained through the use of alternative translation procedures. Partly because of such translated data is used, the interpretation of the empirical results are focused on signs and significance levels of (sets of) coefficients.

For those who state that they will probably move quite soon, the planned future stay is set to one half of a year, for those who states that they will be moving within the next three years the future stay is set to 1.5 years. Future stay is set to five years for both those who answers that they will stay in their present housing unit for at least three years more and those who answers 'No plans at all'. If a household has answered 'Want to live here for the rest of our life' planned future stay is, again somewhat arbitrary, set to nine years. Alternative translation procedures and estimates based on them, are given in an appendix.

A fairly detailed description of marital status³ and of other characteristics of households is an important part of the empirical models. Couples are divided into three age groups according to age of head. The specific age cuts can be seen from table 2. Furthermore, the number of years

over which a couple has been living together is included as an explanatory variable. Couples who has been living together for more than ten years is given a value of 10 for this variable. The purpose of combining couple-dummies, and the time spent as a couple in the empirical models is to see whether the housing careers are mostly influenced by a the 'couple-or-not' state, or whether the time actually spent as a couple is more important. If the 'couple-or-not state' affect transition rates from rented to owner-occupancy one should expect years spent as a couple to be important for tenure state. The housing careers may also be affected by years spent as a couple because the likelihood of the couple staying together in the future is also affected by the number of years they have spent together.

Single person households are described in the same way as the couples: i.e. they are divided into three age groups, and number of years, truncated at ten, spent as singles is part of the set of explanatory variables. Two features of the description of single-person households should be noted. Firstly, a single-person household is defined as a household in which the head is not living with a partner. Therefore there may be children present in a single-person household. There may also be other adults living in the same housing units, such as adult children, friends, parents and so on. The definition of single person households follows Börsch-Supan (1986) in being based upon the assumption that housing decisions are taken at a nucleus-level rather than on an extended household level. Secondly, in an earlier version, dummies for divorced and widows/widowers were included. Their coefficients were small in size and not significantly different from zero, and were therefore skipped. Consequently, age and number of years spent as a single person household (or as a couple) are the only information about the demographic history of a household that is included in the empirical models.

Each sex is given its own set of age dummies in order to check whether age affects tenure choice and mobility differently for single males and females. Such differences may be caused by expected changes of marital status depending differently upon age for males and females (see Haurin and Kamara, 1992). Alternatively their cause may simply be that the central tendency in the distributions of preferences really does differ between the sexes.

One of the objectives of this paper is to acquire new empirical knowledge of how children affect the housing career of a household. On account of this children of a household is

³ In this paper the definition of marital status is based on whether there is two persons living as a couple in the household, not on whether they are married or not.

described in more detail than is usually done in this kind of models. This is done by the way number of children is handled and by entering indicators of age of the oldest child. Instead of using number of children in the household⁴ as an explanatory variable; dummies for one or more children, two or more children and three or more children being present are used. Hence, I allow for the fact that the effect of children may be non-linear in their number. Such non-linearities may arise from some kind of economics of scale in the family economy.

In Section 2, it was argued that the moving costs of a child probably are increasing in its age, and that this age dependency probably is not linear and may not even be continuous. My hypothesis is that the moving costs shifts positively around the 6-8 year age of a child. The first such shift experienced by a family occurs when the eldest child reaches this age. Therefore, dummies are used to classify households according to the age of the eldest child in the household. The specific categories used can be seen from table 2. Table 2 gives the frequencies, measured in percent, of the dummy variables used to describe the demographic characteristics of the households in the sample used to estimate the structural models.

Table 2 - Demographic variables in the sample, in percent of sample size

	Owners	Renters	All
Single male less than 30 years old	2.4	17.0	6.9
Single male 31-40 years old	3.9	5.9	4.5
Single male 41-45 years old	2.9	2.4	2.5
Single female less than 30 years old	2.3	14.1	5.7
Single female 31-40 years old	5.3	7.7	6.0
Single female 41-45 years old	2.1	2.6	2.3
Couple, head less than 30 years old	16.0	28.1	19.5
Couple, head 31-40 years old	43.3	18.0	35.9
Couple, head 41-45 years old	21.8	4.2	16.7
Eldest child 0-3	12.5	13.1	12.7
Eldest child 4-5	7.5	5.6	7.0
Eldest child 6-8	12.1	5.6	10.2
Eldest child 8-18	36.7	10.6	29.0
One or more child(ren) present	68.8	34.9	58.9
Two or more children present	46.1	14.1	36.8
Three or more children present	12.8	3.9	10.2
Number of observations	1,506	622	2,128

⁴ The most frequent ways of treating children in empirical models of housing market behaviour is simply to use the number of children as an explanatory variable, or even more course to add children and adults up to a family size variable. The latter approach implies that the effect of one extra adult in a single person household equals the effect of a child.

One of the main determinants of housing consumption on an individual level is income. However, it is not obvious how income should be entered into empirical models of housing careers. In this paper, I have emphasised that housing demand should be considered within a dynamic perspective, where the present situation of a household should be considered as a part of a rationally formed plan where information is utilised efficiently. It should, then, be obvious that future, and also past, income is part of the set of variables that explain the present housing situation. This is captured by the concept of permanent income. However, permanent income is not observable. A procedure proposed by Goodman and Kawai (1982) has been extensively used in housing studies. Current income is regressed on a battery of explanatory variables and the estimated regression equation is used to make a prediction. Permanent income is then set equal to the income prediction. Transitory income is defined as the difference between current and permanent income. Even though the use of the Goodman-Kawai procedure has been quite successful in empirical studies, Cameron (1986) shows that this way of assessing permanent and transitory income is not without its problems.

Individual income can be decomposed into the product of an hourly wage and labour supply. The choice of individual labour supply and consumption are determined simultaneously. This observation is the argument for an alternative procedure proposed by Haurin (1991). He argues that, because of the simultaneity, neither current income nor the Goodman-Kawai measure of permanent income should be used in housing demand equations. Haurin's alternative is termed 'Full income'. He proposes to regress wage, rather than income, on the explanatory variables. The estimated equation is then used to predict a permanent wage profile over a number of years into the future⁵. The discounted sum of wage times full time work hours is then a measure of human capital, which easily can be transformed to a permanent full income. The permanent full income can be used to purchase housing, other consumption and leisure.

In this paper I have used a full income measure calculated on basis of my cross-section data. Explanatory variables used are type and level of education, age, type of occupation, marital status and regional dummies. The wage equation was estimated as a pooled regression where the coefficients of males and females in different educational groups were allowed to differ. It may be noted that the wage equation showed considerable weaker age-related growth for females than was the case for males. The wage equation is presented in appendix 3. The same

age-gender structure was revealed in Longva and Strøm (1996). The procedure used here differs from Haurin and Chung (1998) in that in my cross section I am unable to identify fixed individual effects. Haurin and Chung who used a panel allowed for such fixed effects.

To check whether the shape of the expected wage profile matters for the housing choices and plans I have calculated the difference between the predicted wage ten years ahead and predicted wage of today. This difference is termed the income tilt. None of the estimated wage profiles are decreasing in age. This is the case due to the fact that the sample on which my empirical models are estimated, are restricted to households headed by persons younger than 45 years old. I.e. no one expects to retire during the ten year span over which the wage profile is calculated. Therefore, all income tilts in the sample is positive. The magnitude of the tilts, however, differs between households.

Before concluding this section on data and explanatory variables, it is pertinent to make a few comments on two variables, which are not included in the set of explanatory variables of my model. The only wealth variable I use is the full income that can be interpreted as a measure of human capital. Housing capital is the major part of the wealth of Norwegian households. Current wealth is, probably to a quite large extent, the result of capital gains made on owner-occupied housing, and 'forced' down-payments made on loans for housing purposes. Hence, it is even more likely that wealth is determined by past tenure choices than it is that present tenure choice depends on wealth. Some of the results in described by Edin and Englund (1991) indicate that this also might be the case in Sweden. Another pragmatic reason for the omission of wealth from the empirical models is that this would have reduced the size of the sample by more than 15% due to missing information on wealth.

Nor does the tenure choice equation include any direct measure of the ratio between the cost of owner-occupancy and tenancy. If it is assumed that rental housing is priced according to some no-arbitrage condition there will be no cross-section variation in rents, nor will there be any variation between households in the user cost of owner-occupancy as every household are facing the same marginal tax rates on capital income. Even though the empirical models do not include any direct measure of the ratio between the user cost of owner-occupancy to that of tenancy, the effect of expected length of stay capture some price effects. As already argued

⁵ I have used a ten-year horizon and a constant annual real discount rate of 3.5%.

the price ratio correlates positively with expected length of stay. This is due to the differences in moving costs in the two tenures.

5. Empirical results

As argued in Section 2, empirical models such as the one used in this paper should not be interpreted as fully specified empirical counterparts of theoretical models of the dynamics of housing demand. Rather, they should be considered as econometric experiments that take account of essential features of the theoretical results, and to be a framework for discussing and testing of different hypothesis of housing market behaviour. Discussions of hypothesis and possible mechanisms will consequently form the central part of the presentation of empirical results.

5.1 Tenure choice and planned length of stay

The ML-estimates of the coefficients of the two-equation model outlined in Section 3 are given in table 3.

Table 3 – Estimated model of planned future length of present stay and tenure, absolute t-values in parenthesis

	Probit model of renting	Lognormal model of length of future stay
Constant	5.049 (7.78)	3.334 (6.39)
Latent tendency to rent ^a		-0.793 (1.79)
Log E[stay] ^a	-0.937 (11.52)	
Log Full income	-0.393 (4.96)	
Tilt income		-0.003 (3.46)
Duration of incomplete spell		-0.050 (0.54)
Duration squared		0.005 (1.42)
Single male less than 30 years old – base case		
Single male 31-40 years old	-0.273 (1.46)	0.835 (1.78)
Single male 41-45 years old	-0.288 (1.19)	1.339 (1.89)
Single female less than 30 years old	-0.051 (0.29)	0.180 (0.64)
Single female 31-40 years old	-0.329 (1.83)	0.426 (0.94)
Single female 41-45 years old	-0.403 (1.61)	-0.533 (1.05)
Years as single	-0.008 (0.36)	0.058 (1.16)
Couple, head less than 30 years old	-0.123 (0.81)	0.291 (0.86)
Couple, head 31-40 years old	-0.243 (1.40)	0.934 (1.96)
Couple, head 41-45 years old	-0.318 (1.53)	1.092 (1.68)
Years as couple	-0.033 (2.16)	0.098 (2.10)
Oldest child –3 years – base case		
Oldest child 4-5	0.159 (0.98)	-0.083 (0.21)
Oldest child 6-8	0.224 (1.41)	0.408 (0.90)
Oldest child 8-18	0.238 (1.58)	0.974 (2.12)
One or more child(ren) present	-0.229 (2.15)	-0.138 (0.54)
Two or more children present	-0.260 (2.20)	0.532 (1.33)
Three or more children present	0.083 (0.55)	-0.583 (1.18)
σ^2		1.065 (32.29)
Log \mathcal{L}	- 935.03	-2,720.85
Restricted Log \mathcal{L}	-1,283.80	-2,898.43
Number of observations	2,125	2,125

^a These two variables are calculated in the first step of the two stage estimation procedure

The differences between the restricted loglikelihood values and those of the model are clearly satisfactory. Tenure is correctly predicted for 53.1 % of the tenants and for 89.4 % of the owner-occupiers. This gives a total share of correct predictions of 78.8 %. The signs of the estimated coefficients do not contradict expectations based on theoretical considerations and previous studies. Apart from noting these desirable properties of the estimated model, the estimation results as presented in table 3, will not be further discussed in the paper! Instead, I

will use the model as a framework for tests of various hypotheses on the determinants of the dynamics of housing market behaviour. These tests are presented in Section 5.2.

5.2 The dynamics of housing market behaviour - some tests

I regard the estimations of this paper as a contribution to an empirical based understanding of the dynamics of housing market behaviour rather than as an empirical counterpart of a closed structural model of the demand side of a housing market. In view of this, I find it more appropriate to use the estimated model as a framework for statistical testing of simple statements rather than to give any full interpretation of the results. Tests of the statements are meant both to give new insight in the determinants of housing choices and to provide guidelines for specifications of empirical housing market models. In this section, the hypotheses are presented and the results of the tests are given and discussed in a verbal and informal way. In appendix 2 the test results are described somewhat more formally.

Only hypotheses that are nested within the full model given in table 3 is tested. A model nested within the full model consists of the full model and a set of linear constraints. Twice the difference between the loglikelihood function of the full model and of the restricted model is kji-square distributed with a number of degrees of freedom equal to the number of linearly independent restrictions (Ben-Akiva and Lerman, 1985 p.28). The uncorrect(ed) standard errors reported in table 3, are hence not used. There is probably also some structural multicollinearity between some of the demographic explanatory variables. It should be sufficient to mention age of household head, years spent as a couple and age of the eldest child. Also this tends to bias estimates of standard errors. Hence the global loglikelihood test seems to be an appropriate tool in this analysis.

Statement 1: Sex matters

If sex of singles does not matter for the dynamics of housing market behaviour, my model is unnecessary complicated. To test for this, the set of age dummies crossed with sex dummies is replaced with pure age dummies for the singles. According to these tests it is not possible to reject the hypothesis that tenure choice is independent of sex. The hypothesis that planned length of future stay is independent of sex is clearly rejected, at a 5%-level of significance.

Hence sex seems to matter for the dynamic choices of housing careers for singles. Inspection of the ML-estimates in table 3 indicates that the expected stay in present dwelling increases monotonically as single men gets older. The increase in expected future stay in age is weaker for the females and is turned towards a drop as the females gets forty years old. Without further research it is not possible to conclude on the reason of this results. One possible explanation is that the correlation between age and expected change of marital status differ between single males and females.

Statement 2: Age strongly affects planned length of stay, but may have no direct effect on tenure choice

Most empirical models of tenure choice reveal quite a strong age dependency. At least, this is true in the case of single equation models. Within the framework of the model of this paper it is possible test whether this age dependency is a direct effect on tenure choice or whether it works indirectly through the effect age has on planned length of future stay. An effect on planned length of stay will affect tenure choice through its effect on the relative price of tenancy as compared to owner occupation. It may be noted that Henderson and Ioannides (1989), in their simultaneous model of tenure and length of residential spell, found that age has a positive but insignificant partial effect on ownership probabilities.

It turns out that the model that containing age effects in the tenure choice equation does not perform significantly better than an equation without such effects. Hence the null hypothesis of no age effect in the tenure choice equation can not be rejected at any sensible level. This result holds both for couples and singles. A null hypothesis of length of planned future stay in present dwelling being independent of age of the head of the household, on the other hand, is rejected at a 1-percent level of significance. This result applies both for singles and couples. A significant negative dependency between length of residential stays and age is also found in Henderson and Ioannides (1989).

These results can be taken as a strong indication of the desirability to use simultaneous models of the different dimensions of housing careers when formulating empirical models of the dynamics of housing market behaviour.

Statement 3: Marital history more important than marital status

Here the term 'marital' is used in a maybe somewhat unusual way. I do not distinguish between married couples and other couples living together. The hypothesis/statement investigated in this subsection is that the choice of tenure and planned length of stay is quite similar for newly formed couples and singles at the same age. If a couple stays together, a difference between the couples and singles will evolve over time. Couples who have stayed together for some time will be less inclined to rent and tend to have longer planned stays.

The first two tests carried out in order to shed light on Statement 3 were to omit the 'years spent as a couple'-variable from respectively the tenure choice equation and the length of future stay-equation. Both these omissions yielded a significantly poorer fit, as measured by the loglikelihood, than the models that include years spent as a couple. The coefficients of the marital status-variables increased in magnitude and were clearly significant different from zero in the model without the 'years spent as a couple'-variable. This is the same as what is found in empirical models of tenure choice that do not include years spent as couple.

Above it is established that length of marital history matters for actual tenure and planned housing careers. This is hardly surprising. Far more surprising results emerge when the hypothesis that, when controlling for length of marital history, marital status does not have any effect on neither tenure choice nor planned length of future stay. Somewhat ad-hoc this hypothesis is tested by constraining the age effect of couples to be equal to those of single males. It is then checked whether the corresponding reduction of the value of loglikelihood functions are significantly greater than zero. The estimations show that the reductions in the value of the log-likelihoods are far from being significantly different from zero. This applies to both the tenure choice and planned length of future stay equations. Hence, the hypothesis that planned housing careers are independent of marital status can not be rejected at any sensible level of significance.

The results in this subsection are consistent with a hypothesis of transition rates from rental to owner-occupied rather than tenure-state, depends on marital status. It might also be that years spent as a couple affects the couples' faith in their relation to last and through this affect their housing market behaviour.

Statement 4: Age of the children affects the families' housing choices

In the theoretical discussion in Section 2, I hypothesised that the non-monetary moving costs of children is increasing in their age, and that these costs makes a positive jump around the time the children go to school. This is expected to make planned length of stay an increasing function of the age of children in the household. In this paper, I have described the age of children in a household by the age of the eldest child.

The full model, presented in table 3, is tested against models without any effect from the age of children to the housing choices. It so turns out that the model which includes children's-age-dummies is not describing tenure choice significantly better than a model which does not contain such explanatory variables. The model describes planned length of future stay better with children's-age-dummies than without them. However, the loglikelihood in the former model is higher than that of the latter only at a 10% level of significance. Therefore, these tests can not really be said to establish my hypothesis.

The reason for the failure to identify a children's-age-effect may, of course, be that it does not exist. It may also be that there is little difference between moving costs of very young children, but that there still is a positive jump in the moving costs around the age a child starts school. In order to test for this, I have formulated a 'full model' where the only children's-age-dummy included is 'presence of school kids'. This revised full model is then tested against models where the 'presence of school kids'-dummy is omitted. Also within this test framework I find that a null hypothesis of tenure choice being independent of presence of school kids can not be rejected. Planned length of future stay in present dwelling, on the other hand, is significantly better described when the dummy for school kids present is included. Hence, my model indicates that presence of school children in a family significantly reduces a family's expected mobility. As far I am aware of this effect has not been identified previously in the literature on residential mobility. Sarmiento (1995) reports that she tested for this effect, but that she was not able to identify any significant effect.

Statement 5: Number of children affects housing market behaviour, but in a non-linear fashion

It seems a little bit unnatural to formulate a model that includes dummies for age of children but not number of children. Therefore I use the same strategy as in the former subsection when formulating the tests. Firstly, a full model without age of children dummies is estimated, then this model is tested against a model without dummy indicators of number of

children. Within this framework the null hypothesis that tenure choice is independent of number of children is rejected at a 2%-level of significance. The corresponding hypothesis for planned length of stay can only be rejected at a level of significance a little bit above 5%.

Both common sense and the tests above indicate that the number of children in a household affect tenure choice and planned length of stay. The next question to be addressed is whether these effects are linear or not. The common practice is to use family size or number of children as explanatory variables in empirical models of tenure choice and residential mobility. Furthermore, the ML-estimates of the coefficients of the dummies for respectively one or more, two or more and three or more children present in the household do not seem to be consistent with a linear effect. The estimates indicate that housing market behaviour of household with two or more children does not differ much from the behaviour of households with two children. These features make it interesting to perform a formal test of whether the effects are linear or not. The impression that inspection of the ML-estimates of the coefficients give are confirmed by the statistical test. The hypothesis of linear effects in the two equations is rejected at a 2%-level.

The non-linear relations between number of children and planned length of stay and the 'latent propensity to chose a rental dwelling' are probably caused by some economies of scale in a family's 'housing consumption technology'. This results together with the results on the effects of age of the children, implies that one should think thoroughly through how one describe family structure when disaggregated models of housing choice are formulated.

Statement 6: Tenure choice is affected by demographic characteristics

After performing several partial tests and finding that sex, age, marital status and age of children primarily affects tenure choice through their effect on planned lengths of stay, it is tempting to conclude that apart from the effect on planned length of stay, tenure is independent of demographics. This strong hypothesis can be tested within the framework of the empirical model of the paper. This can really be said to be a strong hypothesis in light of the consistent agreement in the literature on tenure choice of the importance of demographic variables.

However, the hypothesis that all the coefficients of all dummies which characterise the demographic status of the household are simultaneously equal to zero in the tenure choice equation is rejected at level of significance well below 1%.

Concluding Remarks

An important thesis upon which this paper is based is that tenure and planned mobility, or planned length of stay, are simultaneously determined dimensions of the planned housing career of a household. Estimation of an empirical model that takes account of the simultaneity proved to yield a suitable framework for statistical tests of important hypothesis regarding the determinants of the dynamics of housing market behaviour.

Among other things, it is shown that expected mobility is reduced significantly by the presence of schoolchildren in the household. Many countries encourage home-ownership. I take the empirical results in this paper as indicating that the welfare effects of such policies may be greatest if families with pre-school children are given priority when support of this kind is allocated. This may enable some families to take make the transition to owner-occupation at a point when the moving costs of their children are at their lowest.

This paper has demonstrated the need for care when choosing how to describe household composition in models of housing market behaviour. It is particular important to exercise caution regarding how to describe number of children. In models in which the dynamics of the behaviour are important one should also consider using age of the children among the explanatory variable. Furthermore I hope that I in this paper has lent support to the claim of Edin and Englund (1991), that it is possible to gain insight into the dynamics of housing demand, even on the basis of cross-section data.

The simultaneous two-equation structure used in the paper makes it possible to check whether some of the explanatory variables frequently used in empirical models of tenure choice have a direct effect on tenure or affects tenure choice indirectly via planned length of stay. Tests reveals that neither sex nor age of household head has any significant direct effect on tenure choice. However, both these variables affect planned length of stay significantly.

The strong effect of the 'years spent as a couple' variable verifies that knowledge of the demographic history of a household is important when it comes to understanding of its housing market behaviour. Knowledge of whether past changes in household composition were expected or not and of the expected future development is probably also important. The significant differences in the age pattern of expected future stays between single males and females may be due to such differences in expected future household composition. Haurin and Chung (1998) have modelled housing demand using, at least to some extent, the type of demographic household history described here. However, they do not place their emphasis on tenure choice. To capture the effects on planned housing careers of expected and unexpected changes of the household composition empirically, the analysis should probably be based on panel data.

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Appendix 1

The data for the simultaneous model of tenure and planned length of future stay are categorical data translated over to a continuous scale. The categorical data are taken from the answer to a question of how long to plan to stay in your present housing unit. In A1 the predefined categories are given. In the column Translation 1, the translation procedure used in the paper is given. Translation 2 and 3 gives some alternative translation procedures. In tables A2 and A3 it is shown which results emerged under each of the three translation procedures.

Table A1 – Translation procedures, assessed length of planned future stay in years

	Translation 1	Translation 2	Translation 3
Immediate moving plans	0.5	0.5	1
Will move within the next three years	1.5	2	2
Not within the next three years/No plans	5	6	7
Stay here the rest of our life	9	11	15

Table A2 – Tenure choice under alternative translation procedures

	Translation 1 (0.5;1.5;5;9)	Translation 2 (0.5;2;6;11)	Translation 3 (1;2;7;15)
Constant	5.049 (7.78)	5.362 (8.14)	5.780 (8.61)
Log E[stay] ^a	-0.937 (11.52)	-1.030 (11.53)	-1.133 (11.55)
Log Full income	-0.393 (4.96)	-0.399 (5.03)	-0.415 (5.21)
Single male 31-40 years old	-0.273 (1.46)	-0.222 (1.18)	-0.204 (1.08)
Single male 41-45 years old	-0.288 (1.19)	-0.223 (0.91)	-0.163 (0.67)
Single female less than 30 years	-0.051 (0.29)	-0.019 (0.11)	-0.056 (0.32)
Single female 31-40 years old	-0.329 (1.83)	-0.283 (1.56)	-0.278 (1.53)
Single female 41-45 years old	-0.403 (1.61)	-0.392 (1.56)	-0.363 (1.44)
Years as single	-0.008 (0.36)	-0.006 (0.28)	-0.006 (0.27)
Couple, head less than 30 years	-0.123 (0.81)	-0.085 (0.56)	-0.079 (0.52)
Couple, head 31-40 years old	-0.243 (1.40)	-0.181 (1.04)	-0.162 (0.93)
Couple, head 41-45 years old	-0.318 (1.53)	-0.253 (1.21)	-0.226 (1.07)
Years as couple	-0.033 (2.16)	-0.029 (1.90)	-0.027 (1.75)
Oldest child 4-5	0.159 (0.98)	0.155 (0.96)	0.142 (0.88)
Oldest child 6-8	0.224 (1.41)	0.225 (1.41)	0.235 (1.48)
Oldest child 8-18	0.238 (1.58)	0.250 (1.66)	0.273 (1.81)
One or more child(ren) present	-0.229 (2.15)	-0.231 (2.17)	-0.218 (2.05)
Two or more children present	-0.260 (2.20)	-0.241 (2.04)	-0.235 (1.99)
Three or more children present	0.083 (0.55)	0.064 (0.42)	0.058 (0.38)
Log \mathcal{L}	935.03	934.41	933.58
Restricted Log \mathcal{L}	1,283.80	1,283.80	1,283.80
Share correct predicted tenants	53.1%	53.6%	53.1%
Share correct predicted owners	89.4%	89.4%	89.0%
Total correct predictions	77.8%	78.9%	78.7%
Number of observations	2,125	2,125	2,125

^a These two variables are calculated in the first step of the two stage estimation procedure

Table A3 – Planned length of future stay alternative translation procedures

	Translation 1 (0.5;1.5;5;9)	Translation 2 (0.5;2;6;11)	Translation 3 (1;2;7;15)
Constant	3.334 (6.39)	4.007 (5.93)	5.086 (7.01)
Latent tendency to rent ^a	-0.793 (1.79)	-0.939 (1.63)	-1.230 (1.99)
Tilt income	-0.003 (3.46)	-0.004 (3.22)	-0.005 (4.05)
Duration of incomplete spell	-0.050 (0.54)	-0.048 (0.41)	-0.106 (0.85)
Duration squared	0.005 (1.42)	0.006 (1.29)	0.008 (1.75)
Single male 31-40 years old	0.835 (1.78)	1.068 (1.77)	1.041 (1.58)
Single male 41-45 years old	1.339 (1.89)	1.626 (1.79)	1.885 (1.90)
Single female less than 30 years	0.180 (0.64)	0.322 (0.91)	0.090 (0.23)
Single female 31-40 years old	0.426 (0.94)	0.594 (1.01)	0.445 (0.70)
Single female 41-45 years old	-0.533 (1.05)	-0.721 (1.13)	-0.738 (0.99)
Years as single	0.058 (1.16)	0.073 (1.15)	0.076 (1.09)
Couple, head less than 30 years	0.291 (0.86)	0.414 (0.96)	0.300 (0.63)
Couple, head 31-40 years old	0.934 (1.96)	1.250 (2.03)	1.181 (1.78)
Couple, head 41-45 years old	1.092 (1.68)	1.433 (1.68)	1.385 (1.58)
Years as couple	0.098 (2.10)	0.132 (2.16)	0.139 (2.19)
Oldest child 4-5	-0.083 (0.21)	0.098 (0.19)	-0.135 (0.25)
Oldest child 6-8	0.408 (0.90)	0.467 (0.79)	0.623 (1.03)
Oldest child 8-18	0.974 (2.12)	1.199 (1.99)	1.535 (2.49)
One or more child(ren) present	-0.138 (0.54)	-0.194 (0.59)	-0.167 (0.47)
Two or more children present	0.532 (1.33)	0.701 (1.34)	0.659 (1.22)
Three or more children present	-0.583 (1.18)	-0.783 (1.22)	-0.805 (1.21)
σ^2	1.065 (32.29)	1.144 (34.14)	0.977 (32.46)
Log \mathcal{L}	-2,720.85	2,825.41	2,590.45
Restricted Log \mathcal{L}	2,898.43		
Number of observations	2,125		2,125

^a These two variables are calculated in the first step of the two stage estimation procedure

Tables reveals that the results are not very sensitive to the choice of translation procedure.

Appendix 2 - Some tests of determinants of the dynamics of housing market behaviour

The tests described in Section 5.2 are described in more detail in this appendix. The test static referred to in the tables equals twice the difference between the loglikelihood (LL) under $H1$ and $H0$.

Statement 1: Sex matters

Test 1.1:

	Degrees of freedom	LL Tenure choice	LL Planned length of stay	ΣLL
$H0$: Tenure independent of sex of singles	2	-935.18	-2720.85	-3656.03
$H1$: Full model		-935.03	-2720.85	-3655.88
Test static		0.3	0	0.3
Critical value 10%-level		4.61	4.61	4.61
Critical value 5%-level		5.99	5.99	5.99
Critical value 2%-level		7.82	7.82	7.82

Hence, the null hypothesis can not be rejected at any sensible level.

Test 1.2:

	Degrees of freedom	LL Tenure choice	LL Planned length of stay	ΣLL
$H0$: Planned length of future stay independent of sex of singles	2	-934.86	-2724.92	-3659.78
$H1$: Tenure independent of sex of singles		-935.18	-2720.85	-3656.03
Test static		-0.64	8.14	7.5
Critical value 10%-level		4.61	4.61	4.61
Critical value 5%-level		5.99	5.99	5.99
Critical value 2%-level		7.82	7.82	7.82

The hypothesis that 'Planned length of future stay is independent of sex of singles' is rejected at a level of significance close 2%.

Statement 2: Even though age strongly affects planned length of stay it has no direct effect on tenure choice

Test 2.1:

	Degrees of freedom	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	ΣLL
H0: Tenure independent of age of head of household - singles	4	-937.49	-2720.85	-3658.34
H1: Full model		-935.03	- 2720.85	-3655.88
Test static		4.92	0	4.92
Critical value 10%-level		7.78	7.78	7.78
Critical value 5%-level		9.49	9.49	9.49
Critical value 2%-level		11.67	11.67	11.67

Hence, the null hypothesis can not be rejected at any sensible level.

Test 2.2:

	Degrees of freedom	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	ΣLL
H0: Planned length of future stay independent of age of head of household - singles	4	-940.80	-2730.70	-3671.50
H1: Tenure independent of age of head of household - singles		-937.49	-2720.85	-3658.34
Test static		6.62	19.70	26.32
Critical value 10%-level		7.78	7.78	7.78
Critical value 5%-level		9.49	9.49	9.49
Critical value 2%-level		11.67	11.67	11.67

The hypothesis that 'Planned length of future stay is independent of age of head of household - singles' is hence rejected at a level of significance below 2%.

Test 2.3:

	Degrees of freedom	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	Σ <i>LL</i>
H0: Tenure independent of age of head of household - couples	2	-936.04	-2720.85	-3656.89
H1: Full model		-935.03	- 2720.85	-3655.88
Test static		2.02	0	2.02
Critical value 10%-level		4.61	4.61	4.61
Critical value 5%-level		5.99	5.99	5.99
Critical value 2%-level		7.82	7.82	7.82

Hence, the null hypothesis can not be rejected at any sensible level.

Test 2.4:

	Degrees of freedom	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	Σ <i>LL</i>
H0: Planned length of future stay independent of age of head of household - couples	2	-938.42	-2726.06	-3664.48
H1: Tenure independent of age of head of household - couples		-936.04	-2720.85	-3656.89
Test static		4.76	10.42	15.18
Critical value 10%-level		4.61	4.61	4.61
Critical value 5%-level		5.99	5.99	5.99
Critical value 2%-level		7.82	7.82	7.82

The hypothesis that 'Planned length of future stay is independent of age of head of household - couples' is hence rejected at a level of significance below 2%.

Test 2.5:

	Degrees of freedom	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	ΣLL
H0: Tenure independent of age of head of household - all	6	-938.17	-2720.85	-3659.02
H1: Full model		-935.03	- 2720.85	-3655.88
Test static		6.28	0	6.28
Critical value 10%-level		10.65	10.65	10.65
Critical value 5%-level		12.59	12.59	12.59
Critical value 2%-level		15.03	15.03	15.03

Hence, the null hypothesis can not be rejected at any sensible level.

Test 2.6:

	Degrees of freedom	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	ΣLL
H0: Planned length of future stay independent of age of head of household - all	6	-943.72	-2735.22	-3678.94
H1: Tenure independent of age of head of household - all		-938.17	-2720.85	-3659.02
Test static		11.10	28.74	39.84
Critical value 10%-level		10.65	10.65	10.65
Critical value 5%-level		12.59	12.59	12.59
Critical value 2%-level		15.03	15.03	15.03

The hypothesis that 'Planned length of future stay is independent of age of head of household' for both couples and singles can hence be rejected at any sensible level of significance.

Statement 3: Marital history more important than marital status

Test 3.1:

	Degrees of freedom	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	ΣLL
H0: Tenure independent of years spent as a couple	1	-937.32	-2720.85	-3658.11
H1: Full model		-935.03	- 2720.85	-3655.88
Test static		4.46	0	4.46
Critical value 10%-level		2.71	2.71	2.71
Critical value 5%-level		3.84	3.84	3.84
Critical value 2%-level		5.41	5.41	5.41

The null hypothesis is rejected at a 5%-level.

Test 3.2:

	Degrees of freedom	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	ΣLL
H0: Planned length stay independent of years spent as a couple	1	-935.03	-2722.93	-3657.96
H1: Full model		-935.03	-2720.85	-3655.88
Test static		4.16	0	4.16
Critical value 10%-level		2.71	2.71	2.71
Critical value 5%-level		3.84	3.84	3.84
Critical value 2%-level		5.41	5.41	5.41

The hypothesis that 'Planned length of future stay is independent of years spent as a couple' is rejected at a level of significance below 5%.

In order to test whether the fact that a household consists of a couple or a single has any consequence for the dynamics of housing market behaviour alternative models are estimated. The coefficients of the couple-dummies in the alternative models are constrained to be equal to the corresponding coefficients of the age dummies for single males. In short this is termed tenure choice/planned length of stay independent of 'marital status'.

Test 3.3:

	Degrees of freedom	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	ΣLL
H0: Tenure independent of marital status	3	-935.44	-2720.85	-3656.29
H1: Full model		-935.03	-2720.85	-3655.88
Test static		0.82	0	0.82
Critical value 10%-level		6.25	6.25	6.25
Critical value 5%-level		7.82	7.82	7.82
Critical value 2%-level		9.84	9.84	9.84

The hypothesis that tenure choice is independent of marital status, after controlling for years spent as a couple, can not be rejected.

Test 3.4:

	Degrees of freedom	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	ΣLL
H0: Planned length stay independent of marital status	3	-935.48	-2722.18	-3657.96
H1: Tenure independent of marital status		-935.44	-2720.85	-3656.29
Test static		0.08	3.26	3.34
Critical value 10%-level		6.25	6.25	6.25
Critical value 5%-level		7.82	7.82	7.82
Critical value 2%-level		9.84	9.84	9.84

The hypothesis that 'Planned length of future stay' is independent of marital status can not be rejected at any sensible level of significance.

Statement 4: Age of the children affects the families' housing choices

Test 4.1:

	Degrees of freedom	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	ΣLL
H0: Tenure independent of age of the children in the household	3	-936.47	-2720.85	-3657.32
H1: Full model		-935.03	-2720.85	-3655.88
Test static		2.88	0	2.88
Critical value 10%-level		6.25	6.25	6.25
Critical value 5%-level		7.82	7.82	7.82
Critical value 2%-level		9.84	9.84	9.84

Hence, the null hypothesis is not rejected.

Test 4.2:

	Degrees of freedom	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	ΣLL
H0: Planned length of future stay independent of children's age	3	-935.03	-2724.34	-3659.37
H1: Full model		-935.03	-2720.85	-3655.88
Test static		0	6.98	6.98
Critical value 10%-level		6.25	6.25	6.25
Critical value 5%-level		7.82	7.82	7.82
Critical value 2%-level		9.84	9.84	9.84

The null hypothesis can be rejected, but only at a level of significance close to 10%.

In order to single out a possible effect of presence of school kids present in the family a model with a dummy-indicator for only school kids (i.e. no other childrens-age-dummies) is tested against a model with no indicators for children's age.

Test 4.3:

	Degrees of freedom	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	ΣLL
H0: Tenure independent of presence of school kids	1	-936.49	-2721.35	-3656.84
H1: Full model, only school kids present		-936.12	-2721.35	-3657.47
Test static		0.74	0	0.74
Critical value 10%-level		2.71	2.71	2.71
Critical value 5%-level		3.84	3.84	3.84
Critical value 2%-level		5.41	5.41	5.41

The null hypothesis can not be rejected at any sensible level.

Test 4.4:

	Degrees of freedom	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	ΣLL
H0: Planned length stay independent of presence of school kids	1	-935.12	-2724.34	-3659.46
H1: Full model, only school kids present		-936.12	-2721.35	-3657.47
Test static		3.98	0	3.98
Critical value 10%-level		2.71	2.71	2.71
Critical value 5%-level		3.84	3.84	3.84
Critical value 2%-level		5.41	5.41	5.41

The hypothesis that 'Planned length stay is independent of presence of school kids in a family' is rejected at a 5%-level of significance.

Statement 5: Number of children affects housing market behaviour, but in a non-linear fashion

Test 5.1:

	Degrees of freedom	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	ΣLL
H0: Tenure independent number of children	2	-940.06	-2723.70	-3663.76
H1: Full model - without dummies for age of children		-935.63	-2723.70	-3659.33
Test static		8.86	0	8.86
Critical value 10%-level		4.61	4.61	4.61
Critical value 5%-level		5.99	5.99	5.99
Critical value 2%-level		7.82	7.82	7.82

The null hypothesis is rejected at a 2%-level of significance.

Test 5.2:

	Degrees of freedom	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	ΣLL
H0: Planned length of future stay independent of number of children	2	-935.63	-2726.57	-3662.20
H1: Full model - without dummies for age of children		-935.63	- 2723.70	-3659.33
Test static		0	5.74	5.74
Critical value 10%-level		4.61	4.61	4.61
Critical value 5%-level		5.99	5.99	5.99
Critical value 2%-level		7.82	7.82	7.82

The hypothesis that 'Planned length of future stay is independent of number of children' is rejected at a level of significance a little bit above 5%.

Test 5.3:

	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	ΣLL
H0: Planned length of future stay and tenure linear in number of children	-938.04	-2723.77	-3661.81
H1: Full model	-935.03	- 2720.85	-3655.88
Test static	6.02	5.84	11.86
Degrees of freedom	2	2	4
Critical value 10%-level	4.61	4.61	7.78
Critical value 5%-level	5.99	5.99	9.49
Critical value 2%-level	7.82	7.82	11.67

When each of the two equations is considered in isolation it is possible to reject the null hypothesis of a linear effect of number of children on tenure choice at a 5%-level of significance. A linear effect on length of stay can be rejected at a level slightly above 5%. The joint hypothesis of linear effects in both equations, however, is rejected at a 2%-level.

Statement 6: Demographics determine length of stay, but have no independent effect on tenure choice.

Test 6.1:

	Degrees of freedom	<i>LL</i> Tenure choice	<i>LL</i> Planned length of stay	ΣLL
H0: Tenure independent of demographic characteristics of the households	16	-954.12	- 2720.85	-3674.97
H1: Full model		-935.03	- 2720.85	-3655.88
Test static		38.18	0	38.18
Critical value 10%-level		23.54	23.54	23.54
Critical value 5%-level		26.30	26.30	26.30
Critical value 2%-level		29.63	29.63	29.63

Appendix 3 - Wage equation

The estimated wage equation used in the calculation of the full income measure is as reported in the table below.

Table - Wage regression, dependent variable hourly wage

	Coeff.	Absolute t-value
INTERCEP	77.08	2.89
Male without higher education - dummy (MA)	-65.43	-2.09
Age*MA	3.66	4.82
Age squared*MA	-0.03	-3.96
Smal municipality*MA	5.07	1.44
Medium sized municipality*MA	1.38	0.42
Large municipality*MA	4.99	1.65
Single person*MA	-5.99	-1.53
Divorced or bewidowed*MA	-1.80	-0.29
Oslo*MA	10.93	2.95
Mid-Norway*MA	3.33	0.90
North-Norway*MA	-1.53	-0.33
West-Norway*MA	10.74	3.34
South-Norway*MA	7.27	1.62
Leader*MA	15.38	4.20
Low educational level*MA	1.78	0.57
High educational level*MA	10.70	3.86
Male with higher education - dummy (MH)	-163.77	-4.46
Age*MH	9.03	7.94
Age squared*MH	-0.09	-7.05
Smal municipality*MH	11.03	1.71
Medium sized municipality*MH	21.54	3.59
Large municipality*MH	10.35	1.95
Single person*MH	-12.25	-1.92
Divorced or bewidowed*MH	-32.68	-3.20
Oslo*MH	15.03	2.52
Mid-Norway*MH	3.66	0.60
North-Norway*MH	-10.96	-1.34
West-Norway*MH	10.52	1.81
South-Norway*MH	5.76	0.74
Leader*MH	13.73	2.49
Low degree*MH	-0.96	-0.25
high degree*MH	14.12	3.79
Female no higher education - dummy (FA)	-20.28	-0.64
Age*FA	1.48	1.88
Age squared*FA	-0.01	-1.46
Smal municipality*FA	-0.39	-0.10

Medium sized municipality*FA	-3.66	-1.01
Large municipality*FA	-4.18	-1.28
Single person*FA	-4.11	-0.85
Divorced or bewidowed*FA	-3.44	-0.77
Oslo*FA	7.56	1.89
Mid-Norway*FA	1.91	0.49
North-Norway*FA	5.85	1.23
West-Norway*FA	4.20	1.17
South-Norway*FA	0.56	0.11
Leader*FA	12.45	1.58
Low educational level*FA	2.75	0.92
High educational level*FA	8.75	2.67
Female with higher education - dummy (FH), reference		
Age*FH	1.41	1.13
Age squared*FH	-0.01	-0.85
Small municipality*FH	-4.90	-0.73
Medium sized municipality*FH	-6.09	-1.01
Large municipality*FH	-3.30	-0.63
Single person*FH	2.10	0.42
Divorced or bewidowed*FH	10.90	1.24
Oslo*FH	2.05	0.34
Mid-Norway*FH	-4.62	-0.74
North-Norway*FH	-5.00	-0.58
West-Norway*FH	0.89	0.15
South-Norway*FH	8.63	1.12
Leader*FH	3.47	0.37
Low degree*FH	3.67	1.04
high degree*FH	24.10	4.83
R ² -adj	0.192	
No. observations	4 480	

The estimated wage regression resembles the ones in Longva and Strøm (1996). Two major differences may be noted. They used the log of the wage as a dependent variable and they included industry among their set of explanatory variables. Information of industry is of course important in a wage equation. I omitted it because my equation was meant to be used to predict full income also for persons presently outside the working force. The fit of my equation is however not very much poorer with a R² of 19.2% as opposed to 26.7% for females and 36.2% for males in Longva and Strøm. The total sample in Longva and Strøm was more than a hundred times larger than my sample.

