Squeezed in and squeezed out: the effects of population ageing on the demand for housing.

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Abstract

This paper examines how increasing longevity affects the housing choices of working age and retired people using a heterogeneous agent overlapping generations model that incorporates owner-occupier and rental sectors, credit constraints, detailed tax regulations, and a housing supply sector. Increasing longevity generally leads to declining home ownership rates among young people, with bigger declines if the government increases taxes and pensions rather than relying on additional private provision of retirement income. The model suggests raising tax rates to provide pensions can reduce the welfare of all agents, even those who are net beneficiaries, because they tighten credit constraints when young.

Summary Haiku

The young pay taxes

So the old live in mansions

They wanted when young.

1 Introduction

"The conventional New Zealand housing model is a progression that starts with living in the parental home, moving to rental accommodation, buying a first home, and then trading up first homes as family situation and employment location change. Thereafter, people may trade down as people leave home or retirement nears. The later stage of this 'housing career' may include cashing up the housing asset to pay for retirement associated expenditure."[1]

A key aspect of the evolution of New Zealand's society and economy in the first half of the 21st century will be the increasing number of older people. Due to a combination of increasing longevity and the existence of a large cohort born between 1946 and 1964, the fraction of the New Zealand population aged over 65 years is set to increase from 510,000 in 2006 to 1,350,000 in 2051, or from 12 percent of the population to 25 percent of the population (Statistics New Zealand, 2007). The number of people aged over 85 years will increase even faster, from 1 per cent of the total population in 2006 to 6 percent in 2050.

The purpose of this paper is to explore how housing demand may change as a result of this forthcoming increase in the number of older and retired people. The changes comprise two separate components: a direct effect, or the change in housing demand that will occur because there will be more older people and because their housing patterns may change because of increasing longevity; and an indirect effect, as housing demand by younger people changes, both in response to the larger number of older people and because they anticipate being old for longer themselves. The direct and indirect effects will be interrelated, as both young and old members of societies interact in the same housing market. Indeed, because working age people will comprise a greater fraction of the population than elderly people throughout the period, it is possible that the indirect effects could be greater than the direct effects.

To explore how population ageing may affect the total demand for housing, this paper develops a model that calculates housing demand patterns in

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[1] Davey (2006).

an economy consisting of households that differ by age, income, and wealth. The model is necessarily stylised, but it attempts to incorporate the major features of the housing market, including the way people can choose different size houses; the way they borrow and save; the ways their choices to rent or buy are affected by the tax, retirement income, and healthcare arrangements of the society; and the way these choices are affected by the cost of building new houses. The model is dynamic, both because it allows house prices to change through time and because the households are forward looking and at each stage of their lives they consider their future as well as current housing demands. The focus of the model is the way increasing life expectancy may affect the housing market in the long run, once changes in housing demand throughout a lifecycle are taken into account.

Two assumptions underpin this study. First, it is assumed that households make sensible, forward looking decisions about their housing arrangements at different stages of their lives, and that they respond in a rational manner to financial incentives when making these decisions. Thus households are assumed to save a deposit, to delay buying a house when young if this would mean they would have very little to spend on other things, and to take inflation into account when choosing between lending money or investing in property. Second,the paper assumes that people and governments face binding long run budget constraints. In particular, households cannot spend more than they earn over a lifetime, and governments are assumed to run balanced budgets. This means that if governments face higher expenses associated with population ageing such as higher retirement payments or medical care costs, they raise taxes to pay for them, and these taxes reduce the disposable income of working age people.

The models suggest there will be four main effects of increasing longevity on the housing market. First, there will be more people in the country, particularly more people over 65, and this will mean there will be a need for more houses. Secondly, there will be an increase in the demand for high quality housing by older people. This increase partially reflects the increase in the number of younger old people (people aged 65 – 84), for these people have higher than average wealth and typically live in high quality housing. However, it also reflects a change in the financial incentives facing older people to trade down to smaller houses, for any capital realised from the exchange of a large house for a small

house (or a house in a more desirable area for a house in a less desirable area) is spread over a larger number of years and translates into a smaller annual increase in consumption, while the benefits of living in a better quality house extend over a longer period. Thirdly, there is likely to be an increase in house prices due the greater total demand for housing. While this increase is only likely to be in the order of the increase in population (say 15 – 20 percent), it will make it harder for young people to get a start on the housing ladder, leading to more renting and a substitution away from better quality houses while young. Fourthly, there is likely to be an increase in taxes to pay for longer retirement benefits and higher medical expenses. These taxes will reduce the after tax incomes of younger people, delaying the time when they can first purchase a house and then upgrade to a larger house. In turn, this causes an offsetting reduction in the number of better quality houses in the economy.

The model is used in two ways. First, some of the key parameters of the model are varied to ascertain the factors that are likely to be important in determining how housing patterns will change as the population ages. For example, the model can be used to explore how the cost structure of the building industry is likely to affect the change in housing patterns as the population ages. Secondly, the model can be used to explore how different policy options will affect the overall demand for housing as the population ages. For example, the model can be used to assess what happens if the government were to decide to fund a smaller fraction of retirement income through a state pension as the population ages, so that households would have to save more privately if they were wishing to smooth consumption flows. It is also used to explore what would happen if there were an increase in the availability and popularity of reverse mortgage products, so that older households can better access the equity in their homes.

The key question that the model is designed to address concerns the extent to which population ageing affects the demand for housing among younger households. While the results depend on the exact parameterisations studied, when interest rates and inflation are moderate most of the simulations suggest there will be a sizeable reduction in homeownership among young people as the population ages, and a considerable increase in the time taken to climb the

housing ladder. It proves that the cost structure of the building industry is a particularly important factor in determining how long it takes most people to attain their "peak" house. If housing quality mainly concerns house size, and it is straightforward to build larger houses, population ageing is likely to mean that most new houses are high quality, for there will be a much larger demand for high quality houses amongst older people, and little offsetting demand among working age people. In contrast, if housing quality largely reflects factors that are expensive to produce, population ageing will mean that most new houses are lower quality, for younger households will be less able or less willing than older households to pay the necessary premiums to live in high quality housing. This would be the case, for instance, if housing quality largely reflected location and there was a premium paid to live in suburbs close to a city centre. In this case, the greater number of older people who wish to live in high quality housing will mean an increase in the time spent by working age people in less desirable areas, and most of the new housing that is constructed will be in these areas. The different implications of these two scenarios are potentially quite important, for if population ageing leads to the "graying" of inner suburbs, it may prove that there is a mismatch between the current location of public facilities such as schools and sport-fields and the future location of the young households who will primarily use them.

The model is not tested empirically. However, recent trends in New Zealand's housing markets are broadly consistent with the predictions of the model. For example, between 1996 and 2006 there was an increase in longevity, a rapid increase in the number of people aged over 65, rising house prices, increasing tax rates, and sharply falling home ownership rates among young people, events that are all consistent with the major predictions of the model. Moreover, the fraction of older households living in households with at least three bedrooms increased by 9 percent between 1996 and 2006, from 59 percent to 68 percent. This increase, which has not previously been documented in New Zealand, occurred amongst almost all demographic subgroups including couples, singles, and those aged over 80 years.

The full formal model and the numerical solution technique are not presented in this paper, but are documented in the working paper version of this article, Coleman (2010). The paper is organised as follows. In section 2 of the paper the main components of the model are outlined. The results are presented in section 3, while a discussion of the results and conclusions are offered in section 4. Coleman (2010) also contains a discussion of the major trends in population and housing demand among older households in New Zealand, making use of a variety of data from Statistics New Zealand.

2 A dynamic model of housing demand

The primary contention of this paper is that population ageing will have two effects on the housing market: a direct effect caused by an increase in the older proportion of the population, and by changes in their housing demands; and an indirect effect caused by changes in younger people's housing demand. Older people may change their demands because they are active longer, because they are living with a spouse for longer, or because a longer retirement makes them wish to economise on housing. Young people may change their demands because they anticipate living longer and wish to save more, because they pay more taxes to fund the pensions and healthcare expenditure of older people, or because they respond to changes in house prices. The theoretical framework developed in this paper, which is a version of the Modigliani-Brumberg overlapping generations model, attempts to unravel these competing effects by analysing how the interactions of households who differ by age and income determine house prices, and how these prices affect housing allocations.

The basic structure of the model is relatively straightforward, and the details are presented in Appendix 1 of Coleman (2010). The model comprises a set of overlapping cohorts who are born at different times. Each cohort comprises N= 400 households who differ in terms of income. Each household passes through four distinct stages: two young stages, one middle-aged stage, and one stage in retirement. The household has a different income in each stage, and is allowed to choose a different type of housing. Households can share housing with their parents, rent a low quality (small) house, buy a small house or buy a high quality

(large) house. Households are assumed to choose their most preferred houses, given their age, wealth and after-tax incomes, the cost (including interest charges) of renting or buying different houses relative to other goods, and their ability to raise a mortgage. For a given set of housing prices, housing demand for each of the households during their four stages of life are calculated. These 4N different housing demand functions are then added together so that the total demand for housing can be calculated. Because each life-stage can be a different length, the total population will not be 4N; rather, if the first two stages were ten years long (representing, say, ages 25 – 35 and 35 – 45), the third stage was 20 years long (45 – 65) and the last stage 12 years (65 – 77), aggregate housing demand comprises the demand of 52N households. The key issue the paper addresses concerns the way aggregate housing demand changes as the population ages. Population projections suggest that almost all of the increase in New Zealand's population over the next forty years will occur among those aged 65 or older. Therefore the model treats the population increase as being caused by an increase in longevity, that is, by a lengthening of the final period.

The above paragraph describes how aggregate housing demand is calculated for a particular set of house prices. Supply curves indicating the cost of supplying different quantities of houses are also specified, and prices are determined endogenously by equating the supply and demand for different types of houses. The prices are found using a complex numerical routine that calculates the demand for each of the 4N different households for a set of prices, and then chooses a new set of prices until a set is found at which aggregate demand equals aggregate supply. Demand patterns are calculated at the equilibrium set of prices, including the number of young households that rent and the number of older households that live in high and low quality houses.

The model analyses the way households climb the housing ladder. Their ascent can be characterised by two factors: the ultimate height they reach and the speed at which they attain that height. The ultimate height is largely determined by life-time income. In this model there are only two housing qualities, and in the parameterisations studied most people can afford a high quality house in middle

age[2]. The speed of ascent is mainly determined by (i) the steepness of the earnings profile (ii) inflation and interest rates (iii) the tax incentives facing households and property investors and (iv) the availability of credit from banks. Households ascend slowly when they have a steep earnings curve (implying relatively low incomes while young), when credit is hard to obtain, and when tax laws favour property investors.

In the model, a household can potentially pass through three stages before purchasing a high quality house. First, they can share housing with others – in this case, with their parents. If they do so, the number of houses in the model will be less than the number of people, so if housing is in short supply some sharing will be necessary[3]. Secondly, they can rent a low quality house. It is assumed that if they do this they get slightly lower utility than if they own the house, for they cannot shape it in their own image. Moreover, in New Zealand there are tax advantages to home ownership, as imputed rent is not taxed. Lastly, they can purchase a low quality house.

The focus on the speed with which households ascend the housing ladder means considerable attention is paid to various financial factors that influence the decision to buy, rent, or lease a house. Following Coleman (2008) the model includes a careful representation of the conditions imposed by banks on those obtaining mortgage finance to purchase a house, including realistic constraints on the minimum deposit and the maximum mortgage-repayment to income ratio. These constraints mean that young households may choose to rent rather than buy a house, even though the long term cost is the same, because they cannot obtain suitable financing. It also includes a careful consideration of the tax

[2]In some sense this reflects the relatively modest quality and price of a high quality house in the parameterisations studied (say a nice three bedroom house). Nonetheless, when the price of these houses is raised, most middle aged people will choose to live in them. In part this result reflects that tax incentives that favour home-ownership over other investment classes.

[3]The model only allows young people to share with their parents. In Coleman (2009), "sharing" is modelled by allowing young people to share with each other, paying half rent and getting less utility than living by themselves. The latter model was used to analyse the effect of a capital gains tax on the housing market, not the effect of increasing longevity, and because it has a different although related solution technique, the effects of allowing young people to share with each other have not been explored in this paper. The results from Coleman (2009) suggest the higher taxes associated with increasing longevity would enhance the attractiveness of sharing rental accommodation and reduce homeownership rates. Since "sharing" allows higher consumption when young, some of the other results such as the welfare effects of tax increases may be softened, however.

incentives facing landlords. In this case, because the New Zealand government taxes the inflation component of interest income but does not tax capital gains, competition between landlords means that landlords are prepared to offer artificially low rents when there is inflation in order to obtain tax free capital gains.

The model also gives detailed attention to the role played by government. The government levies tax on labour and capital income, and imposes a goods and services tax. It grants special tax exemptions to housing assets. A key aspect of the model concerns what happens as the population ages and the government spends more on pensions and healthcare. In the basic version of the model, the government raises tax rates on labour income to pay for this expenditure. This lowers the after-tax income of working people, and reduces the amount they have to spend on housing and other goods when young. Other versions of the model examine the effect of different policies: for example, in one simulation the government reduces annual per capita pension payments as the number of older people increases to ensure total pension expenditure is constant, leaving it to individuals to fund their additional retirement years.

The model is dynamic and is solved under the assumption of rational expectations. Since house prices and rents are allowed to change through time, every housing price or rent comprises two parts: a price level at some base period ($t = 0$); and a price (or rent) appreciation rate. The property price appreciation rate is solved simultaneously with prices, and while the property price appreciation is normally the general inflation rate, it need not be. The agents are rational and in each period they choose housing taking into account their remaining length of life, their future income stream, their future housing patterns, and expected future prices. Thus when choosing housing in their first period, a young person takes into account not only their current income, current house prices, and interest rates and rents, but the fact that their income is likely to rise as they get older and more experienced, that they are likely to want a higher quality house when they have more money in the future, and that houses are likely to get more expensive. Depending on a variety of factors including taxes and the inflation rate, and bank imposed mortgage lending criteria, this may lead them to delay purchase, as they figure that it is better to spend money on other things when young and pay off a

house when they have higher incomes later; but for different parameters it could lead them to purchase a higher quality house quickly because they realise inflation will erode the value of any deposit they save.

The model allows the housing supply functions to be varied. Three main variations have been examined. In the first, housing supply is almost perfectly elastic, meaning that there is no price response (other than an inflation adjustment) as the number of houses in the economy increases. This version is used to explore what happened when the main response to increasing longevity occurs because households live longer and pay more taxes, rather than because house prices change. In the second version, high and low quality house prices increase as the number of houses increase, by about 1 percent for each 1 percent increase in the population. This version is used to explore how price feedback effects (as well as increases in longevity and higher taxes) affect housing demand. In the third version, both high and low quality house prices increase as the number of houses increase, but high quality houses increase at a faster rate. This version is used to model what happens if location quality is an important component of housing quality, but high quality locations are in short supply. While various other parameterisations have been experimented with, these three prove to be most interesting for exploring the range of possible housing market outcomes as the population ages.

The model is related to several earlier papers. Its earliest form is the overlapping generations model of Modigliani-Brumberg (1980) that was used to analyse aggregate saving behaviour when agents differ according to their stage in the lifecycle. In terms of more recent literature, it extends the equilibrium lifecycle model of housing markets analysed by Ortalo-Magné and Rady (1998, 2006) and Coleman (2007, 2008). Compared to Ortalo-Magné and Rady, it has a significantly more sophisticated consumption side, it incorporates taxes and more realistic financial constraints, and it incorporates a construction sector. Compared to Coleman (2008), it includes a more elaborate government sector, a more complex treatment of inheritance, and it allows the lengths of different life-cycle stages to vary. Indeed, the latter modification proved most technically demanding as it alters much of the symmetry of the earlier models.

3 Results

3.1 Description of tables

The results show the ways that increases in longevity change tenure patterns and the composition of the housing stock. They are presented as a series of tables showing how equilibrium outcomes change as the length of the last period is increased from 10 to 20 years, approximately representing a change in life expectancy from 75 to 85. The first three tables show the results for three different housing supply functions. In table 1 (supply version 1), the supply of housing is almost perfectly elastic, with prices rising by only 1 percent for every 10 percent increase in the number of houses. In this case, the price of low quality houses is approximately three times the median income of middle-aged households, and high quality houses are approximately half as much again. In table 2 (supply version 2), house prices increase by approximately 1 percent for each percent increase in the number of houses, or by approximately 20 percent as the final period increases from 10 to 20 years. Prices in supply version 1 and 2 are the same when the length of the final period is 10 years. In table 3 (supply version 3), the supply curve for small houses is the same as supply version 2, but the supply curve for high quality houses is much less elastic to reflect the scarcity of premium location land.

Each table is divided into sections that show how different policy options affect the economy as the population ages. The first section shows what happens when taxes are raised to pay for higher expenditure on pensions, assuming that annual government pension paid to each retired person is constant in real terms. The second section shows what happens if taxes are increased further to pay for higher medical expenditure, as well as a longer pension entitlement. The increase in medical expenditure is approximately equal to 3 percent of GDP as the length of the final period is increased from 10 to 20 years. The third section of the table shows what happens when there is no change in total pension expenditure as longevity increases, and thus no change in taxes. This shows what would happen if the additional longevity was entirely funded by private saving, perhaps because the age of pension entitlement was raised one-for-one with longevity.

Tables 1 – 3 form the core of the results. The remaining tables show what happens when various parameters or policy options are changed. In tables 1 – 3, the annual inflation rate is 2 percent and annual real interest rates are 5 percent. Table 4 shows how the results for supply version 2 depend on inflation and interest rates. Table 5 shows how the results depend on the level of house prices, rather than the elasticity of the supply function. Lastly, table 6 shows what happens when households have the option of purchasing actuarially fair reverse mortgages.

3.2 The housing ladder.

In all the scenarios, the effects of increasing longevity can be largely described in terms of their effects on the three stages of the housing ladder: peak housing quality, the time taken to ascend to this peak, and the likelihood of a household trading down in retirement. For all of the parameterisations considered, the general principles are similar.

First, increasing longevity has small effects on peak housing quality for most households. While population ageing means that some poorer households are deterred from buying and living in a high quality house when they are middle aged, in most of the scenarios most households experience no change in their peak housing quality. This is because the tax laws generate large incentives to buy residential housing, rather than interest earnings assets. This means that most middle-aged households are better off if they hold their wealth as property. Since households save for retirement, because the pension level is much lower than an average income, the tax system means that most households choose to live in a high quality house in their middle age. As the population ages, however, households change the time spent in their peak quality houses.

The changes occur at both ends of the lifecycle. The model strongly suggests that longer life expectancy increases the number of older households in high quality housing. In the model the demand for high quality housing in later life represents a tradeoff between the benefits of living in a high quality house and the financial gain that may result from trading down. The financial gain is a one-time lump sum that must be spent over the remaining years of one's life. For each

household there is a critical time period T_j^*, say six years before expected death, when households will be indifferent between remaining in a high quality house and trading down for financial reasons; if the length of the final period length is less than this value, it is advantageous to trade down, as the annual consumption value of the released housing equity exceeds the pleasure of staying in a large house. Thus in the model, the fraction of retired households living in high quality houses increases sharply as a function of the length of the last period, as the annual consumption benefits decrease, making it less attractive to sell. For example, in the first section of table 1, the fraction of older households living in high quality houses increases from 32 percent to 62 percent when the length of the last period is increased from 12 years to 20 years; a similar increase is found in all the parameterisations studied. It is worth noting that New Zealand data is broadly consistent with this observation: between 1996 and 2006, the fraction of people over 65 living in small (1 or 2 bedroom) houses decreased by 9 percentage points to 42 percent.

The structure of the model means each household either lives in a high or a low quality house for their entire retirement. In real life, the choice is not so stark: rather, many households will live in one house type for a while, before moving to another type at the end of their lives, perhaps because of ill health or the death of a spouse. Indeed, financial reasons do not appear to be the main reason why people say they move in retirement. Nonetheless, if the decision to move for health or other reasons depends on the length of time before death, rather than the length of time since turning 65, the economic and social forces that determine the fraction of time retired households spend in high quality houses will have exactly the same effect as the forces in the model that give an incentive to trade down for financial reasons. Thus if health improves as life-expectancy increases, and this delays the shift from a high quality to a low quality house, households will spend more of their retirement in high quality houses. For this reason, summing up the fraction of households that spend their entire retirement in a high quality house (in the model), or summing up the fraction of each

household's retirement that is spent in a high quality house (in the real world), is likely to generate a similar answer[4].

The model also suggests that increasing longevity is likely to increase the time taken to ascend the property ladder, because households have lower after-tax incomes and face higher property prices. Indeed, for most parameters analysed this is a much greater effect than the effect of population ageing on peak housing quality. While in some parameterisations population ageing accelerated the ascent of the property ladder, because households decided they needed to save more during their working life, this accelerated ascent only occurred in reasonably stringent conditions.

3.3 Core scenarios

3.3.1 Taxes increased to pay for pensions

The first section of tables 1 – 3 shows what happens when taxes are increased to pay for higher pension expenditure as the population ages.

Table 1 (supply version 1) indicates what happens when the construction section is very elastic and house prices change little as the population ages. The table is normalised so that the population is 1000 when the length of the final period is 10 years, increasing to 1200 when the final period is 20 years. As longevity increases and the population ages and increases in size, the total number of houses increases, although by slightly less than the increase in the number of households. (The total number of houses increases by 190, or 95 percent of the increase in population.) Approximately 80 percent of these new houses are high quality. The increasing demand for these new high quality houses largely comes from retired people, because as longevity increases there is a sharp increase in the number of older people who wish to live in a large house; or, to be more precise, there is a steep fall in the fraction of households trading down, because most people live in a high quality house in their middle age. As explained above, fewer households trade down as longevity increases because the annual consumption

[4] While it is possible to model the individual household's choice differently so that their retirement housing choices could reflect a period in different quality houses, the programme would be considerably more complicated. The core utility maximisation problem already has 48 Kuhn Tucker conditions, and for each of the households it is solved for 23 different housing permutations for every set of prices. Adding another period would mean a maximisation problem with 144 Kuhn-Tucker conditions and 46 housing permutations, increasing the size of the problem six-fold.

gain from such a move falls compared to the benefit gained from living in a large house.

The rise in taxes necessary to pay for higher pensions increases the average time it takes households to ascend the housing ladder. The increased delay represents two factors: delays leaving home and an increase in renting amongst the youngest cohorts, and thus a reduction in home ownership rates among this group (from 56 percent to 48 percent); and a reduction in the fraction of cohort 0 and cohort 1 households purchasing a large house (from 36 percent to 27 percent). Not all young households are affected, but the effects are felt up and down the income distribution. Some low income households delay leaving home rather than rent by themselves; some middle income households delay the purchase of a small house, choosing to rent instead; some relatively high income households wait to middle age before upgrading to a large house.

In the first section of table 2 (supply version 2) taxes are still raised to pay for additional pension expenditure as the population ages, but in addition house prices rise as the total number of houses increase. The results show small house prices rise in real terms by 23 percent (from $200,000 to $246,000) while large house prices rise by 16 percent (from $311,00 to $362,000.) The increase in house prices accentuates the outcomes in table 1. Three points should be noted. First, because both high and low quality house prices increase by a similar amount, there is little additional benefit for a retired household to trade down as the population ages. Thus the number of retired households living in high quality houses increases at the same rate as in table 1. Secondly, fewer new houses are built, because the higher prices induce more young cohorts to live with their parents. New houses are only built for 82 percent of the increased population, not 95 percent. However, a slightly greater fraction of these new houses are large because of the demand from older households. Thirdly, there is a significantly larger reduction in the fraction of cohort 0 that purchases a house, and the fraction of cohorts 0 and 1 that purchase a large house, as the population ages. As longevity increases from 10 to 20 years, home ownership among cohort 0 drops by 21 percentage points rather than by 8 percentage points, and the fraction of cohort 0 and 1 owning a large house drops by 12 percentage points rather than 9 percentage points. From these results, it would appear that the increase in house

prices associated with population ageing will have its biggest effect on young households by making it more difficult for them to purchase a new house.

In the first section of table 3 (supply version 3) it is assumed that taxes are raised to pay for additional pension expenditure as the population ages, but in this case prices rise more sharply for high quality houses than low quality houses. This produces a twist in the results compared to supply version 2: while the increase in the total number of houses, and the decline in home ownership among cohort 0 is almost the same (for at the margin these households are affected by the price of low quality houses and this is the same in supply versions 2 and 3), there is a much smaller increase in the total demand for high quality houses. Only 25 – 30 percent of new houses are high quality, in contrast to the 85 – 90 percent figure in table 2. In turn, the fraction of high quality houses declines as the population ages. As longevity increases from 10 to 20 years, there is a smaller increase in the fraction of retired households living in large houses (up 30 percentage points rather than 43 percentage points) and a larger decrease in the fraction of cohorts 0 and 1 living in large houses (down 17 percentage points rather than 12 percentage points.) There is also a sharper reduction in the number of middle aged households living in high quality houses, down 13 percentage points rather than 5 percentage points. Even in this case, however, more than 80 percent of middle-aged households live in a high quality house.

3.3.2 Taxes increased to pay for pensions and medical care

The second sections of tables 1 – 3 show what happens when there is an increase in government funded medical expenditure as well as pension expenditure. Medical expenditure increases by 3 percent of GDP as longevity increases from 10 to 20 years, compared to a 5 percent increase in pension expenditure. The results are similar to those when pension expenditure increases, although home ownership rates among the young cohorts are slightly lower. The small effect of medical expenditure reflects differences in the way that the utility benefits of health care and pensions are modeled. In the model, health expenditure provides no income or utility in old age; rather it prevents large negative shocks to utility. Thus, unlike pension payments, medical expenditure does not alter the shape of the income or consumption profiles through time; rather the additional taxes that pay for higher medical expenditure merely lower lifetime disposable

income, rather than tilt it towards older age. Consequently, these taxes do not intensify the effects of credit constraints on young households, and have very little effect on housing choices[5].

3.3.3 No changes in taxes or total pension expenditure as longevity increases

The third sections of tables 1 – 3 shows what happens if total pension expenditure and taxes are unchanged as longevity increases. In this scenario, households must save for their additional years of retirement if they wish to smooth consumption. This changes the results considerably, as the most tax efficient way of saving is to purchase a house. When the supply is nearly perfectly elastic (supply version 1) the increase in longevity leads to an increase in the total number of houses and the number of older people living in large houses, as before. In this case, however, the fraction of cohort 0 owning, and the fraction of cohorts 0 and 1 living in large houses scarcely changes as the population ages, because young households have tax incentives to buy; in fact it increases by 1 percentage point. In supply versions 2 and 3, the number of young people owning houses or purchasing large houses still decreases, because of the increase in house prices, but the decline is smaller than when the government raises taxes to pay for additional pensions. In table 2 the fraction of cohort 0 who own their own homes declines by 10 percentage points as longevity increases from 10 years to 20 years, not 21 percentage points, and the fraction owning large houses decreases by 6 percentage points rather than 12 percentage points.

These simulations suggest that the government's approaches to population ageing may have significant implications for young people's homeownership rates. If the government increases taxes on labour income to pay for population ageing, homeownership rates are likely to fall by more than if the government adopts policies that put more emphasis on private provision – for example, by increasing the age of entitlement, or by encouraging or making mandatory private saving, so long that this saving can be used to purchase a house. The "Kiwisaver" scheme, which allows households to use subsidised savings as a deposit on a house, is an example of a policy that could reduce the impact of population ageing on young people's home ownership rates.

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[5] Several variations with different values of the health expenditure variable were calculated. In all of the cases, the level of healthcare had very little effect on housing profiles.

Home ownership rates are not the only measure of welfare, and in fact are quite a poor measure. It is possible that a government tax-pension scheme makes low income people better off, because they pay fewer taxes than high income people but get the same pension. However, somewhat surprisingly, when the lifetime utility of each household is calculated, *everybody* would be better off saving for their own additional years of retirement rather than have a government increase their taxes when working and pay them a pension when retired. Middle and high income people are worse off because they pay more taxes than they get in additional pension, and some find they have to slow their ascent of the housing ladder. Low income people are worse off because when they are young the increase in taxes hurts them more than high income people (owing to their very low consumption levels at this stage) and they are also delayed climbing the housing ladder. The welfare loss for low income people is smaller than for high income people because the transfer element of the tax-pension policy means they have higher lifetime income. These results are not, of course, a serious argument against government pension schemes, for the international evidence strongly suggests that government pension schemes have been the major reason for the near elimination of elderly poverty for reasons that have not been included in this model. (See, for example, the discussion in Gruber 2004.) Nonetheless, they suggest that the incidence of the taxes used to raise funds to pay pensions may have important welfare consequences. Even small increases in the taxes on low lifetime income people when they are young can reduce welfare, even if they receive longer-lasting pensions when they are old.

3.3.4 Summary of the core results

There are four results that deserve emphasis. First, the model suggests that population ageing will have little effect on most households' peak quality housing. Most of the changes in the housing demand of working age households will reflect the amount of time they spend in their peak quality houses, rather than the size of their houses. Secondly, population ageing is likely to see a big increase in the demand for high quality housing among retired households. Thirdly, there is likely to be a fall in the number of young (25 – 45) households living in large houses. Fourthly, unless the supply elasticity of high quality houses is much less

elastic than the supply elasticity of low quality houses, population ageing will mean most new houses will be high quality houses.

3.3.5 The effect of inflation and interest rates.

The results in tables 1–3 examine what happens when real interest rates are 5 percent and the inflation rate is 2 percent. Table 4 explores the effect of variations in interest rates and the inflation rate. The results are shown for the case that taxes are increased to pay for additional pension expenditure in supply version 2 (section 1 of table 2).

Inflation may be important because it reduces home ownership rates among the young. There are two reasons why this occurs. First, an increase in inflation raises real mortgage payments at the start of a mortgage and reduces them at the end of a mortgage, making it more difficult for young households to purchase a house (Modigliani 1977). Secondly, an increase in inflation attracts landlords into the rental market to take advantage of tax free capital gains. If the supply of houses is relatively inelastic, landlords bid up prices in order to take advantage of these capital gains; when the housing supply is relatively elastic (the case modeled here), landlords reduce rents to attract tenants and enter the property market (Coleman 2008). Either way, the interaction of inflation with the tax system tends to reduce homeownership rates among young households.

The effect of real interest rates is more complex. On the whole, declining real interest rates should be good for young households, for they are net borrowers and lower rates mean lower financing costs. However, lower real interest rates also make property a more attractive investment to landlords, particularly when inflation is moderate or high. Coleman (2007) suggests that the latter effect dominates, so that home ownership rates among cohort 0 decline as real interest rates fall[6]. Low real interest rates can also make it harder for households to accumulate funds for their retirement, which may affect their willingness to live in large houses when retired.

[6] This aspect of the model is consistent with New Zealand data. Real interest rates declined steadily from 10 percent to 5 percent between 1990 and 2006, and homeownership rates fell among young people

The simulations in table 4 suggest that although inflation has a large effect on the overall level of young households' ownership rates, increases in longevity reduce the home-ownership rates of young households irrespective of the inflation rate. The table shows that a reduction in the inflation rate from two percent to zero percent will increase homeownership rates among the youngest cohort by over 20 percentage points, will increase the fraction of cohorts 0 and 1 owning large houses by 8 percentage points, and will decrease the fraction of the older households owning large houses modestly. (The decrease occurs because when inflation is zero more households buy a house when young, but can't afford a large house at both ends of their lives.) These are level effects, occurring at all life expectancy values. In contrast, the change in the speed that young households reduce homeownership rates as longevity increases is not particularly large. For example, when longevity increases from 10 to 20 years, homeownership rates among cohort 0 decline by 16 percentage points when the inflation rate is 0 percent rather than 21 percentage points when the inflation rate is 2 percent. The change in the fraction of young households owning large houses as longevity increases is even smaller.

The effects of changing real interest rates are more complex. The effects of real interest rates on ownership patterns can also be split into level effects and the effects on rates of change. In level terms, the simulations suggest a decline in real interest rates have a positive effect on the total number of houses (because rents are lower, inducing less sharing), a small positive effect on the fraction of cohort 0 and 1 that owns a large home (because finance costs are lower), and a large negative effect on the fraction of cohort 0 that owns a home (because of competition from landlords). For example, a decline in real interest rates from 5 percent to 4 percent leads to an approximately 1.5 percent increase in the total number of houses, a 2 percent increase in the number of cohort 0 and 1 households owning a large house, and at least a 25 percent decrease in cohort 0 home ownership rate.

The simulations suggest that real interest rates have little effect on the rate at which the quality composition of the housing stock changes as the population ages. Irrespective of real interest rates, population ageing increases the demand for high quality houses by older people and reduces the demand by young

people. The effect of real interest rates on the rate at which cohort 0 homeownership rates decline as the population ages is more complex. When the inflation rate is 2 percent and real interest rates are 5 percent, home ownership rates fall steeply as the population ages. When the inflation rate is 2 percent and real interest rates are 4 percent, homeownership rates among young cohorts are very low—under 10 percent—for all levels of longevity, and thus cannot fall by much. In this case, population ageing has very little effect on homeownership rates among young households because they are always low. When the inflation rate is 0 percent and real interest rates are either 4 percent or 5 percent, cohort 0 homeownership rates are high when the length of retirement is 10 years, and declines sharply as the population ages. In summary, if there is a decline in real interest rates as well as population ageing over the next forty years, it is likely that an increasing fraction of the housing stock will be leased.

3.4 Other supply scenarios

The results in tables 1 – 3 show that the ease with which new houses can be built is a crucial determinant of the effects of population ageing on the housing market. Table 5 shows the results for three additional housing supply functions. In each case, the slopes of the house supply functions are the same as supply version 2, but the price level have been increased. The first section of table 5 has the results when the prices of high and low quality houses are increased, keeping quality the same, by approximately $50000. In the second section, the price of low quality houses is unchanged, but the price of a high quality house is increased by $50000, again keeping quality unchanged. In the third section, both the price and the quality of large houses are increased to reflect what happens as high quality houses become better. In each section the table shows what happens if pension expenditure and taxes are increased as the population ages, so table 5 is directly comparable to section 1 of table 2.

The results are broadly similar to those described already. The easiest case to consider is when both the quality level and the price of high quality houses is increased. In this case there is almost no qualitative or quantitative change in the effect of population ageing on the patterns of homeownership: as before, population ageing causes an increase in the fraction of older households living in large houses, and an increase in the fraction of young households renting and

living in small houses. The only major difference is an increase in the fraction of cohort 0 households owning houses (at all levels of longevity) as it cost more money and a larger deposit to purchase a high quality house, and than the most tax efficient way to save these funds is to start by buying a small house.

When high quality houses are simply more expensive (without a commensurate increases in quality) the effect of population ageing on housing demand is largely unchanged except far fewer households will own large houses in their retirement. The simulations suggest that the amount of money that can be made from trading down compared to the benefit of living in a larger house is so tempting that most older households will do it. In the real world a large fraction of households never trade down in retirement. This suggests that the parametres of the model may need to be modified to better reflect the desire of many (but by no means all) households to age in their long term homes even when the financial incentive to trade down is very large. Nonetheless, even though in this case the level effect may be wrong, the model still suggests that as the population ages there will be a large increase in the fraction of older households choosing to live in high quality houses, and a significant increase in the fraction of young households living in low quality houses.

The results when the prices of both types of houses are increased, keeping quality unchanged, are again similar to before, with one exception. In this case, homeownership levels among cohort 0 are significantly reduced, because more people live with their parents when they are young and because more households rent rather than take out a much bigger mortgage[7]. The simulations suggest that homeownership rates among cohort 0 are so low at all values of longevity that they scarcely decline as longevity increases, in contrast to the earlier result that increases in longevity reduce home ownership rates. Otherwise the fraction of older households who live in large houses, and the fraction of cohorts 0 and 1 who live in small houses, increase as the population ages at a very similar rate as suggested in supply version 2.

[7] The higher house prices mean both rents and mortgages will be higher. Nonetheless, a mortgage costs more than rent, and the increase in mortgage payments reduces consumption so low that many households choose to rent rather than accept a deep cut in consumption.

3.5 Reverse mortgages and inheritance

So far it has been assumed that the only way that a retired household can extract equity from housing is to sell a large house and buy a small house. However, retired households may be able to use reverse mortgages to extract some of the equity of their house and use the proceeds to increase consumption in the last period. If they were to do this, they could also reduce their saving in earlier periods in anticipation of taking out a reverse mortgage later on.

In table 11 the effect of older households obtaining a reverse mortgage equal to 20 percent of the value of the house is explored. The debt accumulates over time, and is paid off upon death out of the value of the household's estate. The interest rate on the loan is the standard (pre-tax) mortgage rate. The table shows the effect of these reverse mortgages when pensions and taxes are increased as the population ages, and supply version 2 is assumed (c.f. section 1 of table 2).

The main effect of a reverse mortgage is that a greater fraction of older households own high quality houses, for a reverse mortgage lets them have their house and eat it too. When life-expectancy is 10 years, the fraction of retired households owning a high quality house increases by 23 percentage points. When life expectancy is 20 years, so that more households want to own a high quality house in any case, the increase is 11 percentage points. The increase in the number of older households living in high quality houses means that the fraction of high quality houses in the economy increases.

The effect on working age households is mixed. This is because for some households (those that don't receive an inheritance) the availability of reverse mortgages will reduce the amount they need to save for retirement; while for other households (those who do receive an inheritance), the availability of reverse mortgages will increase the amount they need to save for retirement. The latter effect reflects the general equilibrium nature of the model: those receiving an inheritance receive a smaller inheritance because their parents took out a reverse mortgage, and this more than offsets the reduction in their need to save because they will take out a reverse mortgage. Overall there is a small increase in the fraction of cohort 0 households owning a house and a small decrease in the fraction of middle aged households living in large houses, but the effects on

working age people are outweighed by the increase in the fraction of older households who live in large houses.

The issue of reverse mortgages raises a wider issue: how are important are inheritances in determining the effects of population ageing on the housing market? The model can be solved for several different assumptions about the way inheritances are passed on. As described in Appendix 1, the default rule assumes that half of the middle aged people in the economy get an inheritance (equal to the value of two houses, with the value of these houses depending on their place in the income distribution), while half get nothing[8]. The simulations suggest that the life-cycle housing patterns of most households depend on whether or not they inherit. Nonetheless, several other inheritance rules were explored, and while the effects on particular individuals of different inheritance allocations can be large, the effect on the aggregate economy is small. For example, if everyone inherits the house of the person in the same position in the income distribution in the cohort born before them, the aggregate effects of population ageing are almost the same as when half the people get nothing, although the identity of the people who live in large houses does change. In contrast, the timing of inheritances is very important. If people inherit when very young (from their grandparents, for example), they find it much easier to climb the housing ladder. For this reason, I have a maintained an assumption that inheritances are received in middle age. While this maximises the length of time people spend climbing the property ladder, the assumption is broadly consistent with the evidence and seems likely to become more so as the population ages.

4 Discussion and conclusions

The focus of the research has been to identify the main economic factors that will change housing demand for households at different stages of the housing lifecycle as longevity increases and the population ages. It proves that many of the factors considered in the model have large effects on housing patterns. Factors such as interest rates, inflation, tax rules, and building costs can

[8] To be precise, every odd numbered person in the income distribution gets nothing, while an even number person j receives the houses owned by person j-1 and j in the cohort born before them.

dramatically change the level of homeownership at young ages, the speed with which households climb the housing ladder, and the overall fraction of high quality houses in the economy. Almost of these factors are important because of the way they affect the credit constraints on young households, or the incentives to invest in housing rather than other assets. While the effect of most of these factors on housing demand have been explored, the paper has focused on two factors which have particularly large effects on housing patterns as longevity increases and the population ages. The first factor is the extent to which the government will increase taxes and its aggregate expenditure as the population ages, because it provides pensions and medical care to an increasingly large share of the population. If the government maintains the annual per capita value of pension expenditure, by 2050 population ageing will result in a large increase in government expenditure, by approximately 5 percent of GDP. Increases in medical expenditure will raise this amount further. In most versions of the model it is assumed that taxes will be increased on all households to raise these funds. As the increase in taxes reduces the disposable income of working age (and other) households, many young households will find it preferable to rent for longer and to delay their purchase of a large home. Consequently, population ageing is likely to lead to a reduction in aggregate housing demand by young households, and a substitution away from larger or better quality houses. The aggregate effect of this tendency to delay the purchase of a better quality house is relatively modest, however, unless house prices increase quite steeply as the total population increases. If house prices do not change, the model suggests that the tax increase needed to pay for expenses associated with a doubling of the older population will reduce homeownership rates and the fraction of younger households living in large houses by approximately 10 percentage points.

The role played by taxes on the changing patterns of housing demand as the population ages can be seen by examining what would happen if the government did not raise pension or medical expenditure, or taxes, as ageing occurs. In this case, again holding house prices constant, the aggregate demand for housing by young people scarcely changes as the older population doubles in size, in contrast to the situation when taxes are increased and homeownership rates decline by approximately 10 percentage points. The difference occurs because

households have greater incentives to save for retirement and because housing is a tax advantaged asset class. It is possible that homeownership rates among the young could increase in these circumstances, although in the scenarios analysed most additional saving takes place during middle age due to the joint impact of credit constraints and a steeply rising life-cycle wage profile.

Welfare analysis of these two cases suggests that for the same increase in longevity, policies in which taxes are raised to pay for additional pensions lowers welfare for almost all households compared to the alternative of letting people save for retirement themselves. It is by no means obvious that this result would hold for low income people, because low income people receive much higher pension benefits than the additional taxes they pay. (It is not surprising that it holds for high income people, because they pay more in taxes than they get in additional pensions.) In the model, however, the benefits come at the end of life, while the taxes fall on the beginning and the middle. Because people typically have much lower incomes when they are young, the model suggests the effect of higher taxes at young ages, including lower consumption and a delayed ascent of the housing ladder, offset the benefits of greater pension income in retirement.

The author does not recommend that pension expenditure should remain constant as the population ages, even though it would be simple to implement such a policy by raising the age of entitlement. The model is too stylised for make such a recommendation, excludes too many factors, and has a too simplistic assumption about the way taxes will be increased as the population ages. But the result does suggest that the structure of any tax changes that are implemented to pay for population ageing are very important. In particular, policies that increase taxes on people when they are young may induce quite large welfare losses. It is possible that age-specific as well as income specific taxes could mitigate these welfare losses.

The model suggests that changing the tax rate has little effect on the quality level of most households' peak quality houses--the houses in which people typically live when they are middle aged. This is because New Zealand's tax laws generate large incentives to buy residential housing rather than interest earnings assets and mean most middle-aged households are better off if they hold their wealth as property. Since there are incentives for households to save for

retirement in the model (because the pension level is much lower that average income), the tax system means that most households choose to live in a large house in their middle age. This seems unlikely to change as the population ages.

The second factor that appears likely to have a major effect on the demand for housing as the population ages is the supply elasticity of the construction sector. Population ageing will lead to an increase in the total number of people in the country, and unless the housing supply is extremely elastic this will mean house prices will rise. The model indicates that these house price increases will choke off demand among young people, lowering home ownership and the fraction of young households living in large houses. These price effects reinforce the effects of higher taxes, and are quite large. When the elasticity of supply is approximately 1 percent--which seems likely to be the value in New Zealand--population ageing causes price feedback effects on young people that are similar in size to the effect of the tax increases[9]. Consequently, the total effect is about twice as large compared to the case for which supply is perfectly elastic. Again, there is very little effect on the peak housing quality attained by most people. When the supply elasticity for high and low quality houses is similar, the reduction in the demand for high quality houses by young people is much smaller than the increase in the demand for large houses by older people. Consequently, as the population ages the vast majority of new houses will be high quality.

This result need not occur. If the supply of high quality houses is less elastic than the supply of low quality houses, there is an additional feedback effect. In this case the price feedback effects have a much larger effect on the demand for high quality houses than the demand for low quality houses, as the higher rate of price increase for high quality houses acts to curtail demand for this type of house. The effect is much greater on young households (who are credit constrained) than older households (who are wealthier); indeed, the supply elasticity for high quality houses only needs to be half as big as the supply elasticity for low quality houses for the decline in the demand for high quality houses by young people to almost completely offset the increase in the demand for high quality houses by older people. In these circumstances, population ageing

[9] In New Zealand, for instance, the population increased by 54 percent between 1962 and 2002, while real house prices increased by 80 percent, implying an elasticity of 1.2.

will mean most new houses in the economy will be low quality houses, and population ageing will cause a substantial change in ownership patterns. In particular, high quality houses will be increasingly inhabited by older people.

This scenario has an obvious interpretation. If the dominant feature of a high quality house is location, and the convenient access it provides to high quality facilities, it is quite likely that the supply elasticity for houses in nice suburbs is much lower than the supply elasticity for houses in far-away or less desirable suburbs. In this case the housing ladder will be characterised by a shift from worse to better suburbs rather than from smaller to larger houses. As the population ages, the high quality suburbs will get "grayer", while younger households will increasingly live in newer, less desirable suburbs as they cannot afford the better locations. In turn, this may generate a mismatch between the current location of public facilities such as schools and sport-fields and the location of the young households who will primarily use them, and an increase in the use of transport services.

These two scenarios are quite different. If the main feature that distinguishes high and low quality houses is the size of the house, the model predicts that while there will be a decline in the fraction of young households owning houses, including a decline in the fraction owning large houses, overall population ageing will lead to a large increase in high quality large houses. In contrast, if the main feature that distinguishes quality is location, the model predicts that population ageing will squeeze young households out of the more desirable housing markets, that most new houses will be built in less desirable locations. In both cases, however, the tendency of middle-aged households to live in better quality houses is unchanged.

It remains to discuss some of the weaknesses of the model. First, for technical reasons it has proved difficult to incorporate the effect of income growth into the model. Nonetheless, earlier work shows that the effect of successive cohorts earning larger and larger incomes is similar to the effect of a decline in real interest rates (Coleman 2007). This intensifies the effect of credit constraints on young households, and is likely to reduce their home-ownership rates. However, in this model a 1 percent decline in real interest rates has relatively little effect on the way population ageing affects the housing demand, and only a

modest effect on the mixture of large and small houses owned by young households, changing the ratio by 2 – 3 percentage points.

Secondly the model explicitly assumes households are forward looking and that they smooth consumption over their lifecycles. While to some extent this assumption is likely to be realistic, the amount of information that agents are assumed to have is unrealistically large. Nonetheless, it is not clear that this is a problem. In the model, the housing patterns chosen by households are determined by their budget constraints as well as their preferences. The model is very careful to capture the way that credit constraints limit the housing choices of young agents, and the way that pension programmes affect disposable income through taxation. Since most of the model's results are driven by the way households respond to taxes and house prices when they are credit constrained, it is likely that the results would change little if different assumptions about preferences and information sets were adopted.

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Table 1. Supply curve 1: both curves very elastic

Length of last period	10	12	15	17	20
Total population	1000	1040	1100	1140	1200
	Taxes raised to pay additional pension expenses				
Number small houses	405	415	422	434	443
Number big houses	565	593	643	668	717
Total number houses	970	1008	1064	1102	1160
% new houses large		74%	83%	78%	80%
Price small house	199,000	200,000	201,000	202,000	203,000
Price large house	317,000	318,000	321,000	323,000	325,000
% cohort 0 owning	56%	54%	52%	49%	48%
% cohorts 0-1 large	36%	34%	32%	30%	27%
% cohort 2 large	95%	95%	94%	93%	90%
% cohort 3 large	19%	32%	48%	53%	62%
% total large	58%	59%	60%	61%	62%
	Taxes increased to pay additional medical and pension expenses				
Number small houses	405	418	438	446	467
Number big houses	565	588	624	652	686
Total number houses	970	1006	1062	1098	1152
% new houses large		63%	64%	68%	66%
Price small house	199,000	200,000	201,000	202,000	203,000
Price large house	317,000	318,000	320,000	322,000	324,000
% cohort 0 owning	56%	54%	50%	47%	43%
% cohorts 0-1 large	36%	34%	29%	27%	25%
% cohort 2 large	95%	94%	93%	91%	88%
% cohort 3 large	19%	32%	46%	53%	59%
% total large	58%	58%	59%	59%	60%
	Taxes constant, no increase in total pension payment				
Number small houses	409	412	414	420	430
Number big houses	562	599	656	690	741
Total number houses	970	1011	1070	1110	1171
% new houses large		91%	95%	92%	89%
Price small house	200,000	200,000	202,000	202,000	204,000
Price large house	317,000	319,000	322,000	323,000	326,000
% cohort 0 owning	56%	55%	56%	57%	57%
% cohorts 0-1 large	36%	36%	37%	37%	37%
% cohort 2 large	95%	95%	94%	92%	89%
% cohort 3 large	18%	31%	45%	52%	60%
% total large	58%	59%	61%	62%	63%

In section 1, taxes are increased as the population ages to pay for higher aggregate pension expenditure. When the elderly population doubles, pension expenditure increases by approximately 5% of GDP

In section 2, taxes are increased as the population ages to pay for higher aggregate pension and medical expenditure. When the elderly population doubles, expenditure increases by approximately 8% of GDP.

In section 3, pension expenditure is maintained at initial levels and taxes are unchanged.

Table 2. Supply curve 2: both curves upward sloping

Length of last period	10	12	15	17	20
Total population	1000	1040	1100	1140	1200
	Taxes raised to pay additional pension expenses				
Number small houses	409	416	423	422	428
Number big houses	556	582	624	658	700
Total number houses	965	998	1047	1080	1128
% new houses large		77%	82%	88%	88%
Price small house	200,000	209,000	223,000	233,000	246,000
Price large house	311,000	321,000	336,000	347,000	362,000
% cohort 0 owning	52%	47%	40%	37%	31%
% cohorts 0-1 large	35%	32%	27%	25%	23%
% cohort 2 large	95%	94%	93%	92%	91%
% cohort 3 large	18%	33%	48%	56%	61%
% total large	58%	58%	60%	61%	62%
	Taxes increased to pay additional medical and pension expenses				
Number small houses	405	417	425	435	442
Number big houses	559	580	619	639	677
Total number houses	964	997	1044	1074	1119
% new houses large		65%	75%	73%	76%
Price small house	199,000	209,000	222,000	231,000	244,000
Price large house	311,000	321,000	336,000	345,000	359,000
% cohort 0 owning	52%	46%	38%	33%	29%
% cohorts 0-1 large	35%	31%	26%	23%	21%
% cohort 2 large	95%	94%	93%	91%	89%
% cohort 3 large	20%	34%	49%	53%	59%
% total large	58%	58%	59%	59%	60%
	Taxes constant, no increase in total pension payment				
Number small houses	409	413	404	402	410
Number big houses	556	588	648	685	730
Total number houses	965	1000	1052	1087	1140
% new houses large		89%	105%	105%	99%
Price small house	200,000	210,000	225,000	235,000	250,000
Price large house	311,000	322,000	339,000	350,000	366,000
% cohort 0 owning	52%	48%	43%	43%	42%
% cohorts 0-1 large	35%	33%	32%	31%	29%
% cohort 2 large	95%	95%	93%	93%	90%
% cohort 3 large	18%	32%	49%	57%	64%
% total large	58%	59%	62%	63%	64%

In section 1, taxes are increased as the population ages to pay for higher aggregate pension expenditure. When the elderly population doubles, pension expenditure increases by approximately 5% of GDP

In section 2, taxes are increased as the population ages to pay for higher aggregate pension and medical expenditure. When the elderly population doubles, expenditure increases by approximately 8% of GDP.

In section 3, pension expenditure is maintained at initial levels and taxes are unchanged.

Table 3. Supply curve 3: high quality supply curve steeply upward sloping

Length of last period	10	12	15	17	20
Total population	1000	1040	1100	1140	1200
	Taxes raised to pay additional pension expenses				
Number small houses	398	424	460	480	517
Number big houses	567	574	588	599	610
Total number houses	965	998	1047	1079	1127
% new houses large		22%	25%	29%	27%
Price small house	199,000	209,000	223,000	232,000	246,000
Price large house	309,000	323,000	345,000	361,000	381,000
% cohort 0 owning	52%	47%	39%	35%	30%
% cohorts 0-1 large	36%	31%	25%	23%	19%
% cohort 2 large	96%	94%	92%	87%	82%
% cohort 3 large	21%	32%	41%	47%	51%
% total large	59%	58%	56%	56%	54%
	Taxes increased to pay additional medical and pension expenses				
Number small houses	398	424	461	470	517
Number big houses	567	573	584	599	603
Total number houses	964	997	1044	1069	1120
% new houses large		20%	21%	31%	23%
Price small house	199,000	209,000	222,000	229,000	244,000
Price large house	309,000	322,000	342,000	358,000	374,000
% cohort 0 owning	52%	46%	38%	41%	25%
% cohorts 0-1 large	36%	30%	24%	22%	18%
% cohort 2 large	96%	94%	91%	86%	81%
% cohort 3 large	21%	33%	41%	50%	52%
% total large	59%	58%	56%	56%	54%
	Taxes constant, no increase in total pension payment				
Number small houses	398	424	461	487	524
Number big houses	567	576	592	601	616
Total number houses	965	1000	1052	1088	1140
% new houses large		26%	28%	27%	28%
Price small house	200,000	210,000	225,000	235,000	250,000
Price large house	310,000	325,000	349,000	364,000	388,000
% cohort 0 owning	52%	47%	45%	41%	40%
% cohorts 0-1 large	36%	32%	27%	26%	24%
% cohort 2 large	95%	94%	90%	87%	80%
% cohort 3 large	21%	30%	41%	45%	50%
% total large	59%	58%	56%	55%	54%

In section 1, taxes are increased as the population ages to pay for higher aggregate pension expenditure. When the elderly population doubles, pension expenditure increases by approximately 5% of GDP

In section 2, taxes are increased as the population ages to pay for higher aggregate pension and medical expenditure. When the elderly population doubles, expenditure increases by approximately 8% of GDP.

In section 3, pension expenditure is maintained at initial levels and taxes are unchanged.

Table 4. Variations in interest rates and inflation rates for supply curve 2

Length of last period	10	12	15	17	20
Total population	1000	1040	1100	1140	1200
	inflation = 0, real interest rates = 5				
Number small houses	389	397	408	416	430
Number big houses	573	598	637	662	695
Total number houses	962	995	1045	1077	1125
% new houses large		74%	77%	77%	75%
Price small house	199,000	208,000	222,000	232,000	246,000
Price large house	311,000	321,000	336,000	346,000	361,000
% cohort 0 owning	75%	72%	67%	64%	59%
% cohorts 0-1 large	43%	40%	36%	33%	28%
% cohort 2 large	94%	93%	92%	91%	94%
% cohort 3 large	12%	27%	43%	50%	52%
% total large	60%	60%	61%	61%	62%
	inflation = 0, real interest rates = 4				
Number small houses	411	427	447	457	488
Number big houses	564	583	614	639	658
Total number houses	975	1010	1061	1096	1145
% new houses large		55%	58%	62%	55%
Price small house	203,000	212,000	227,000	237,000	251,000
Price large house	314,000	325,000	340,000	351,000	366,000
% cohort 0 owning	51%	46%	35%	27%	22%
% cohorts 0-1 large	45%	42%	38%	35%	30%
% cohort 2 large	95%	95%	94%	93%	93%
% cohort 3 large	3%	15%	30%	38%	42%
% total large	58%	58%	58%	58%	57%
	inflation = 2, real interest rates = 4				
Number small houses	434	438	438	442	450
Number big houses	545	575	624	654	696
Total number houses	979	1013	1062	1096	1146
% new houses large		87%	95%	93%	90%
Price small house	204,000	213,000	227,000	237,000	251,000
Price large house	315,000	325,000	341,000	351,000	367,000
% cohort 0 owning	9%	6%	2%	0%	0%
% cohorts 0-1 large	37%	34%	31%	28%	26%
% cohort 2 large	96%	96%	95%	94%	93%
% cohort 3 large	6%	24%	41%	48%	55%
% total large	56%	57%	59%	60%	61%

In each section, taxes are increased as the population ages to pay for higher aggregate pension expenditure. When the elderly population doubles, pension expenditure increases by approximately 5% of GDP

Table 5. Additional variations in supply curves, inflation = 2.

Length of last period	10	12	15	17	20
Total population	1000	1040	1100	1140	1200
	Both house prices increased				
Number small houses	403	400	397	411	412
Number big houses	528	563	613	633	678
Total number houses	931	963	1010	1044	1090
% new houses large		109%	108%	93%	95%
Price small house	266,000	275,000	289,000	299,000	312,000
Price large house	377,000	387,000	402,000	412,000	427,000
% cohort 0 owning	22%	21%	20%	21%	19%
% cohorts 0-1 large	27%	25%	23%	21%	18%
% cohort 2 large	94%	93%	92%	91%	90%
% cohort 3 large	21%	38%	52%	54%	62%
% total large	57%	58%	61%	61%	62%
	High quality house prices increased				
Number small houses	550	592	631	644	655
Number big houses	416	407	419	437	474
Total number houses	966	999	1049	1081	1129
% new houses large		-25%	4%	19%	36%
Price small house	200,000	209,000	224,000	233,000	247,000
Price large house	355,000	364,000	379,000	389,000	404,000
% cohort 0 owning	45%	42%	38%	35%	27%
% cohorts 0-1 large	23%	21%	19%	17%	15%
% cohort 2 large	81%	79%	76%	74%	70%
% cohort 3 large	0%	3%	13%	22%	33%
% total large	43%	41%	40%	40%	42%
	High quality house prices increased and quality improved				
Number small houses	375	377	389	391	390
Number big houses	588	620	656	687	736
Total number houses	963	996	1045	1077	1125
% new houses large		96%	83%	86%	91%
Price small house	199,000	208,000	222,000	232,000	246,000
Price large house	359,000	370,000	385,000	395,000	410,000
% cohort 0 owning	63%	60%	55%	52%	44%
% cohorts 0-1 large	36%	33%	28%	26%	24%
% cohort 2 large	96%	95%	94%	93%	92%
% cohort 3 large	30%	45%	56%	62%	68%
% total large	61%	62%	63%	64%	65%

In each section, taxes are increased as the population ages to pay for higher aggregate pension expenditure. When the elderly population doubles, pension expenditure increases by approximately 5% of GDP

Table 6. Reverse mortgages and inheritances; supply curve 2, inflation = 2.

Length of last period	10	12	15	17	20
Total population	1000	1040	1100	1140	1200
	Supply curve 2: standard inheritance, no reverse mortgage				
Number small houses	409	416	423	422	428
Number big houses	556	582	624	658	700
Total number houses	965	998	1047	1080	1128
% new houses large		77%	82%	88%	88%
Price small house	200,000	209,000	223,000	233,000	246,000
Price large house	311,000	321,000	336,000	347,000	362,000
% cohort 0 owning	52%	47%	40%	37%	31%
% cohorts 0-1 large	35%	32%	27%	25%	23%
% cohort 2 large	95%	94%	93%	92%	91%
% cohort 3 large	18%	33%	48%	56%	61%
% total large	58%	58%	60%	61%	62%
	Supply curve 2: standard inheritance, reverse mortgage				
Number small houses	368	377	400	407	406
Number big houses	596	622	649	674	724
Total number houses	964	998	1049	1081	1130
% new houses large		75%	62%	67%	77%
Price small house	199,000	209,000	224,000	233,000	247,000
Price large house	312,000	322,000	338,000	348,000	363,000
% cohort 0 owning	54%	48%	44%	42%	40%
% cohorts 0-1 large	35%	32%	27%	25%	24%
% cohort 2 large	94%	93%	90%	88%	85%
% cohort 3 large	41%	52%	60%	65%	72%
% total large	62%	62%	62%	62%	64%
	Supply curve 2: different inheritance, no reverse mortgage				
Number small houses	386	382	395	405	414
Number big houses	577	614	650	673	713
Total number houses	963	995	1044	1077	1127
% new houses large		114%	90%	84%	83%
Price small house	200,000	209,000	223,000	232,000	247,000
Price large house	312,000	322,000	337,000	348,000	363,000
% cohort 0 owning	56%	53%	46%	42%	35%
% cohorts 0-1 large	35%	32%	27%	26%	24%
% cohort 2 large	97%	97%	95%	93%	90%
% cohort 3 large	25%	42%	54%	58%	65%
% total large	60%	62%	62%	62%	63%

In each section, taxes are increased as the population ages to pay for higher aggregate pension expenditure. When the elderly population doubles, pension expenditure increases by approximately 5% of GDP

Table 7. Key model parameters.

Parameter	Description	Value	Source/Rationale
Ti	Length of period	(10, 10, 20, 10-20) years	To approximate work history from age 25 – 75
N	Population of cohort	400	Arbitrary; initial population = 2000
Y_t^0	Average income of 25-35 cohort	50000	NZ Census 2001: average male and female earnings, 25-35 year olds, are $32800 and $23300 respectively
ω_j	Income distribution	Uniform on [20000,80000]	
g_i	Lifecycle income Pattern	{1, 1.5, 1.5, 0.1+25000}	NZ Census, 1966- 2001. Based on real lifecycle earnings of cohort turning 20 in 1946, 1961.
B	Discount factor	0.97 annualised	Arbitrary
$\{v^R, v^F, v^H\}$	Utility from housing	$\{0.33, 0.35, 0.45\}$	Arbitrary
κ_i	Inheritance timing	{0,0,1,0}	Arbitrary
H	Mortgage term	25 years	Standard mortgage term
Δ	Maximum debt service-income ratio	30%	Reflects NZ banking conditions
Θ	Maximum loan to value ratio	80%	Reflects NZ banking conditions
τ^{g*}	GST rate	0.10	Tax take equals 10% of labour income; arbitrary, but close to NZ rate.
τ_1, τ_2, τ^*	Income tax rates and threshold	20%, 33% $50000	Reflects NZ rates in 2000.
α_0^F, α_1^F α_0^H, α_1^H	Housing supply parameters	(10, 180000 15, 100000)	Supply version 1.
		(150, -80000 10, 100000)	Supply version 2
		(150, -80000 300, -225000)	Supply version 3