The long term effects of capital gains taxes in New Zealand

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Abstract

This paper develops a model of the housing market incorporating a construction sector, a rental sector, and a housing demand sector to examine the long term consequences for the housing market of different types of capital gains taxes. The sector is based on an overlapping generations model of the economy that included a detailed representation of the credit constraints and tax regulations affecting households. The model suggests that capital gains taxes will raise rents, increase homeownership rates, rebalance the housing stock towards smaller houses, and increase the net foreign asset position. The implications for welfare are much less clear, however, particularly for young low income households that will face higher rents.

JEL classification
E40, E58

Keywords
Inflation, credit constraints, capital income taxes, housing markets, home-ownership rates, monetary policy

Summary haiku

Money debases;
the Crown claims the widow's mite,
and poor people rent.

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1 Introduction

This paper develops a model that analyses the long term effects of capital gains taxes on New Zealand's residential property markets. The model is an extension of the model developed by Coleman (2008) that analysed how New Zealand's tax system might be distorting the housing market when the inflation rate is positive but relatively modest. That paper argued that even two to three percent inflation rates may significantly lower homeownership rates, partly because young households face binding credit constraints whose effects intensify as the inflation rate increases, but also because interest income but not capital gains are taxed. The paper further argued that most of the effects on the housing market stemming from the interaction of inflation with the tax system could be avoided by exempting the inflation component of interest income from tax, or by reducing the inflation rate to zero. However, a third option exists: introducing a tax on capital gains may reduce the distortionary effects of the current tax system. To assess this possibility, this paper investigates how various capital gains tax regimes affect housing markets when there is inflation.

The model is a version of the overlapping generations lifecycle model pioneered by Modigliani and Brumberg (1980), and adapted to analyse housing issues by Ortalo-Magné and Rady (1998, 2006). At the heart of the model is a dynamic, forward looking maximization problem in which agents make choices about the type of housing in which they live, how much they consume and save, and how much they borrow and lend. These agents, who differ by income, age, and wealth, have choices over whether to rent or buy, to live in large or small houses, or to share housing with other people. They face realistic bank imposed constraints on the amount they can borrow and the repayment schedule they face if they a purchase a house, and they face a tax system that closely reflects that prevailing in New Zealand. Particular attention is paid to the various ways that taxes on housing income differ according to whether one is an owner-occupier of housing or a landlord. House prices and rents are determined endogenously in the model, and reflect the interaction of decisions by households, landlords, and a construction sector to supply or demand housing. The model calculates dynamic steady-state paths for house prices and rents, and a set of equilibrium housing supply and demand patterns that depend on fundamental parameters such as interest rates, construction sector supply elasticities, the inflation rate, and the particulars of the tax system. The paper examines how these prices and demand patterns change as taxes and the inflation rate change, and uses these results to evaluate the consequences of different possible tax systems.

The paper examines the effects of four variants of a capital gains tax regime. While all four are accruals based, they differ according to whether owner-occupied housing is taxed or exempt, and whether capital gains are treated as income and taxed at households' marginal income tax rates, or whether capital gains are simply taxed at a flat rate. Many of the results of the four variants are similar, although there are important differences, particularly in the amount of revenue that is raised by the tax. In general, when the inflation rate is moderate, capital gains taxes lead to an increase in rents, an increase in the home-ownership rate, a small reduction in number of large houses in the economy, and an increase in the net foreign asset position. However, the effects on economic welfare are ambiguous, for many low-income households suffer a welfare loss from the increase in rents. The simulations suggests the welfare consequences will be worse for low income households if owner-occupied housing is exempt from the tax, although this result is dependent on the revenue from a capital gains tax being refunded to households (including low income households) through a reduction in the GST rate.

The primary purpose of the paper is to explore the possible economic consequences of different types of taxes, not to make a recommendation as to their desirability or practicality. Nonetheless, the paper notes that the welfare consequences of a capital gains tax applied to all households are similar to the welfare consequences of a flat rate property tax. Similarly, the welfare consequences of a capital gains tax that exempts owner-occupied housing are similar to the welfare consequences of a tax system that exempts the inflation component of interest income from income tax. Both of these alternative tax regimes may be easier to implement than a capital gains tax. Consequently, it may be possible to devise alternative tax regimes that have similar effects to a capital gains tax without some of their perceived adverse consequences.

The paper is organised as follows. Section 2 outlines the structure of the model. (The technical details of the model are contained in a lengthy appendix.) Section 3 discusses the results of the simulations, beginning with an exploration of the welfare consequences of the effects of inflation on the housing market, and concluding with a discussion of the welfare consequences of different capital gains tax systems. Conclusions are offered in section 4.

2 An intergenerational model of housing demand

2.1 The basic framework

The model is an extension of the model used by Coleman (2008) to analyse the effect of inflation, credit constraints and New Zealand's tax system on the housing market. In turn, it is based on the overlapping generations housing model of Ortalo-Magné and Rady (1998, 2006). The details of the model are described in the appendix, but the basic structure of the model has four key parts: the demand for rental and owner-occupied housing; the supply of rental housing; and the total supply of housing.

The demand for housing is based on an intertemporal utility maximisation model of consumer demand applied to a large number of agents who differ by age, income, and wealth. In the model, there are four cohorts each containing 400 agents, with each agent passing through four distinct stages (two young stages, one middle-aged stage, and one stage in retirement) before dying. The agents have different exogenously determined labour income, which follows a life-cycle pattern. The agents consume a single non-storable good, pay tax, save for retirement, and have choices over different types of housing at each stage of their lives – whether they share housing with other agents, rent a small house (an apartment), buy a small house or buy a large house. The agents choose their most preferred housing options, given their age, wealth and after-tax incomes, the cost of renting or buying different houses, and their ability to raise a mortgage. Agents can borrow or lend at exogenously determined interest rates, although young agents face bank imposed credit constraints limiting the amount they can borrow. In the last period of life agents consume all wealth except their house, which is inherited by a younger generation.

The model is dynamic and house prices and rents can change through time. Indeed, when choosing their housing options agents take into account both the rate at which house prices appreciate and the tax treatment on any capital gains that they make. Strictly speaking, in the model house prices and rents comprise two parts:

a price level at some base period (t = 0); and a price (or rent) appreciation rate. The model calculates the rate of property price appreciation as part of the process by which it calculates equilibrium prices; while it is normally the general inflation rate, it does not need to be.

Agents are assumed to be forward looking, so when they choose housing in a particular period they take into account not only their current income and current housing prices, but their remaining length of life, future house prices, their future income stream, and their desired future housing patterns. 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 when inflation and nominal interest rates are high, because they cannot obtain suitable financing.

The utility maximisation model generates housing demand for each of the agents during each of their life stages, for a given set of rent and house price paths. These different housing demand functions are then aggregated together. The resulting aggregate demand functions describe how the demand to rent, the demand for small houses, and the demand for large houses varies as a function of the rent and the price of each type of house, as well as all the basic parameters of the model such as income, interest rates, and tax rates.

Rental accommodation is supplied by agents who become landlords. It is assumed that entry into the rental sector is competitive, so landlords bid for houses and set rents at levels that leave them indifferent between the after-tax returns from lending money and the after-tax returns from investing in residential property. The marginal competitive landlord is assumed to be a middle aged agent who is on the top marginal income tax rate. Particular care has been taken to ensure that taxes in the model replicate the taxes currently imposed on housing in New Zealand. If house prices increase over time, a capital gains tax will lower returns to landlords, and, for a given level of house prices, rents will be higher than they would otherwise have been.

Prices are determined endogenously in the model by equating the total demand for different types of houses with the supply of different types of houses.

Cost functions describing the costs of building large and small houses are specified exogenously in the model, and can take any form. In this model, I focus on the case that there are separate upward sloping supply curves for the quantity of large and small houses, each with approximately unit elasticities. An elasticity of 1 is broadly consistent with the long run increase in prices and the quantity of houses in New Zealand between 1960 and 2005. Two different parameterisations that reflect house prices that are relatively high or relatively low in comparison to income because of high or low construction costs are examined. Several other combinations of supply elasticities have also been analysed, including the cases when the supply of both classes of houses are either perfectly elastic or perfectly inelastic, and the case that the supply of small houses is more elastic than the supply of large houses.

A solution to the model is obtained by finding a set of prices that equate the aggregate demand for different types of housing with the aggregate supply of these types of housing. The prices are solved using a complex numerical routine that calculates the housing demand for each of the 1600 different households for a set of prices, and then chooses a sequence of prices until a set is found at which aggregate demand equals aggregate supply. For this equilibrium set of prices, overall demand patterns are calculated.

As Coleman and Scobie (2009) argue, the effect of taxes, inflation, and interest rates on the housing market depend on a few crucial elasticities including (i) the elasticity of the total supply of houses to the price of houses (the elasticity of the supply of housing); (ii) the elasticity of the supply of rental housing with respect to rents; (iii) the elasticity of the demand for rental housing with respect to rents and the prices of houses; and (iv) the elasticity of the total demand for housing with respect to rents and the price of houses. The elasticity of the supply of housing with respect to prices is set equal to 1 in the main versions of the model discussed below, but the results have also been analysed when this elasticity is near zero or very large. The supply of rental housing is perfectly elastic with respect to rent, because landlords are assumed to be perfectly competitive and to supply rental housing until the long run after-tax return on rental accommodation is equal to the after-tax return on interest income. The demand elasticities are not directly imposed, but are implicitly derived from the consumer maximisation problem and depend on the basic parameters in the model. These elasticities can have a major effect on the model's results and warrant further discussion.

The elasticity of the demand for rental accommodation to housing rentals and the prices of houses is a measure of the extent to which households are prepared to substitute between renting and home-ownership. This will depend on the relative utility households get from sharing, renting, or owning a house. These parameters are explicitly specified in the model; typically, households are assumed to gain less utility from renting rather than owning, because they can shape an owned house in their own image, and less utility from living in shared accommodation than living by themselves. The substitutability between rental and owned accommodation will be greater the smaller the differences between renting and owning. The more willing households are to substitute between rented and owned housing, the less will be the utility loss from various housing market imperfections or policy interventions.

The elasticity of total housing demand, with respect to house prices or rents, measures the extent to which new households form when prices change as adult children leave home, or as young adults form households by themselves rather than sharing with a group of others. This elasticity is important as it is the only mechanism by which total housing demand can be altered. The more willing are households to share with others, the smaller are the price changes necessary to equilibrate the housing market.

This paper departs from the earlier work by Ortalo-Magne and Rady (2006) and Coleman (2008) by introducing a mechanism to substantially increase this elasticity. In these earlier papers, the only way households could share was for the youngest households to remain at home with their parents. In this paper, the youngest two cohorts can share by renting half a house. If they do so, they pay half the rent and obtain utility which, while less than the utility of a whole rented house, can either be greater than or less than half the utility of a rented house. This option proves to be attractive to many households, particularly to those with low incomes or steep life cycle earnings, resulting in a higher elasticity of total demand with respect to both rent and house prices than in these earlier papers. As a result, smaller price changes are needed to induce changes in total housing demand than in these earlier papers, and the welfare changes of policy interventions are smaller.

The model analyses the way households climb a "housing ladder" over the course of their lives. In large part their ascent can be characterised by two factors: the ultimate height they reach and the speed that they attain that height. The ultimate height is largely determined by the ratio of life-time income to the user-cost of housing: people with higher life-time incomes will be able to afford larger houses than people with low lifetime income. In the parameterisations studied a majority of people choose a large house in middle age, partly because the tax system favours home ownership as imputed rent is not taxed. The speed of ascent is determined by the steepness of the earnings profile, interest rates and the availability of credit from banks, and the tax incentives facing both households and property investors. In equilibrium, the mix of small and large houses in the economy is determined both by the length of time spent climbing the housing ladder and the peak rung a household attains. Policies that extend the length of time climbing the housing ladder do not, however, necessarily reduce the demand for large houses because an agent can use the money saved by living in a small house while young to live for longer in a large house while old.

2.2 Modelling capital gains taxes.

When the inflation rate is positive, income from interest paying assets is taxed more heavily than income from other forms of capital assets because the inflation component of nominal interest earnings is taxed, while capital gains are not. The asymmetry of this treatment means that the tax system generates an incentive for agents to borrow and invest in assets that appreciate over time, potentially inducing agents to invest too heavily in residential housing assets, and lowering home ownership rates among younger and lower income agents. One possible method to eliminate the asymmetrical tax treatment would be to exempt the inflation component of interest income from income tax, as it is not income. Another potential method would be to impose a capital gains tax on residential property and other assets.

Four different capital gains tax schemes are considered. The first scheme treats capital gains as income, and taxes these gains at a taxpayer's marginal income tax rate. Owner-occupied housing is exempt. As landlords are assumed to be higher income, middle aged agents, the applicable tax rate is the top marginal tax rate, 33 percent[1]. The second scheme also taxes capital gains at the standard marginal income tax rates of 20 or 33 percent, but in this case owner-occupied housing is taxed. The third scheme imposes a flat rate capital gains tax of 20 percent, with an exemption for owner-occupied housing. This tax scheme is similar to that which operates in the United States of America. The fourth scheme is similar, except all housing including owner-occupied housing is liable to a flat capital gains tax of 20 percent.

The model's results when the capital gains of owner-occupied housing are taxed are conceptually problematic. Almost no countries apply capital gains taxes to owner-occupied housing, for a variety of economic and political reasons. One reason is that these taxes are usually only imposed on realised gains when a house is sold, a rule that might deter households from moving from one location to another, perhaps in response to work opportunities. Another reason concerns the financial hardship such a tax could cause when a household dissolves, perhaps because of divorce. These negative effects, which may have first order welfare consequences, cannot be modelled in this paper and are ignored. To avoid these sorts of issues, it is assumed that if a capital gains tax is introduced without an exemption for owner-occupied housing, it is imposed on an accruals basis: that is, the household is liable for capital gains tax each year, whether or not it is realised through the sale of the house. These results are used to provide a reference case for the effect of a capital gains tax.

The rate of property price appreciation is an outcome of the model, and property prices appreciate in real terms over time when there is population or income growth, unless the supply of housing is perfectly elastic. In the results presented below, however, there is neither income growth nor population growth and so property prices increase at the inflation rate. In these circumstances a capital gains tax only taxes the increase in nominal housing wealth that is due to inflation and thus it reduces the distortion that arises from the asymmetrical taxation of interest income and other assets. Nonetheless, the tax system remains non-neutral with respect to the inflation rate because tax rates on real capital income are an increasing function of the inflation rate when the inflation component of interest income is taxed.

[1] The top marginal tax rate in New Zealand is currently 38 percent, although it was 33 before 2000. However, most landlords could choose to put a leased property in a trust which is only taxed at 33

The revenue raised by taxing capital income and/or capital gains depend on both the tax rates and the inflation rate. In the model, any additional revenue raised from changes in the tax system or changes in the inflation rate are refunded through a change in the Goods and Services Tax (GST) rate, so that the amount of tax raised is invariant to the tax system.

3 Results

3.1 The effect of inflation

3.1.1 Price and distributional effects of inflation

Inflation has three major effects on the housing market. First, it increases the rate at which property prices increase in nominal terms, generating nominal capital gains for the owners. Since nominal interest earnings rather than real interest earnings are taxed, there is an incentive for owners of capital to invest in residential housing when the inflation rate is high. This incentive applies to both landlords and owner-occupiers, so by itself inflation does not necessarily lead to a decline in the home-ownership rate, although it may lead to over investment in residential housing.

Secondly, inflation may lead to a reduction in nominal rents. This is because (i) after tax real returns from interest earning assets decline as the inflation rate increases, as the inflation component of interest income is taxed, and (ii) landlords get a portion of their return as capital appreciation, and are prepared to pay more for houses or to accept less rent in order to become landlords. The balance between lower rents and higher prices will depend on the supply elasticity of housing. When supply is relatively elastic, and new construction limits the amount property prices increase, rents will tend to fall.

Thirdly, inflation exacerbates the credit constraints facing agents who borrow to buy houses. This is because bank imposed restrictions on the amount households can borrow are rarely adjusted for inflation, even though nominal interest rates increase when the inflation rate rises. If banks do not increase the amount credit-constrained households can borrow when nominal debt servicing payments increase, it becomes more difficult for these households to purchase houses

percent. I have chosen to solve the model for a top marginal tax rate of 33 percent in part because this rate is often seen as a goal by political parties, and in part because of the way landlords can use trusts.

(Modigliani, 1976; Kearl, 1979). In addition, if rents fall, inflation makes it attractive for young, credit constrained agents to rent rather than purchase and home ownership rates are likely to decline.

Tables 1a and 1b show how inflation affects long term housing market outcomes in the model when there is no capital gains tax and there is an elastic supply of housing. In table 1a construction costs and house prices are approximately 25 percent higher than in table 1b. The tables show how prices and rents, the number of houses, the fraction of people owning, and the steady-state level of net financial assets vary with the inflation rate. In both cases, a 2 percent increase in the inflation rate leads to a 6 percent reduction in rents, a 0.8% reduction in the number of houses in the economy, a 3-4 percentage point increase in the fraction of the population renting, and a 2-3 percentage increase in the fraction of the housing stock that is owned by landlords and leased. More people rent at all ages. Irrespective of construction costs, there is a reduction in the number of small houses as the combination of falling rents and tighter credit constraints induces more young households to share, reducing aggregate demand for housing. The effect on the number of large houses in the economy differs in the two cases. When construction prices are high, rising inflation increases the total demand for large houses despite falling demand among younger cohorts: there is an increase in the demand by older households, because of the tax advantages of using a house as a saving vehicle. However, when construction costs are low, most people who want to live in a large house can afford to do so for most of their lives, and inflation has a very small effect on the quantity of large houses.

These results are subtly different than those reported in Coleman (2008). First, the effect of inflation on homeownership is smaller than reported there, because owning half a house is a more attractive option than renting a whole house. Secondly, in that model the total demand for housing increased rather than decreased as the inflation rate increased. The difference stems from the way the process of household formation is modelled. In Coleman (2008), the total number of households varies only because of changes in the number of adult children who lived with their parents. In that case, a decline in rent attracted children out of the parental home and increased the total demand for housing. In this model, the total number of households varies because of changes in the number of young adults who live by themselves rather than with others. In this case a decline in rents could either lead to an increase in the total demand for housing, as agents decide to stop sharing and rent by themselves, or a reduction in the total demand for housing, as agents decide to stop owning, and rent shared accommodation instead. In the parameterisations studied in this paper the latter effect dominates, so that total housing demand decreases as inflation increases, credit constraints intensify, and rents decline[2].

3.1.2 The welfare effects of inflation

In keeping with earlier work by Modigliani (1976), Kearl (1979), and Feldstein (1996, 1997), Coleman (2008) argued inflation reduced the welfare of many but not all households because of binding credit constraints on young agents. In the model, inflation has a large effect on young people because almost all agents would increase their utility if they could borrow more when young, either to smooth consumption in the face of rising life-cycle income, or to buy a house, or both. They do not borrow more because banks only make collateral backed loans. In this environment, inflation has ambiguous effects on welfare. Those agents who wish to purchase a house find inflation tightens credit constraints, because nominal interest rates increase and banks do not change their lending terms and conditions to make an allowance for the way inflation reduces the real value of the nominal outstanding debt. This makes it more difficult for the agents whose real incomes increase over time to smooth consumption, for they have to reduce their consumption to make higher nominal interest payments if they purchase a house. In contrast, those agents who rent benefit from inflation, because it lowers the rent they pay and enables them to spend more while young than they otherwise could.

Whether inflation causes welfare losses or improvements on average depends on the relative size of the populations that rent and own when young. In turn, this depends on the ratio of house prices to incomes. When construction costs are high, a large fraction of young people will wish to share accommodation with others rather than live in a house alone. In this case inflation increases their welfare, because it reduces the negative effects of borrowing constraints that prevent them from smoothing their consumption through time. When construction costs are

[2] Whether or not sharing is attractive will depend on the relative utility of sharing compared to renting a whole house. The model was solved for several different parameterisations in which the utility from

lower, or social norms make it normal for young adults to either live with family or live by themselves, inflation lowers welfare by making it harder for young agents to buy their first homes. In the parameterisations analysed in this paper, inflation is on balance welfare enhancing because there are more agents who benefit from lower rents than there are agents who suffer from higher interest payments at the start of the mortgage. In Coleman (2008), the latter effect dominated, so inflation lowered welfare for most people. This difference reflects two sets of parameter changes: the current model allows agents to share housing with each other, rather than just their parents; and it has a higher house price to income ratio, which reduces the attractiveness of home ownership at young ages even when the inflation rate is zero. In the real world, which of these two competing effects dominates is an empirical matter. The answer will depend in part on the social mores and conventions of society, particularly the acceptability of sharing housing with non-family members.

Inflation causes one additional welfare effect in the model: it changes the equilibrium number of houses and house prices, which changes the user costs of housing. If inflation leads to an increase in total housing demand, because lower rents entice adult children to leave home earlier, house prices will rise. This tends to lower the welfare of other agents, because the user cost of housing rises and these agents have less to spend on other goods[3]. This effect is an example of the negative pecuniary externality that occurs when agents disregard the effect of their actions on the prices paid by other members of the economy. In contrast, if total housing demand falls in response to inflation, house prices fall, and the welfare of other agents increases. In the parameterisations analysed in this paper, inflation lowers total housing demand, so there is a small positive pecuniary externality that improves the welfare of all agents because of lower house prices.

3.2 The effect of capital gains taxes with an exemption for owner-occupied housing.

Tables 2a and 2b show the long term effects of capital gains taxes when the inflation rate is two percent, owner-occupied housing is exempt, and there is an elastic housing supply. The parameterisations are consistent with tables 1a and 1b,

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sharing half a house was either less than or more than half the utility from renting a whole house. In all of the parameterisations analysed, an increase in inflation led to a decline in the total housing stock.

with construction costs and house prices approximately 25 percent higher in table 2a than in table 2b. The first columns show the equilibrium values of various aspects of the housing market under current tax regulations. The second and third columns shows how these values change when capital gains are treated as income and taxed at marginal income tax rates (20%, 33%) and when capital gains are taxes at a flat rate 20 percent rate. Note that most landlords are high income agents, so the former scheme is effectively a flat rate capital gains tax with a 33 percent tax rate. The fourth column shows how these values change when the inflation component of interest income is exempt from income tax. In each case, there is neither income nor population growth and property prices appreciate at the inflation rate. Consequently, when the inflation rate is zero a capital gains tax has no effect.

3.2.1 Taxing capital gains on leased property at marginal income tax rates

The main effect of the (20%, 33%) capital gains tax is to increase rents by approximately $1300 or 11 percent (table 2a)[4]. There is also a small increase in house prices, by 0.6 – 0.8 percent. The latter occurs because the demand for property increases: the increase in rents makes renting less attractive and there are a number of agents who cease living in shared rental accommodation and purchase and live in a house by themselves.

The decline in renting is most noticeable among older households. Among younger (cohort 0 and 1) households, renting only declines modestly, for credit constraints are sufficiently tight on most low income agents that renting is still more attractive than home ownership, particularly as most of these agents share rental housing and thus only experience half of the rent increase. In both tables 2a and 2b, 2.5 – 3.5 percent of cohort 0 and cohort 1 cease renting. In contrast, middle-aged and retired households almost completely cease renting, because the capital gains tax raises the long run cost of renting above the cost of owning as only landlords pay the

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[3] Annual consumption falls by approximately the real interest rate multiplied by the additional housing cost. Higher house prices also lower the net foreign asset position.

[4] Small house prices are $225000, so the capital gain is $4500 when the inflation rate is 2 percent; if the landlord has to pay 33 percent of this sum in tax, the rent has to be raised to make the same after tax return as investing in interest earning assets. The $1300 increase in rent is not exactly equal to 0.33* $4500 for two reasons. First, in the model the timing convention is that the landlord is paid rent and pays income tax at the start of the period, but pays capital gains tax at the end of the period. The after-income-tax value of the $1300 rent increase is invested for the length of the period (in this case 12.5 years); in this case the extra interest is approximately the same value as the income tax paid. Secondly,

capital gains tax. The total effect of the capital gains tax on the rental market depends on the number of people initially renting, which depends on construction costs and house prices. When construction costs are high, a large number of agents rent under the current tax rules and a capital gains tax reduces the fraction of agents renting by over six percentage points; when they are low, fewer middle aged and older agents rent, and the capital gains tax only reduces the fraction renting by three percent.

There are two other economic effects. First, the simulations indicate the capital gains tax raises little revenue, for the GST rate only declines by 0.1 percentage points. This is partly because the capital gains tax reduces the number of rental houses, and thus leads to a reduction in the income tax paid by landlords on their rental income. Secondly, the simulations suggest that there is a small increase in the net financial asset position of the economy. The amount is larger when construction costs are high rather than low, and reflects the increase in saving that occurs as some households switch from being life-time renters to middle-aged home-owners due to the increase in rents.

3.2.2 Taxing capital gains on leased property at a constant 20% rate

The results are qualitatively similar if the capital gains tax is applied at a flat 20 percent rate, except the effects are quantitatively smaller as the average tax rate is 20 percent rather than 33 percent. The increase in rents is only 60 percent as large, and there is a correspondingly smaller decrease in the fraction of agents that rent and the fraction of houses that are leased. Interestingly, more revenue is raised under the lower flat rate capital gains tax when construction costs are high, as there is a much smaller decline in renting. Nonetheless, the amount of tax raised under either capital gains tax regime is small and the reduction in GST is less than 0.2 percent in either case.

3.2.3 Taxing capital gains on leased property: results for other supply functions

When the supply of small house is elastic but the supply of large houses is inelastic, the results are similar to the case when both the supply curves are elastic. Once again, the primary effect of the capital gains tax is to increase rents, reduce the

property prices increase by approximately 1 percent once the CGT is introduced, leading to a 1% or $100 increase in rents.

fraction of the population that is renting and the fraction of the housing stock that is leased, and increase the total housing stock.

When both supply curves are inelastic, the results are a little different. In table 2c, the number of flats and houses is constant and, because there is an overall shortage, prices are high. As before, a capital gains tax raises rents and reduces the number of people renting, particularly amongst those who are middle aged or retired. However, house prices increase quite sharply, by four or five percent. The house price increase is needed to reduce the total demand for housing, because an increase in rents without an increase in house prices leads to a reduction in the number of agents sharing rental accommodation and an increase in the total demand for housing. The only way to reduce the total demand for housing is to raise house prices, and make it attractive to share. When the supply of housing is elastic, the price rise is not necessary, as new houses are built to meet the additional demand. If a rise in rents lead to a reduction in total demand, because some young agents responded to the increase in rents by moving back to their parents' home, a capital gains tax could lead to a fall in house prices as well as an increase in rents. Consequently, the way prices would behave in New Zealand if a capital gains tax were introduced will depend on the size of the elasticity of total demand for housing to rent.

3.3 Exempting the inflation component of interest from income tax

Coleman (2008) argued that the tax system would have less effect on the housing market if the inflation component of interest income were exempt from income tax. He argued that by exempting the inflation component of interest income from tax, and by only allowing the deduction of real rather than nominal interest payments, landlords would have less incentive to enter the property market when the inflation rate was positive, raising rents and home ownership rates.

The fourth columns of tables 2a – 2c show what happens if neither capital gains nor the inflation component of interest income were taxed. In all of the housing supply versions considered, the effects on rents, prices, and home ownership rates are similar to what happens if a flat 20 percent capital gains tax regime with an exemption for owner-occupiers were introduced. There are two differences, however. Because tax revenue declines slightly when the inflation component of interest income is exempted from income tax, the GST rate has to be increased slightly, rather than cut. The increase is always less than 0.2 percentage points, however, partly because the loss of tax on interest income is offset by a reduction in the deductions allowable against rental income. Secondly, there is a larger increase in the net financial asset position than in either of the capital gains tax regimes considered. This is because exempting the inflation component of interest income from tax raises after tax real interest rates, encouraging saving and capital accumulation among working age agents[5]. Since a capital gains tax does not affect after tax interest rates, after tax returns are higher when the inflation component of interest is tax exempt than when a capital gains tax is introduced.

3.4 The effect of an accrual capital gains regime applied to all agents

Table 3 shows what happens to the housing market if capital gains taxes are applied to all households on an accruals basis, either as a flat rate (20%) or at marginal income tax rates (20%, 33%).The results are for the case that the housing supply is elastic and construction costs are high, but the results for other housing supply parameters are qualitatively similar.

The capital gains tax leads to an increase in rents. When the capital gains tax rate is a flat 20 percent, there is little effect on the quantity of housing rented, however, because owner-occupiers are also liable for capital gains tax, so the cost of owning a house rises by a similar amount. There is a significant switch from large houses to small houses, however, as the capital gains tax raises the user cost of large houses by more than the user cost of small houses. This reduces the demand for large houses at all ages. The substitution between large and small houses also occurs because of a sizeable drop in the GST rate that makes the consumption of goods relatively more attractive than the consumption of housing. The capital gains tax revenue is much larger than when owner-occupied housing is exempt, and the GST rate declines by over two percentage points rather than 0.2 percentage points.

When capital gains are taxed as income at marginal income tax rates, there is a substantial decline in the number of middle-aged and retired households renting.

[5] While the model has a steady state saving rate of zero, as people run down the assets they accumulate while working when they are retired, the economy's net asset position increases when the saving rate among working age people increases.

This is because rents increase by more than the amount of capital gains tax that would be paid by low income renters, so it is cheaper in the long term for low income households to purchase rather than rent. Indeed, the reduction in the number of households renting is similar to when owner-occupied housing is exempt from capital gains tax.

In this model, the effects of a capital gains tax applied to all households are very similar to the effects of a flat rate property tax. This is because property prices increase at the inflation rate, so a flat rate capital gains end up taxing houses at a rate that is proportional to value. Coleman and Grimes (2009) discuss the effects of introducing a property tax at greater length.

3.5 The welfare implications of capital gains taxes

The above analysis suggests that capital gains taxes raise rents, increase home-ownership rates, cause a substitution towards smaller houses, and improve the net foreign asset position because they reduce the distortions caused by the interaction of inflation with the tax system. Whether capital gains taxes raise welfare, however, will depend on two things: the extent to which inflation reduces welfare, because of its negative effects on credit-constrained owner-occupiers; and/or the extent to which inflation enhances welfare because of its positive effects on credit-constrained renters. In the parameterisations of the model studied in this paper, the welfare losses to the renters exceed the benefits to the owners, for there are more young renters than young owners. In this case, a capital gains tax will tend to have negative welfare effects as it raises rents, although this need not be the case.

Figure 1 shows how different tax schemes affect lifetime welfare for people with different income levels when the supply of housing is elastic and construction costs are low. The figure shows the average change in utility for each income decile[6]. Three points stand out. First, a capital gains tax scheme that exempts owner-occupied housing has lower welfare for most people than one which does not.

[6] The effects on the welfare of the lowest decile are not shown as they largely reflect the inheritance arrangements in the economy. In these simulations odd numbered agents receive no inheritance, but even number agents inherit the houses of the two retired agents with the same rank in the income distribution. When there are no capital gains taxes, most decile one agents rent throughout their lives and neither leave an inheritance nor receive one. When a capital gains tax is introduced, many of these agents buy a house, and bequeath it in old age. The logic of the model means that even-numbered

Secondly, a capital gains tax scheme that exempts owner-occupied housing reduces welfare for most low income people, because of the increase in rents. Thirdly, a capital gains tax scheme that exempts owner-occupied housing has similar welfare properties as a tax scheme that exempts the inflation component of interest income from tax. These three results occurred in most of the parameterisations studied, even though the exact nature of the welfare changes depends on a number of factors such as the housing supply elasticities and the way people inherit property.

Several features of these results are of interest. First, a capital gains tax scheme without an exemption for owner-occupied housing has very similar properties to the flat rate property tax scheme analysed by Coleman and Grimes (2009). As discussed above, this is not surprising, for in the model taxing capital gains on an accrual basis when the inflation rate is constant is like having a flat rate property tax. Since the welfare effects are similar, and since the effects on rents, prices, and home-ownership rates are similar, a flat rate property tax could be a substitute for a capital gains tax if it were believed the inflation rate would continue to be low and stable. Given the political difficulties of introducing a capital gains tax on owner-occupied residential housing in other countries, a flat rate property tax may be an attractive option.

Secondly, the welfare properties of capital gains regimes that do or do not exempt owner-occupied housing are significantly different, even though they have a similar effect on rents. The differences are caused by two factors. First, when owner-occupied housing is taxed, much more tax is collected. The consequent cut in the GST rate partially compensates renters for the rise in rents, and leads directly to an improvement in their welfare. In addition, there is a reduction in the total demand for property, so house prices fall relative to the case that only landlords pay the tax. This leads to a reduction in the direct user cost of housing to all agents. This provides a gain to all agents in the economy except the first generation, who suffer a capital loss.

Thirdly, a tax regime that exempts the inflation component of interest income from tax has similar welfare properties as a tax regime that taxes capital gains

agents also inherit one or more houses, and are much better off. Although this effect dominates the welfare calculations for the lowest income decile, This result is not emphasised in this paper.

tax on leased residential property. Again, it may be politically easier to introduce such a tax regime than a capital gains tax.

Figure 2 shows the welfare effects of different tax regimes when the supply of housing is elastic but construction costs are high. The results are similar, although there is a downwards spike in the 6th decile that reflects the effect of inheritance arrangements. (In this case it reflects the change that occurs when people start inheriting large houses rather than smaller houses.) Once again, the welfare consequences of a capital gains tax that includes owner-occupiers are better than a tax that does not; the welfare consequences of capital gains tax regimes that exclude owner-occupiers are negative for low-income agents because the taxes increase rents; and the welfare consequences of capital gains taxes that exempt owner-occupiers are similar to the welfare consequences of tax regimes that exempt the interest component of interest income from tax. The welfare losses for low income agents are higher when construction costs are high, partly because more people rent but also because rents are higher and thus increases in rents cause more severe cuts in consumption.

4 Discussion and conclusions

This paper has explored some of the consequences of introducing a capital gains tax on residential property in New Zealand. It has done this in the context of a stylised model that attempts to understand the factors that determine housing market outcomes in the long term. The model focuses on three main factors: the cost of supplying new housing; the financial incentives facing landlords; and the tax and financial incentives facing households as they choose different housing options over the course of their lives.

The model suggests that a capital gains tax will have the following effects: it will lead to an increase in rents; it will lead to a reduction in the number of people renting, and an increase in homeownership rates; it will lead to an increase in the net foreign asset position; and it will lead to a decline in the fraction of large houses in the economy. It is possible that homeownership rates could rise by several percent if a capital gains tax were introduced, with a similar sized increase in the net foreign asset position.

Two other results seem general. First, a capital gains tax that exempted owner-occupied housing would raise little revenue, whereas one that applied to all households would raise enough to allow a sizeable reduction in the GST rate. For this reason, low income households that rent are better off when a capital gains tax does not have exemptions. Secondly, the increase in rents and the increase in home-ownership rates will be larger if the capital gains tax rates on owner-occupied residential property are lower than those on leased residential property, either because the former is specifically exempted from capital gains tax or because landlords typically have higher marginal tax rates than households who typically rent.

Beyond these general outcomes, the paper demonstrates that the welfare implications of a capital gains tax depend a lot on the detailed structure of the economy. It matters whether the supply of housing is elastic or inelastic. It matters whether construction costs are high or low. It matters whether people prefer to own rather than rent. It matters whether young people respond to rent increases by sharing with more people, or by deciding to buy a house themselves. Indeed, some of these factors matter so much that they determine whether a capital gains tax is largely beneficial or harmful.

It is both a weakness and a strength of the modelling approach that it cannot be more definitive about the welfare effects of a capital gains tax. From a technical perspective, the weakness is clear: a model that delivers different answers when the housing choice set is structured differently makes it difficult to know whether the model's outcomes are robust or contrived. The strength is more subtle: the modelling approach suggests that the welfare effect of different policies depend a lot on several deep parameters in the models, suggesting empirical research on the nature of these parameters is important before policies are introduced.

This paper has ignored many of the practical and political issues that would have to be solved if capital gains taxes were to be introduced. While the simulations of the model suggest a capital gains tax that includes owner-occupied housing has better welfare properties than a capital gains tax that does not, the political and practical difficulties of introducing an accruals based capital gains tax should not be underestimated. Applying a capital gains tax only to realised gains has its own problems, notably the incentives it generates to remain in unsuitable houses or living arrangements in order to avoid the tax. Yet the simulations also suggest that a flat rate property tax has many of the same properties as an accrual based capital gains tax with no exemptions, and if a capital gains tax is desired but not considered practical this may be a suitable alternative. The similarity between these two taxes will be greater if nominal property price appreciation is dominated by inflation rather than real factors, and if the inflation rate is relatively stable.

Most OECD countries that have capital gains taxes exempt owner-occupied housing from the tax and only tax leased residential property when a sale is realised. This is a much more straightforward tax to implement than an accruals based tax, but still removes some of the housing market distortions that arise from taxing differently that inflation component of interest earnings and the inflation component of capital gains. Nonetheless, the simulations suggest the effects of this type of capital gains tax could be largely replicated by exempting the inflation component of interest income from tax, a strategy that may be easier to implement in practice. Such a strategy would have the added advantage that real after-tax interest rates and returns to capital are unaffected by the inflation rate.

The key issue underlying the whole paper is whether the effects of moderate inflation on the housing market largely lowers or improves welfare. In line with earlier work, this paper identifies two ways that inflation affects welfare. First, inflation makes it more difficult for people to purchase a house, or upgrade to a bigger house, because nominal interest rates increase and banks do not change their lending criteria to recognise the way inflation erodes the real value of the existing debt. This is the familiar issue of mortgage tilt, which lowers welfare (Modigliani, 1976.) Secondly, inflation leads to lower rents if interest earning assets are taxed more heavily than capital gains. This improves the welfare of those who are credit constrained and rent. Whether the effect of inflation on the housing market improves or lowers welfare therefore depends on the fractions of the population who find it eases rather tightens the credit constraints they face. In this paper, I have focussed on parameterisations in which inflation raises welfare for many agents, while in earlier work I focused on the case that inflation lowered welfare. In practice, this is an empirical question, the answer of which will depend on the cost of housing and the way agents value renting and home-ownership. If, under the current tax system, inflation lowers rents and raises the welfare of many people, policies that counteract the effects of inflation on the housing market will tend to lower welfare.

Conversely, if inflation mainly causes hardship among those who wish to borrow to purchase a house, a capital gains tax will raise welfare.

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6 Tables

Table 1a: The effect of inflation on housing outcomes

Elastic supply, high construction costs				
	Π=0	Π=1	Π=2	Π=3
Rent	11900	11650	11250	10850
$P^F(0)$ (small)	225200	224500	223600	222700
$P^H(0)$ (large)	382900	382400	382000	381400
N^{TOT} (all) /popn	93.9%	93.6%	93.1%	92.8%
N^F (small) /popn	53.0%	52.4%	51.4%	50.6%
N^H (large) /popn	40.9%	41.1%	41.8%	42.1%
% houses rented	10.7%	12.2%	13.6%	15.1%
% agents renting	16.1%	17.9%	19.5%	21.2%
% cohort 0 renting	38%	41%	43%	44%
% cohort 1 renting	11%	13%	16%	17%
% others renting	8%	9%	10%	12%
% cohort 1 large	60%	58.5%	57.5%	56%
GST rate	12.3%	12.1%	12.0%	12.0%
Net financial assets/GDP	28%	29%	31%	33%

The table shows how rents, house prices, house numbers (number of houses divided by the population) and the fraction of the population that rents vary with the inflation rate. Net financial assets/GDP is total lending minus total borrowing divided by labour income.

Table 1b: The effect of inflation on housing outcomes

Elastic supply, low construction costs				
Rent	9650	9350	9050	8700
$P^F(0)$ (small)	182400	181300	180500	179500
$P^H(0)$ (large)	325600	324400	323800	322300
N^{TOT} (all)	96.8%	96.4%	96.1%	95.6%
N^F (small)	42.8%	42.5%	42.0%	42.1%
N^H (large)	54.1%	53.9%	54.1%	53.5%
% houses rented	3.6%	5.3%	6.7%	7.9%
% agents renting	6.6%	8.7%	10.4%	11.9%
% cohort 0 renting	25%	26%	28%	30%
% cohort 1 renting	1%	4%	6%	8%
% others renting	1%	2%	3%	5%
%cohort 1 large	71.5%	71%	71%	70%
GST rate	12.0%	11.8%	11.5%	11.5%
Net financial assets/GDP	48%	48%	50%	53%

The table shows how rents, house prices, house numbers (number of houses divided by the population) and the fraction of the population that rents vary with the inflation rate. Net financial assets/GDP is total lending minus total borrowing divided by labour income.

Table 2a: The effects of capital gains taxes on residential property; owner-occupied housing exempt, inflation rate = 2 percent.

Elastic supply, high construction costs				
		Change from introducing ……		
	No CGT	Flat rate CGT, 20%	CGT at marginal rates 20%, 33%	Inflation part of interest tax exempt
Rent	11250	+$750	+$1300	+$800
$P^F(0)$ (small)	223600	+$1000	+$1800	+$900
$P^H(0)$ (large)	382000	+$900	+$1800	+$700
N^{TOT} (all) /popn	93.1%	0.4%	0.8%	0.4%
N^F (small) /popn	51.4%	0.6%	0.9%	0.7%
N^H (large) /popn	41.8%	-0.2%	-0.1%	-0.3%
% houses rented	13.6%	-3.8%	-6.2%	-3.5%
% agents renting	19.5%	-3.9%	-6.5%	-3.6%
% cohort 0 renting	42.5%	-2.0%	-3.5%	-2.3%
% cohort 1 renting	15.5%	-1.0%	-2.5%	-1.8%
% others renting	10.0%	-6.3%	-10.0%	-5.3%
GST rate	12.0%	-0.2%	-0.1%	0.1%
Net financial assets /GDP	30.6%	2.2%	4.1%	7.0%

The table shows how rents, house prices, house numbers (number of houses divided by the population) and the fraction of the population that rents would change if a capital gains tax exempting owner-occupiers were introduced. The inflation rate is assumed to be 2 percent. Net financial assets/GDP is total lending minus total borrowing divided by labour income.

Table 2b: The effects of capital gains taxes on residential property; owner-occupied housing exempt, inflation rate = 2 percent.

Elastic supply, low construction costs				
		Change from introducing ……		
	No CGT	Flat rate CGT, 20%	CGT at marginal rates 20%, 33%	Inflation part of interest tax exempt
Rent	9050	+$600	+$1050	+$650
$P^F(0)$ (small)	180500	+$1100	+$1500	+$1200
$P^H(0)$ (large)	323800	+$1100	+$1600	+$1300
N^{TOT} (all) /popn	96.1%	0.4%	0.6%	0.5%
N^F (small) /popn	42.0%	0.4%	0.5%	0.4%
N^H (large) /popn	54.1%	0.1%	0.1%	0.1%
% houses rented	6.7%	-2.3%	-2.6%	-2.6%
% agents renting	10.4%	-2.7%	-3.1%	-2.9%
% cohort 0 renting	28.3%	-1.8%	-3.0%	-2.3%
% cohort 1 renting	6.3%	-2.0%	-2.5%	-2.5%
% others renting	3.5%	-3.5%	-3.5%	-3.5%
GST rate	11.5%	0.0%	0.0%	0.3%
Net financial assets /GDP	50.0%	1.2%	1.3%	7.1%

The table shows how rents, house prices, house numbers (number of houses divided by the population) and the fraction of the population that rents would change if a capital gains tax exempting owner-occupiers were introduced. The inflation rate is assumed to be 2 percent. Net financial assets/GDP is total lending minus total borrowing divided by labour income.

Table 2c: The effects of capital gains taxes on residential property; owner-occupied housing exempt, inflation rate = 2 percent.

Inelastic supply, high prices				
		Change from introducing ……		
	No CGT	Flat rate CGT, 20%	CGT at marginal rates 20%, 33%	Inflation part of interest tax exempt
Rent	11350	+$1100	+$1850	+$1100
$P^F(0)$ (small)	225900	+$7000	+$11000	+$6300
$P^H(0)$ (large)	378300	+$5000	+$16300	+$6200
N^{TOT} (all) /popn	93.2%	0.0%	0.0%	0.0%
N^F (small) /popn	50.1%	0.0%	0.0%	0.0%
N^H (large) /popn	43.1%	0.0%	0.0%	0.0%
% houses rented	13.3%	-2.6%	-5.1%	-2.4%
% agents renting	19.2%	-2.4%	-4.7%	-2.3%
% cohort 0 renting	42.0%	-0.5%	0.3%	-0.3%
% cohort 1 renting	15.3%	0.8%	0.5%	-0.3%
% others renting	9.8%	-5.0%	-9.8%	-4.3%
GST rate	11.9%	-0.2%	-0.2%	0.1%
Net financial assets /GDP	32.0%	2.1%	3.4%	7.5%

The table shows how rents, house prices, house numbers (number of houses divided by the population) and the fraction of the population that rents would change if a capital gains tax exempting owner-occupiers were introduced. The inflation rate is assumed to be 2 percent. Net financial assets/GDP is total lending minus total borrowing divided by labour income.

Table 3: The effects of capital gains taxes on all households; $\pi = 2$.

Elastic supply, high prices					
		Change from introducing taxes on ……			
		All households		landlords only	
	No CGT	Flat rate CGT, 20%	CGT at (20%, 33%)	Flat rate CGT, 20%	CGT at (20%, 33%)
Rent	11250	+$700	+$1200	+$750	+$1300
$P^F(0)$ (small)	223600	-$100	+$400	+$1000	+$1800
$P^H(0)$ (large)	382000	-$2100	-$1500	+$900	+$1800
N^{TOT} (all) /popn	93.1%	0.0%	0.2%	0.4%	0.8%
N^F (small) /popn	51.4%	2.5%	2.6%	0.6%	0.9%
N^H (large) /popn	41.8%	-2.5%	-2.4%	-0.2%	-0.1%
% houses rented	13.6%	-0.4%	-5.4%	-3.8%	-6.2%
% agents renting	19.5%	-0.3%	-5.1%	-3.9%	-6.5%
% cohort 0 renting	42.5%	0.8%	-0.8%	-2.0%	-3.5%
% cohort 1 renting	15.5%	-1.0%	-0.8%	-1.0%	-2.5%
% others renting	10.0%	-0.5%	-9.5%	-6.3%	-10.0%
GST rate	12.0%	-2.2%	-2.5%	-0.2%	-0.1%
Net financial assets /GDP	30.6%	0.8%	6.5%	2.2%	4.1%

The table shows how rents, house prices, house numbers (number of houses divided by the population) and the fraction of the population that rents would change if a capital gains tax on all houses were introduced. The inflation rate is assumed to be 2 percent. Net financial assets/GDP is total lending minus total borrowing divided by labour income.

Table 4. Parameterisation of the model.

Parameter	Description	Value	Source/Rationale
T	Length of period	12.5 years	To approximate work history from age 25 – 75
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 [25000,85000]	
g_i	Lifecycle income pattern	{1, 1.5, 1.5, 0.15+20000}	NZ Census, 1966- 2001. Based on real lifecycle earnings of cohort turning 20 in 1946, 1961.
B	Discount factor	0.97 annualised	Arbitrary
$\begin{Bmatrix} v^{½R}, v^R, \\ v^F, v^H \end{Bmatrix}$	Utility from housing	$\begin{Bmatrix} 0.18, 0.32, \\ 0.35, 0.45 \end{Bmatrix}$	Arbitrary
κ_i	Inheritance timing	{0,0,1,0}	Arbitrary
γ	Annual house maintenance	0.01	Arbitrary
H	Mortgage term	25 years	Standard mortgage term in 1990s
δ	Maximum debt service-income ratio	30%	Reflects NZ banking conditions
Θ	Maximum loan to value ratio	90%	Reflects NZ banking conditions
τ^{g*}	Target GST rate	0.14	Tax take equals 14% 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.

Housing Supply parameters

α_0^F, α_1^F α_0^H, α_1^H	Elastic High price	0, 150 125000, 50	Arbitrary, generates approximately 1% price elasticity for flats.
	Elastic Low Price	-50000, 150 100000, 50	
	Inelastic High Price	-149m, 100000 -68m, 100000	Generates N^F = 689 N^H = 802
	Inelastic Low Price	-153m, 100000 -83m, 100000	Generates N^F = 665 N^H = 873
	Flats elastic Houses inelastic	0, 150 -80m, 100000	N^H = 800
	Perfectly elastic	P^F = 225000 P^H = 370000	

7 Figures

Figure 1

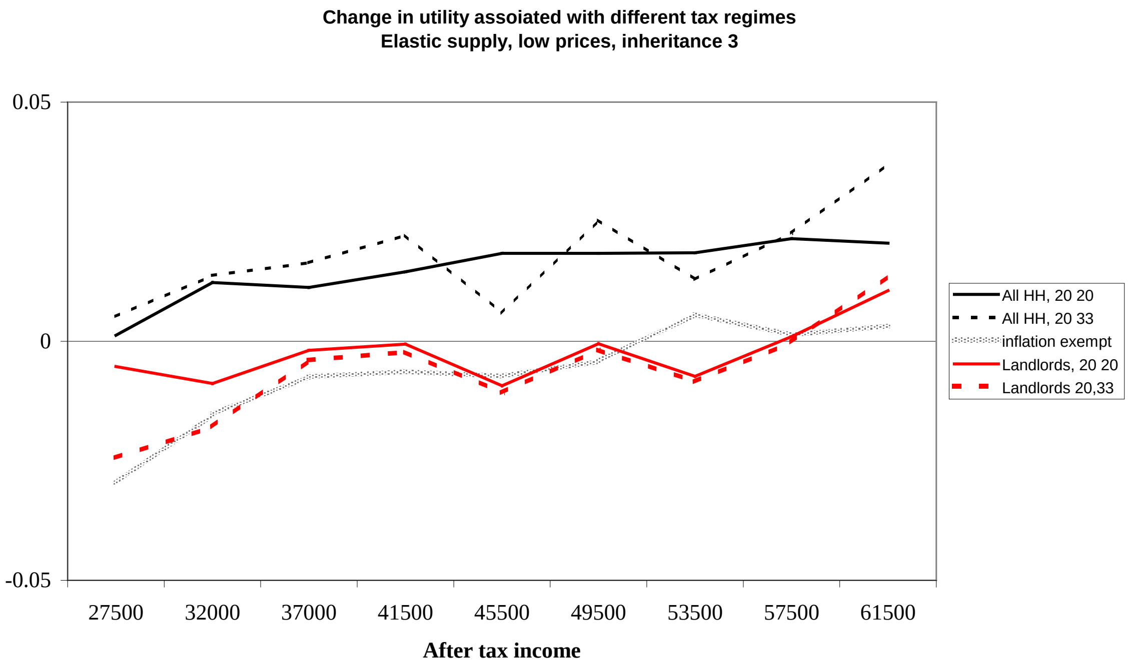
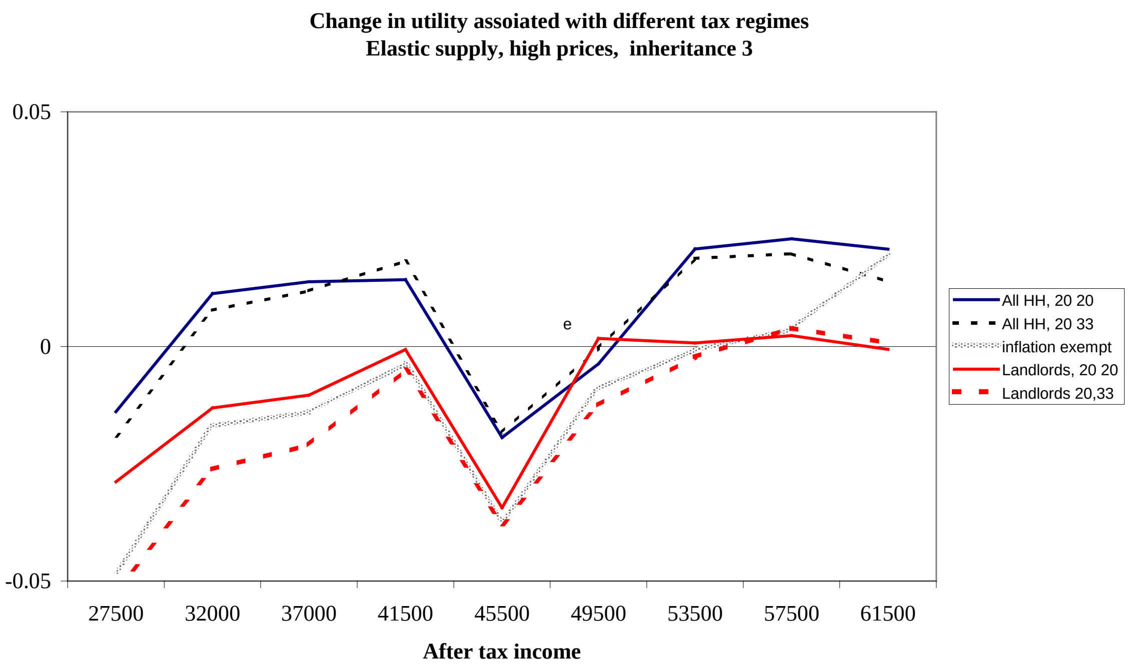


Figure 2



8 Appendix 1

This appendix provides a formal description of the model. The same model is used by Coleman and Grimes (2009). The building blocks of the model are equations describing the supply and demand for two different types of houses, small houses (denoted F for flats) and large houses (denoted H). The demand for these houses are derived from the preferences of four separate cohorts of agents. Each cohort comprises a number of different agents. The N agents in each cohort live for four periods T = 12.5 years long labelled $i = \{0,1,2,3\}$.

A1.1 Agents, housing options, and inheritances

In period t, agent *j* born in period *t-i* has real pre-tax labour income

$$Y_t^{i,j} = \omega_j g_i Y_{t-i}^0 \qquad (1)$$

where ω_j = idiosyncratic factor affecting agent j relative to average cohort earnings;

g_i = factor reflecting the life-cycle earnings of the cohort in its i^{th} period; and

Y_{t-i}^0 = average income of cohort at time of birth.

While any pattern of income is possible, agents are assumed to have a constant place in the within-cohort income distribution as they age. Agent 1 has the lowest income. Nominal income is $P_t Y_t^{i,j}$, where P_t is the pre-tax price of the good. Agents pay taxes on their nominal incomes[7]. There are two marginal tax rates: τ_1 for agents with real income in period t less than τ^*; and $\tau_2 \geq \tau_1$ for agents with real income greater than or equal to τ^*. It is assumed that the tax threshold is automatically adjusted for

[7] In Coleman (2008) only capital income, not labour income was taxed.

inflation. An indirect goods and services tax is applied to goods other than housing at rate τ^g, so the post tax price of the good is $(1+\tau^g)P_t$. Incomes and the prices of goods both increase at a constant inflation rate π, where $1+\pi = P_{t+1}/P_t$.

Agents obtain utility from the consumption of goods and housing. An agent chooses real consumption $c_t^{i,j}$, and has housing choices described by a vector of four indicator variables $\mathbf{I}_t^{i,j,h} = \left\{ I_t^{i,j,\frac{1}{2}R}, I_t^{i,j,R}, I_t^{i,j,F}, I_t^{i,j,H} \right\}$ that equal one if the agent has housing tenure *h* in period *i* of his or her life at time *t*, and zero otherwise. There are four possible housing tenures: an agent can share a rented small house (or flat) with another agent (½R), rent a small house or flat by themselves (R), purchase a small house (F), or purchase a large house (H). In period t agents obtain utility

$$u(c_t^{i,j}, \mathbf{I}_t^{i,j,h}) = \ln(c_t^{i,j}) + \sum_h v^h I_t^{i,j,h} \quad (2)$$

It is assumed $v^H > v^F > v^R$ and $2v^{\frac{1}{2}R} \geq v^R > v^{\frac{1}{2}R}$. Agents born at time t choose consumption and housing paths to maximise discounted lifetime utility:

$$U = \sum_{i=0}^{3} \beta^i u(c_{t+i,}^{i,j} \mathbf{I}_{t+i}^{i,j,h}) \quad (3)$$

In each period, agents choose one of the four housing options, so there are 256 possible housing patterns over a lifetime. Rather than calculate the utility of each of these patterns, agents are restricted to choose from a much smaller set of patterns, $\mathcal{H}$.

The three restrictions are: (i) only period 0 and period 1 agents may choose to share a rental property (½R); (ii) except in the last period, agents' housing choices must not worsen through time; and (iii) agents can only rent in the last period if they rent or share throughout their whole life. By this means, the set $\mathcal{H}$ is reduced to 31 members, $\mathcal{H} =$ {½R½RRR, ½R½RRF, ½R½RFF, ½R½RHF, ½R½RHH, ½RRRR,

½RRRF, ½RRFF, ½RRHF, ½RRHH, ½RFFF, ½RFHF, ½RFHH, ½RHHF, ½RHHH, RRRR, RRRF, RRFF, RRHF, RRHH, RFFF, RFHF, RFHH, RHHF, RHHH, FFFF, FFHF, FFHH, FHHF, FHHH, HHHF, HHHH}. An agent's optimal discounted utility is calculated for each of these patterns, and the agent is assumed to choose the pattern that provides the greatest discounted utility.

Households receive their income, borrow or lend, consume, and purchase, rent, or sell property at the start of each period, although they gain utility from housing by living in it throughout the period. In the last period, agents sell or realise all assets except their last owned housing unit, repay any debts, and consume all of their wealth. They die at the end of period 3, at which point their housing unit is distributed to younger cohorts. At time *t* a fraction κ_i is left to the cohort born at *t-i* for *i=0,1,2*; in this paper, $\kappa_2 = 1$, so that agents do not receive an inheritance until relatively late in life. Two inheritance distributions were considered. In the first one, the housing belong to the jth agent in cohort 3 is left to the jth agent in cohort 2, thus preserving the income distribution. In the second one (and the main one used in the simulations in this paper) the houses owned by agents j and j+1 in cohort 3 are left to agent j+1 in cohort 2, and agent j gets no inheritance. This distribution ensures that half the agents in the model solve optimisation problems in which an inheritance is not taken into account, while the other half solve problems in which credit constraints bind particularly hard early in life because they expect to inherit a large amount of wealth. In the maximisation equation below, $Inherit_t$ is the value of the expected inheritance.

A1.2 Taxes and the housing market

Five features of the tax system have been incorporated into the model. First, interest and rent income is taxed at an agent's marginal tax rate. Secondly, there is a goods and services tax that is applied to consumption but not to rent or property. In the model, the goods and service tax rate is set endogenously at a rate that makes the total tax take except for labour income taxes (tax on capital income plus tax on goods and services plus capital gains taxes) equal to a set fraction of labour income, in this case $\tau^{g^*} = 14$ percent. This ensures that any changes in the structure of capital incomes taxes do not have revenue implications for the Government. Thirdly, imputed rent is tax exempt and a landlord can deduct interest payments associated with a mortgage when calculating taxable income. Agents do not receive utility from government expenditure. Fourthly, there is a capital gains tax that can vary with income, $\tau^c(Y^i)$. We use an indicator variable L^c to indicate whether the capital gains tax applies to all households ($L^c = 1$) or just landlords ($L^c=0$). Fifthly, there is a property tax (see below). Landlords can deduct their property tax against expenses.

Flats and large houses cost P_t^F and P_t^H to purchase. There are also annual property charges γP_t^h which can be thought of as maintenance or property tax charges. The vector $P_t^{\gamma h} = \{0, 0, \gamma P_t^F, \gamma P_t^H\}$ describes the charges paid by the occupiers of the four different housing tenures, for landlords are responsible for paying the charges on rented houses. When the flats are leased, the price P_t^R is paid in advance at the beginning of the lease. Landlords are assumed to be agent in period 2 of their lives.

The number of landlords is endogenous; an indicator variable $I_t^{i,j,R*}$ indicates the number of rental properties owned by the jth agent.[8]

Because there is no uncertainty, the after-tax return from purchasing a flat in period *t*, leasing it, and selling it in period *t+1* is equal to the after-tax return from lending money. As such, the relationship between rent, tax rates, flat prices, and interest rates is

$$(P_t^R - \gamma P_t^F)(1-\tau_2)(1+r_t(1-\tau_2))^T + P_{t+1}^F - \tau^c(P_{t+1}^F - P_t^F) = P_t^F(1+r_t(1-\tau_2))^T \quad (4)$$

or

$$P_t^R = P_t^F\left(\frac{(1+\gamma(1-\tau_2)(1+r_t(1-\tau_2))^T - (1+\pi_t^F(1-\tau^c))}{(1-\tau_2)(1+r_t(1-\tau_2))^T}\right) \quad (5)$$

where π_t^F is the rate of price appreciation for flats. The right hand side of equation 4 is the after-tax return in period *t+1* from investing P_t^F in interest earning bonds. The left hand side is the after-tax return at *t+1* from using the same sum to purchase a rental flat at time t. It comprises the after-tax rent paid at time t and reinvested at interest (with an adjustment for property maintenance charges), plus the proceeds from selling the rental unit at time *t+1,* adjusted for capital gains tax. Since interest payments by landlords are fully tax deductible, the return to a landlord is independent of their level of gearing. It is assumed that the landlords are high income agents in period 2 of their lives, so after-tax returns are calculated using the top marginal tax rate τ_2.

[8] If there is demand for 2*f* flats, the *f* highest income individuals are assumed to own 2 flats each.

There are separate supply functions for the two types of houses, and the quantity of each is determined in equilibrium along with rents and prices. Linear supply functions are specified:

$$\begin{aligned} P_t^F &= \alpha_0^F + \alpha_1^F \left(Q_t^F + Q_t^H \right) \\ P_t^H &= P_t^F + \alpha_0^H + \alpha_1^H Q_t^H \end{aligned} \tag{6}$$

In this specification the price of flats is an increasing function of the total number of properties (to reflect the possible scarcity of land), while the price of houses is determined as a variable premium over the price of flats (to reflect the additional building costs). In most of the simulations presented below, parameters are chosen so that a 1 percent increase in the number of properties leads to about a 1 percent increase in the price of flats.

A1.3: The lending market

There is a non-profit financial intermediary that accepts deposits and issues mortgages at an interest rate r_t. Agents can lend or borrow as much as the bank allows them at the one period interest rate r_t, subject only to the restriction that they have a zero debt position at the end of their life. The economy is open and real interest rates are determined exogenously. There are no restrictions on the deposit contract, and interest on a deposit made at time *t* is paid at time *t+1*. Agents pay tax on this interest at their marginal tax rate, but do not get a tax deduction for interest paid on borrowed funds unless they borrow to fund a rental property.[9] An agent's positive funds are labelled $B_t^{i,j}$.

[9] To reduce computational complexity, the marginal tax rate is calculated on the basis of labour income, not total income. Otherwise the marginal tax rate is determined endogenously.

The mortgage contract is subject to three restrictions.[10]

i) *The loan to value restriction.*

The mortgage may not exceed a certain fraction of the value of the property. In particular, the gross amount borrowed $D_t^{i,j-}$ cannot exceed the value of property multiplied by the loan to value ratio θ: that is

$$D_t^{i,j-} \leq \sum_{h \in F,H} \theta P_t^h I_t^{i,j,h} \tag{7}$$

(Note $D_t^{i,j-} > 0$ if the agent borrows.) This restriction means that agents who rent cannot borrow to smooth consumption, although they can save.

ii) *The regular cash payment restriction*

Banks only issue η-year table mortgages, and require a "cash payment" in the period the mortgage is issued. This restriction is imposed to mimic a standard condition of a table mortgage, namely that a customer is required to make regular cash repayments *CP* of equal size throughout the life of the mortgage rather than a large repayment at its terminal date. The payment size *CP* is chosen to ensure the mortgage is retired at the end of the term: if D^{0-} is initially borrowed, the annual payment is

$$CP = D^{0-} r \left[\frac{(1+r)^{\eta}}{(1+r)^{\eta} - 1} \right] \tag{8}$$

η is assumed to be 25 years.

It is not possible to exactly replicate this feature of a standard mortgage contract in the model. However, a close approximation is achieved by requiring the customer to make a payment that pays off some of the interest and principal in any period he or

[10] Note that banks impose these restrictions even though there is no uncertainty in the model

she has debt. In particular, a customer with gross debt of $D_t^{i,j-}$ is required to open up a separate account with the bank and make a deposit of size

$$D_t^{i,j*} = D_t^{i,j-} \frac{r_t}{1+r_t}\left[\frac{(1+r_t)^{\eta/T}}{(1+r_t)^{\eta/T}-1}\right] \tag{9}$$

into this account. This deposit earns (untaxed) interest at rate r_t. This means the net borrowing position of a borrowing agent, $D_t^{i,j} = D_t^{i,j-} - D_t^{i,j*}$, is less than the gross borrowing position. Without this "cash payment" feature, many agents would prefer to purchase rather than rent simply because the interest payment occurs a period later than the rental payment. When the "cash payment" requirement is imposed, purchasing a house requires a larger payment to the bank in period *t* than the cost of renting a house.

iii) *The mortgage-repayment-to-income restriction*

The maximum amount an agent can borrow is restricted to ensure the mortgage repayment given by equation 8 is smaller than a fraction δ of income:

$$D_t^{i,j-} \frac{r_t}{1+r_t}\left[\frac{(1+r_t)^{\eta/T}}{(1+r_t)^{\eta/T}-1}\right] \le \delta P_t Y_t^{ij} \tag{10}$$

Note that this constraint is expressed in terms of nominal interest rates.

The mortgage conditions are only imposed on agents in periods 0 and 1 of their lives in order to simplify the solution algorithm. In period 2 agents can borrow unrestricted amounts. The absence of a restriction in period 2 has little effect because agents are in their peak earning years, receive their inheritance at this time, and are actively saving or reducing debt to finance their retirement.

A1.4 Utility maximisation

An agent born at time *t* solves the following constrained maximisation problem (the jth superscript is omitted):

$$Max_{\{c_{t+i},\mathbf{I}^{i,h}_{t+i}\}}\ U=\sum_{i=0}^{3}\beta^{i}u(c^{i}_{t+i,}\mathbf{I}^{i,h}_{t+i}) \qquad (11)$$

$$-\lambda_0\left(P_tY_t^0-B_t^0+D_0^t-(1+\tau^g)P_tc_t^0-\sum_h(P_t^h+P_t^{\gamma h})I_t^{0,h}\right)$$

$$-\sum_{i=1}^{3}\lambda_i\left(\begin{array}{l}(1+\pi)^iP_tY_{t+i}^i+B_{t+i-1}^i(1+r_{t+i-1}(1-\tau^i))-D_{t+i-1}^i(1+r_{t+i-1})-B_{t+i}^i+D_{t+i}^i\\ -(1+\pi)^i(1+\tau^g)P_tc_t^i-\sum_h(P_{t+i}^h+P_{t+i}^{\gamma h})I_{t+i}^{i,h}+\sum_{h=F,H}I_{t+i-1}^{i-1,h}(P_{t+i}^h-\tau^cL^c(P_{t+i}^h-P_{t+i-1}^h))\\ +\kappa_iInherit_{t+i}\\ +\left[P_{t+i}^R(1-\tau^i)I_{t+i}^{i,R*}+((P_{t+i}^F-\tau^c(P_{t+i}^F-P_{t+i-1}^F)-P_{t+i-1}^F(1+r_{t+i-1}(1-\tau^i))I_{t+i-1}^{i-1,R*}\right]\end{array}\right)$$

$$-\sum_{i=0}^{1}\chi_i\left(D_{t+i}^{i,-}-\sum_h\theta P_{t+i}^h\,I_{t+i}^{i,h}\right)$$

$$-\sum_{i=0}^{1}\phi_i\left(D_{t+i}^{i,-}\frac{r_{t+i}}{1+r_{t+i}}\left[\frac{(1+r_{t+i})^{\tau/T}}{(1+r_{t+i})^{\tau/T}-1}\right]-\delta Y_{t+i}^i\right)$$

$$-\sum_{i=0}^{3}\varsigma_i\left(B_{t+i}^i\right)-\sum_{i=0}^{3}\nu_i\left(D_{t+i}^i\right)$$

Lines 2 and 3 of equation (11) are the budget constraints facing the agent in the four periods. Lending and borrowing are entered separately as there are different after-tax interest rates, and there are terms to reflect maintenance charges, capital gains tax, inheritance and rental income. Lending and borrowing in period 3 are restricted to equal zero, and τ^i is the marginal tax rate applying in period *i* of the agent's life. The Kuhn-Tucker conditions in lines 4 and 5 reflect the loan-to-value ratio constraints and the mortgage-repayment-to-income ratio constraints respectively. The Kuhn-Tucker conditions in line 6 reflect the requirement that non-negative amount are lent and borrowed. The agent solves the problem by calculating the maximum utility for each housing pattern in the set $\mathcal{H}$, and then selecting the housing pattern with the highest utility. The use of log-linear utility functions means it is relatively straightforward to calculate an analytical solution for the optimal consumption path given a particular housing pattern, even though each solution has 48 parts corresponding to the 48 possible combinations of Kuhn-Tucker conditions.

A1.5 Equilibrium conditions

In the simulations, the steady state equilibrium is found for an open economy in which agents borrow or lend at the world interest rate. In the steady state, the following price relationships hold:

$$(1+r_t)/(1+\pi_t)=1+r \qquad (12a)$$

$$\frac{P_{t+1}^F}{P_t^F}=1+\pi^F \qquad (12b)$$

$$\frac{P_t^H}{P_t^F}=\rho^H \qquad (12c)$$

$$\frac{P_t^R}{P_t^F}=\left(\frac{(1+\gamma(1-\tau_2)(1+r_t(1-\tau_2))^T-(1+\pi_t^F(1-\tau^c))}{(1-\tau_2)(1+r_t(1-\tau_2))^T}\right)=\rho^R \quad (12d)$$

Equation (12a) states that real interest rates are constant. The rate r is the foreign real interest rate. Equation (12b) states that flat prices appreciate at a constant rate. Equation (12c) states that the ratio of house prices to flat prices is constant. Equation (12d) is a restatement of equation 5, linking rents to interest rates and the flat price appreciation rate.

For a set of parameters $\{N,T,Y_t^0,\omega_j,g_i,\pi,\beta,v_h,\kappa_i,\mathcal{H},\gamma,\eta,\theta,\delta,\tau^{g*},\tau_1,$ $\tau_2,\tau^*,\tau^c,L^c\}$ and housing parameters $\{\alpha_0^F,\alpha_1^F,\alpha_0^H,\alpha_1^H\}$ the steady state equilibrium is described by a set of prices $\left\{r, \pi^F, \rho^H, \rho^R\right\}$, a GST rate τ^g, a set of housing and consumption demands $\{c^{s,j}_{t-i+s}, \mathbf{I}^{s,j,h}_{t-i+s}\}_{s=0,\ldots,3}$ for each agent j in each cohort born in period *t-i*, and a net foreign asset position B_t^{net} such that all agents have maximal utility and

$$\sum_{i=0}^{3}\sum_{j=1}^{N} c_t^{i,j} + \gamma(Q^F P_t^F + Q^H P_t^H) + Tax_t = \sum_{i=0}^{3}\sum_{j=1}^{N} y_t^{i,j} - \left(\frac{r-\pi}{1+\pi}\right) B_t^{net} \quad (13a)$$

$$\sum_{i=0}^{3}\sum_{j=1}^{N} (B_t^{i,j} - D_t^{i,j}) - P_t^F \sum_{j=1}^{N} I_t^{2,j,R*} = B_t^{net} \quad (13b)$$

$$\begin{aligned} Tax_t = & \sum_{i=0}^{3}\sum_{j=1}^{N} y_t^{i,j}(\tau_1 + (\tau_2 - \tau_1)(y_t^{i,j} - \tau^*) I(y_t^{i,j} - \tau^*) \\ & + \tau^g \sum_{i=0}^{3}\sum_{j=1}^{N} c_t^{i,j} + \sum_{i=0}^{3}\sum_{j=1}^{N} B_{t-1}^{i,j} r \tau_t^{ij} \\ & + (\sum_{j=1}^{N} P_t^F \tau_t^{2,j} I_t^{2,j,R*} - \sum_{j=1}^{N} P_{t-1}^F r \tau_t^{3,j} I_{t-1}^{2,j,R*} - \tau^c \sum_{j=1}^{N} (P_t^F - P_{t-1}^F) I_{t-1}^{2,j,R*} \\ & + L^c \sum_{i=1}^{3}\sum_{j=1}^{N} \tau^c (P_t^F - P_{t-1}^F) I_{t-1}^{i-1,j,F} + \tau^c (P_t^H - P_{t-1}^H) I_{t-1}^{i-1,j,H} \end{aligned} \quad (13c)$$

and
$$\sum_{i=0}^{3}\sum_{j=1}^{N} (\tfrac{1}{2} I_t^{i,j,\frac{1}{2}R} + I_t^{i,j,R} + I_t^{i,j,F}) = Q^F \quad (13d)$$

$$\sum_{i=0}^{3}\sum_{j=1}^{N} I_t^{i,j,H} = Q^H \quad (13e)$$

where Q^F and Q^H are the number of houses produced when the supply of properties is elastic,

$$Q^H = \frac{P^H - P^F - \alpha_0^H}{\alpha_1^H} \quad \text{and } Q^F = \frac{P^F - \alpha_0^F}{\alpha_1^F} - Q^H .$$

Equation (13a) requires that total consumption plus house maintenance plus tax plus real earnings on the net bond position in each period equals total production. Equation (13b) is the net supply of foreign bonds, given that landlords are assumed to borrow 100 percent of the price of a flat. This will change through time if there is inflation. Equation 13c says that the total tax take is equal to labour income tax plus GST revenue plus tax on interest plus tax on rent adjusted for the interest rate tax deduction for landlords and the capital gains tax they pay, plus the capital gains tax paid by home-owners. Note that while it has been assumed landlords borrow 100 percent of the value of the property, tax revenue would not change if landlords had different gearing as the tax rate on positive balances is the same as the tax deduction they get when they borrow. Equations (13d) and (13e) require that the total demand for flats equals the supply of flats, and that the total demand for houses equals the supply of houses.

A1.6 Parameterisation

The set of baseline parameters $\{N, T, Y_t^0, \omega_j, g_i, \pi, \beta, v_h, \kappa_i, \mathcal{H}, \gamma, \eta, \theta, \delta,$ $, \tau^{g*}, \tau_1, \tau_2, \tau^*, \tau^c, L^c\}$ and housing parameters $\{\alpha_0^F, \alpha_1^F, \alpha_0^H, \alpha_1^H\}$ have been chosen to approximate features of the New Zealand economy. These are listed in table 4. Except for income distribution, the income parameters approximately match the basic lifecycle and cohort income patterns of New Zealanders reported in census documents, 1966-2001, under the assumption that the basic agent is a household comprised of a male and female of the same age. For simplicity, annual income is assumed to be uniformly distributed over the range $25000 to $80000.

In the baseline model, the discount rate is 3 percent, the real interest rate is 5 percent (assumed equal to the world rate), and banks impose borrowing restrictions that limit households to borrow up to 90 percent of the value of a property and to pay no more than 30 percent of their income in debt servicing. The banking sector parameters are changed in some of the simulations, but these reflect the conditions facing New Zealand borrowers since the year 2000.

The tax rates also reflect New Zealand tax settings in 2000. In the baseline model, the marginal tax is 20 percent for households with incomes less than $50000, and 33 percent for households with incomes above that level. The model is also solved for a set of tax rules that exclude the inflation component of interest income from tax, and which only allow landlords to deduct real interest payments from their taxable income.[11] The GST rate was chosen to ensure that capital income taxes and consumption taxes total to 14 percent of labour income.

The parameters $(\upsilon^{\frac{1}{2}R}, \upsilon^{R}, \upsilon^{F}, \upsilon^{H}) = (0.18, 0.32, 0.35, 0.54)$ mean (approximately) that at the margin a household would be prepared to spend 18 percent of their income on shared accommodation rather than have no accommodation, and 32 percent of their income to rent a whole flat; the additional benefit from living in an owner-occupied flat rather than a rented flat is 3% of income, and the additional benefit from living in a large house a further 20 percent. These parameters are quite arbitrary, but have been varied by the author to ensure the results are not completely sensitive to these choices. The housing supply parameters were chosen so that that the elasticity of flats with respect to prices was 1 percent in the elastic case. The model was solved for inflation rates ranging from 0 to 3 percent, reflecting the legal requirement that the Reserve Bank of New Zealand achieve stability in the general level of prices.

[11] In this case the constraints in equation 11 and the aggregation condition (13c) are modified accordingly.

A1.7 Solution technique

The solution is found numerically. The algorithm searches for a set of prices $\left\{\tau^{g}, P_{t}^{R}, P_{t}^{F}, P_{t}^{H}\right\}_{t=-3,..0,...3}$ so that when each agent *j* born in period *t-i, i= 0,…3* is consuming a sequence of goods and tenure options $\{c_{t-i+s,}^{s,j} \mathbf{I}_{t-i+s}^{s,j,h}\}_{s=0,...,3}$ that solves their constrained utility problem given by equation (11), the aggregation conditions 13a – 13e applied at time *t* are satisfied. In the steady state, the vector $\left\{\tau^{g}, P_{t}^{R}, P_{t}^{F}, P_{t}^{H}\right\}_{t=-3,..0,...3}$ can be calculated from the vector $P^{*}=\{\tau^{g}, P_{0}^{F}, \pi^{F}, \rho^{H}\}$ and the parameters $\left\{r, \tau_{2}\right\}$.

The basic structure of the algorithm is as follows.

a) Let the vector $P^{*,k}=\{\tau^{g}, P_{0}^{F}, \pi^{F}, \rho^{H}\}^{k}$ be the *k*th estimate of the steady state solution P^{*}. Given $P^{*,k}$, calculate the optimal consumption and housing tenure paths for each of the N households who are born at *t=0* by searching over the different possible tenure paths in the set $\mathcal{H}$.

b) Use these results to calculate the demand for consumption goods and housing at time *t=0* for all households in the economy.

c) Use these results to calculate aggregate consumption, the aggregate demand for flats, and the aggregate demand for houses at time *t=0*. Then calculate the excess demand functions given by 13a – 13e.

d) If the excess demand functions are not sufficiently close to zero, a new estimate of the equilibrium prices P^{*}, $P^{*,k+1}$, is calculated. This is done using a discrete approximation to the Newton-Rhapson method. A set of quasi-derivatives is calculated by recalculating the set of excess demand functions at the prices $\{\tau^{g}+\Delta_{1}, P^{F}, \pi^{F}, \rho^{H}\}$, $\{\tau^{g}, P^{F}+\Delta_{2}, \pi^{F}, \rho^{H}\}$,

$\{\tau^g, P^F, \pi^F + \Delta_3, \rho^H\}$ and $\{\tau^g, P^F, \pi^F, \rho^H + \Delta_4\}$. These quasi derivatives are used to calculate the updated price vector using Broyden's method. The process is continued until the sequence of estimates $P^{*,k}$ converges.

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