Housing ABM, December 2015

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1 Introduction

The model consists of houses that are bought and sold by households on a housing market; households take out mortgages from a bank, which is regulated by a central bank. Owner-occupiers can also choose to buy and sell properties as buy-to-let investments. These are offered on a rental market and rented out by households that decide to rent rather than buy. Households that cannot afford to rent or buy are put into social housing.

Houses have no intrinsic properties other than a single ‘quality’, which acts as a proxy for size, location, condition etc. The model is time-stepping with a step of one month.

2 Household lifecycle

Households enter the model, age, and exit. Upon entry, households are endowed with an age (taken from an empirical distributions), a value representing their income percentile (chosen with uniform probability) and wealth (based on average wealth for their income) but no existing housing. 8% of households that are above the 50th percentile of income are given a buy-to-let ‘gene’ which gives them the desire to enter the buy-to-let market.

The age of a household represents the age of the ‘household reference person’ (HRP) (a concept that exists in many household surveys). As a household ages, its income percentile remains fixed and its income changes based on the empirical distribution of income by age in the UK. Income is bounded by a lower limit of £5,900 (the current level of income support for a married couple). Each month, each household has a certain probability of ‘death’ based on its age, taken from empirical rates for the UK. On exit, all of a household’s financial and housing wealth is given to another, randomly chosen, household.

3 Simulation initialisation

In order to initialise a simulation with a realistic assignment of houses and mortgages to households, the model goes through a 'spinup' period before any simulation. For a given target population, the necessary total birth rate is calculated and the population is allowed to grow to its equilibrium distribution while holding the total birth rate fixed.

During this period, houses are put on the sale market by a 'construction sector' when the household to house ratio falls below a fixed value. New houses will be put onto the house sale market at the current market price and will drop the price at a rate of 5% per month if unsold.

4 Households

4.1 A month in the life...

In each one-month time-step, each household:

1. ages by 1 month and possibly dies
2. receives its gross employment income and pays income tax and national insurance according to UK tax law for a single person in the 2014/15 tax year (this needs changing to account for probability of household status given income and age).
3. makes mortgage and/or rental payments and collects any rent due
4. consumes
5. decides whether to try to rent/buy a new house
6. decides whether to sell any owned houses
7. rethinks the price of any house on the rental/sale market or removes from the market.

4.2 Household consumption

Households have a fixed, subsistence-consumption set at the married couple's monthly lower earnings limit for UK income support. After this is subtracted from disposable income, the household's discretionary consumption is calculated as

$$E = \alpha \max\left(b - e^{4.07\log(i) - 33.1 + \varepsilon}, 0\right) \tag{1}$$

where b is the household's liquid wealth and i is gross annual income. This formula ensures that the aggregate wealth distribution fits the empirical distribution of wealth given income for the UK, while ensuring that households with higher income consume more.

4.3 Decisions while in "social housing"

All agents are born into "social housing". Although we refer to this as social housing, this also represents homelessness, living with parents while looking for a house or living in temporary accommodation (e.g.hotel, staying with friends) while between houses.

Agents never choose to be in "social housing", but are put there if they fail to secure any other form of housing at a given time. If they find themselves in social housing they will always consider renting or buying and will bid on the appropriate market. When in social housing, no rental payments are deducted from income.

4.3.1 Decision to rent or buy a home

If an agent is in need of a new home (if in social housing, at the end of a rental contract or directly after the sale of a house), they need to decide between renting and buying. The probability of deciding to buy is given by

$$P_{buy} = \frac{1}{1 + e^{K_{rb}(C_r(1+C_R)-C_b)}}$$

where K_{rb} is a constant, C_r is the average annual rent on a house of the buyer's desired quality, C_R is a constant, representing the intrinsic cost of renting rather than owning, and C_b is the expected annual mortgage payment minus the expected annual capital appreciation of a house of the buyer's desired quality.

Desired quality is the maximum quality house that, at current market prices, the household would expect to get if they entered the house sale market (see section 4.4.1).

4.4 Decisions as a Homeowner

4.4.1 Buying a home

If a household decides to buy a home, it will bid on the house sale market. The desired amount of the bid is given by

$$\frac{\sigma i e^{N(0,\epsilon)}}{1.0 - AP}$$

where i is income, P is expected house price appreciation, $N()$ is Gaussian noise, σ, A and ϵ are parameters.

The actual amount bid is the closest amount possible to the desired bid, after accounting for any bank-decided constraints on mortgages available to the agent.

4.4.2 Downpayment on a new home

On buying a home, if the household has liquid wealth of 1.25 times the price of the house, they will pay outright. Otherwise they will choose the i^{th} percentile from a log-normal distribution (parameters depending on whether they are FTB or OO), where i is their income percentile (calibrated against emprical LTV distributions).

4.4.3 Decision to sell a home

The probability that an agent will sell their home is a linear function of the number of houses currently on the market and the mortgage interest rate.

4.4.4 Sale price decision

Houses are offered on the market at a price, q, given by

$$\ln q = 0.095 + \ln(\bar{p}) - D \ln\left(\frac{\bar{d}+1}{\langle d \rangle + 1}\right) + \varepsilon \tag{2}$$

where $\bar{p}$ is the average sold-price of houses of this quality, $\bar{d}$ is the average days on the market for all house qualities, $\langle d \rangle$ is the prior expectation of the number of days on the market, D is a tunable parameter (currently set to 0), and $\varepsilon = N(0, 0.01^2)$.

If a house remains on the market from the previous time-step, with a 6% probability its price is reduced by an amount drawn from a Gaussian distribution with mean around -1.6% and SD 0.6%. This is calibrated against data on house price reductions from Zoopla. If the price drops below the amount needed to pay the mortgage on the house, it is withdrawn from the market.

4.4.5 Decision on how much to spend on rent

If a household decides to rent, they will bid 0.3 times their income for rent.

4.5 Buy-To-Let Investor's decisions

4.5.1 Buy-to-let rental offers

A BTL investor will put a house on the rental market whenever a rental contract ends, or when a new buy-to-let house is bought that doesn't already have a tenant.

The rent BTL investors charge is given by:

$$r = e^{C+log(\bar{p})-D*log((d+1.0)/31.0)+E*N(0,1)} \tag{3}$$

where $C = 0.01$, $D = 0.02$, $E = 0.05$. $N(0,1)$ is a Gaussian noise term with average 0 and variance 1. $\bar{p}$ is the average mark-to-market rental price for house of this quality.

If a house on the rental market does not get filled, the price is multiplied by 0.95 each month.

The length of a rental agreement is chosen randomly from 12 to 24 months with uniform probability. This is based on figures from ARLA.

4.5.2 Decision to sell BTL property

Buy-to-let investors decide to sell houses in their current portfolio based on the realised interest coverage ratio of that house and the expected capital gains on the house. BtL investors differ in the weightings they assign to these two streams of income. The weighted sum of these streams is then passed through a logistic function to give a probability for deciding to sell the house.

The price at which the property is offered is decided in the same way as with homes.

4.5.3 Decision to buy BTL property

BtL investors decide to buy houses based on the expected yield and expected capital gain of the best performing house quality on the market. Different investors put different weightings on these two income streams. The sum of the weighted streams is passed through a logistic function to get a probability of bidding on the house-sale market.

The maximum amount they can invest is determined by the LTV, ICR and affordability constraints that the bank imposes as defined below.

A BTL investor will be willing to invest up to the amount of the maximum mortgage the bank is willing to approve.

4.5.4 Downpayment

On buying a house, if the household has liquid wealth of 1.25 times the price of the house, they will pay outright. BTL investors will choose downpayment from a Gaussian distribution, calibrated against data.

5 Banks

There is a single bank in the model which represents the mortgage lending sector in the aggregate.

5.1 Mortgage approval

The bank will approve a home mortgage as long as it conforms to LTV, LTI and affordability constraints. The affordability constraint ensures that a household has enough total income to pay all its mortgages. Subject to meeting those criteria, all demand is met in any period. The maximum mortgage amount, then, is calculated as

$$q = \min\left(\frac{b(1-\theta)}{\theta}, i * \psi, \phi * pdi\frac{1-(1+r_{stress})^{-N}}{r_{stress}}\right) \tag{4}$$

In the case of buy to let investors, a central-bank imposed Interest Coverage Ratio is imposed in place of the income to value ratio.

The constraints are described in the following table.

Term / constraint	Description
$\frac{b(1-\theta)}{\theta}$	LTV constraint. b is the household's bank balance, θ is the minimum loan to value haircut (i.e. 1 minus the loan to value ratio). θ is 0.1 for first-time buyers, 0.2 for homeowners moving home and 0.4 for buy-to-let investors.
$i * \psi$	LTI constraint. i is household gross income and ψ is the maximum loan to income ratio
$\phi * pdi\frac{1-(1+r_{stress})^{-N}}{r_{stress}}$	Affordability test given a down-payment of all cash in the bank and a monthly payment equal to the share ϕ of the household's disposable income available for mortgage payments. pdi is a household's disposable income (including income from rent), r_{stress} is the fixed monthly interest rate based on a stress scenario and N is the number of monthly payments to pay off the mortgage. ϕ is 0.25.

5.2 Interest rates

Mortgage interest rate spread, r, is calculated according to

$$r_{t+1} = r_t + k(S - T)$$

where k is a constant, S is the aggregate rate of supply of credit and T is a constant target rate of supply.

6 Housing market clearing

6.1 House sales clearing

Clearing proceeds as follows: Home-buyers are matched to the best quality house they can afford and BtL investors are matched to the best yield house they can afford. Where a given offered house is matched with more than one bidder, the price is 'bid-up' and offered at random to one of the bids that can still afford to buy. For a total number, b, of bids received in the timestep, the number of bid-ups, k, is drawn from a geometric distribution such that:

$$p(k) = (1 - e^{-7b/30})^{k-1} e^{-7b/30}$$

Each bid-up increases the price of the house by 0.75%.

Failed bids then get to bid again. This re-bidding carries on up to the smaller of $N/1000$ and $1 + n/5000000$ times, where N is the population and n is the total number of orders on the market.

6.2 Rental clearing

Rental clearing proceeds in the same way as house-sales-clearing, but without yield-driven BtL bidders.

7 Central bank

The central bank sets LTV, LTI, interest cover ratio (ICR) and affordability policies. Policies can be of three different types:

1. Strict limits, e.g. a hard LTV limit of 90% for all households (though the limit may differ between types of agents, such as first-time buyers or owner-occupiers);

2. 'Soft' limits, e.g. an LTI cap of 3.5 on new mortgage lending, but allowing for 15% of new mortgages above this limit;

3. State-contingent policies, e.g. an LTV limit of 85% if credit growth over a certain time is above a certain threshold; otherwise no limit.