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Bank of Finland Research
Discussion Papers
20 • 2015

Matching and credit frictions in the housing market*

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This version: September 2015

Abstract

We study the interaction of matching and credit frictions in the housing market. In the model, risk-averse households may save or borrow in order to smooth consumption over time and finance owner housing. Prospective sellers and buyers meet randomly and bargain over the price. We analyze how borrowing constraints influence house price determination in the presence of matching frictions. We also show that credit frictions greatly magnify the effects of matching frictions. For instance, in the presence of matching frictions, a moderate tightening of the borrowing constraint increases idiosyncratic price dispersion and the average time-on-the-market substantially. *Keywords:* Housing, Borrowing constraint, Matching. *JEL:* E21, R21, C78.

1 Introduction

The housing market is imperfect in many ways. Because of matching frictions, it takes time to find a trading partner. When a potential partner is found, the price is usually determined in a negotiation. Often the negotiations break down and a match does not lead to trade. In addition, housing market outcomes are affected by financial constraints. Most directly the constraints manifest

*We thank Jonathan Halket, John Hassler, Per Krusell, Tuukka Saarimaa, Marko Terviö, Juuso Vanhala and seminar participants at HECER, NorMac, and Bank of Finland for useful comments. An earlier version of this paper circulated under the title "Matching in the housing market with risk aversion and savings". Financial support from the Academy of Finland and OP-Pohjola research foundation is gratefully acknowledged.

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themselves through the availability of credit. Credit frictions also matter more indirectly because of uninsurable income uncertainty. When contemplating buying a house with a mortgage, households need to consider their ability to service the mortgage in case their incomes fall in the future.

Matching and credit frictions are likely to be interrelated in the sense that matching frictions make credit frictions more relevant for household welfare, and vice versa. To see this, notice first that in the absence of matching frictions, all trades (in the same period) take place at the same price (per quality adjusted housing units) and all households can count on being able to buy or sell at the prevailing market price. Because of matching frictions, however, borrowing constrained households that would like to sell their house quickly for liquidity reasons may not be able to do so.

In this paper, we study the interaction of matching and credit frictions. We first analyze how borrowing constraints influence house price determination in the presence of matching frictions. We also seek to understand how household borrowing constraints are reflected in key housing market outcomes that are closely related to matching frictions, such as the average time-on-the market.

In order to study these issues, we develop a new modeling framework by building on two strands of literature. We introduce matching frictions following, for example, Wheaton (1990), Albrecht et al. (2007), and Díaz and Jerez (2013). In these models, potential house buyers and sellers meet and bargain over the price.[1] The previous housing market matching models assume risk-neutral preferences and abstract from households' savings decisions. As a result, they are not directly applicable when considering the role of credit frictions for housing market outcomes.

We therefore embed the matching frictions into a Bewley-Huggett-Aiyagari -type framework where risk-averse households face uninsurable income shocks and make savings decisions (Huggett 1993, Aiyagari 1994). This allows us to study how borrowing constraints and households' asset positions affect housing market outcomes in the presence of matching frictions.[2]

[1]Existing models make different assumptions regarding how agents meet and how prices are determined. For instance, Albrecht, Gautier and Vroman (2015) consider directed search with limited commitment to the asking price, Díaz and Jerez (2013) consider directed search with posted prices, Carrillo (2012) considers directed search combined with a bargaining game, and Piazzesi and Schneider (2009) consider random matching with take-it-or-leave-it offers.

[2]There are many models that incorporate housing choices into a Bewley-Huggett-Aiyagari -type incomplete

In our model, each household either rents or owns its house. Some households prefer owner housing over rental housing and the tenure preferences may change over time. If a renter household becomes dissatisfied with rental housing, it wants to buy a house. Similarly, some owner households may want to move to rental housing in which case they consider selling their house. Prospective sellers and buyers meet randomly and bargain over the price. Households may save or borrow with a financial asset but can only borrow against owner housing.

In the model, the asset distributions of potential buyers and sellers are both key equilibrium objects. For instance, when bargaining over the price, sellers need to consider the distribution of all potential buyers because it influences the value of not selling today and staying in the market. Similarly, buyers need to consider the distribution of sellers as that influences the value of not buying today.

The combination of precautionary savings and matching frictions relates our analysis to recent labor market matching models with a precautionary savings motive such as Krusell et al. (2010). In their model, unemployed workers and firms with vacancies are matched and bargain over the wage.[3] While workers are heterogeneous in their assets, all recruiting firms are identical. In our housing market model, where current buyers are future sellers and vice versa, both parties of the bargaining process are heterogeneous in their assets.

We calibrate the model using data on Finnish households' portfolios and the Finnish housing market. In order to capture the importance of both borrowing constraints and matching frictions, we match, among other things, the share of highly leveraged recent house buyers and the average time it takes to sell a house (average time-on-the-market).

We first use the calibrated model to study how the outcome of the bargaining process depends on the traders' asset positions. We find that it is sensitive to asset positions whenever either the potential buyer or seller is close to being borrowing constrained. For instance, poor sellers might be willing to sell at a relatively low price because of liquidity reasons whereas a wealthier seller would prefer to wait for a better match. Combined with asset heterogeneity, which stems endogenously

markets set-up with borrowing constraints. See, for instance, Ríos-Rull and Sanchez-Marcos (2008), Díaz and Luengo-Prado (2010), and Iacoviello and Pavan (2012). However, to the best of our knowledge, all the previous applications abstract from matching frictions.

[3] An earlier example of a model that combines labor market matching frictions and precautionary savings is Costain and Reiter (2005). In their model, bargaining takes place between worker unions and firms.

in the model, this feature has two realistic implications. First, not all matches result in trade.[4] Second, at any given point in time, identical houses sell at different prices.[5] In particular, the stationary equilibrium features non-trivial deviations from the average market price in cases where the seller and the buyer are both close to being borrowing constrained. Since houses are identical in the model, these results reflect solely the role of borrowing constraints and households' asset positions in determining the outcome of the bargaining process.

We then consider how changes in the borrowing constraint influence the stationary equilibrium in the presence of matching frictions. An important insight from the analysis is that credit frictions magnify the effects of matching frictions. A tightening of the borrowing constraint decreases the share of all matches that result in trade. As a result, it increases the average time-on-the-market much like an increase in matching frictions would do. Moreover, while some matching frictions are needed to generate idiosyncratic price dispersion, a tightening of the borrowing constraint increases it. These results reflect the fact that a tighter borrowing constraint makes the surplus from trade more sensitive to traders' asset positions. The results are quantitatively relevant in that a moderate tightening of the borrowing constraint increases both the average time-on-the-market and price dispersion substantially.

Empirically, the average time-on-the-market is very volatile (Días and Jerez, 2013). Our results show that the observed large fluctuations in the average time-on-the-market may be related to (reasonable) changes in household credit conditions.

Our results are also interesting in light of the recent calls for stricter loan-to-value restrictions for housing lending. The aim of such a 'macroprudential' policy would be to make households and

[4] Merlo and Ortalo-Magné (2004) document that in the UK one third of all matches are unsuccessful. It also seems widely recognized that there is idiosyncratic dispersion in quality adjusted house prices even though it is difficult to measure it accurately. See, for instance, Leung et al. (2006) and the references therein.

[5] These two equilibrium properties arise also in some previous housing market matching models but for very different reasons. Typically, they relate to exogenous preference heterogeneity that affects the surplus from trade. The heterogeneity may be match-specific, as for instance, in Williams (1995) and Díaz and Jerez (2013). Alternatively, individuals may be inherently different as in Carrillo (2012), where agents differ in their intrinsic motivation to trade. We believe that preference heterogeneity is indeed relevant for housing market outcomes. However, we find it more likely that changes in household credit conditions rather than changes in preferences are key drivers of changes in aggregate housing market outcomes, such as the average time-on-the-market. This is one reason why we focus on asset heterogeneity and credit frictions.

banks less vulnerable to housing market fluctuations by reducing household leverage. In the model economy, reducing the maximum loan-to-value ratio indeed limits household leverage. However, by making potential home buyers more likely to be borrowing constrained, it effectively makes the housing market less liquid. This may complicate the situation for those home owners that need to sell for liquidity reasons.

We proceed as follows. In the next section, we describe the set-up, discuss the household problem and the matching process, define the recursive stationary equilibrium, and outline our numerical solution algorithm. In section 3, we discuss the calibration. We present the main results in section 4. Section 5 is a conclusion.

2 Model

2.1 Set-up

Time is discrete and there is a continuum of households of mass one. Households live forever. In each period, households work, consume nondurables, and occupy a house. The economy is small and open to international capital markets in the sense that the interest rate and the wage rate are exogenously determined.

Each household either owns or rents one house. In state $d = r$, the household is renting. In state $d = o$, the household owns the house it lives in. The share of owner houses out of total housing stock is fixed and equal to $m^o \in (0, 1)$. As a result, the share of households living in rental housing is $1 - m^o$.

We assume that owner and rental houses are different in a way that is relevant to some households only. Specifically, some households derive the same utility flow from rental and owner housing while others suffer a utility cost from living in rental housing. This tenure preference may change over time. In each period, households that do not suffer the utility cost may be hit by a tenure preference shock, which means that they suffer the utility cost if they continue to live in rental housing. Similarly, households that suffer the utility cost related to rental housing may be hit by a tenure preference shock which eliminates the utility cost.

Our interpretation of these tenure preference shocks relates to the fact that owner houses tend be larger than rental houses. While the rental market for smaller houses often works well, the rental market for larger houses is typically quite thin. Therefore, households that want to move to a large house, say because of having children, often need to buy it. In contrast, households that do not have a strong preference for larger houses may easily find a suitable rental house.[6]

The tenure preference state is denoted by $z = 1, 2$. In state $z = 1$, the household derives the same utility from owner and rental housing. In state $z = 2$, the household suffers a utility cost if it lives in rental housing. Given current state z, the probability of next period state z' is $P(z', z)$.

Each household will therefore be in one of the following four situations: i) Those with $d = r$ and $z = 1$ are renting without suffering a utility cost related to rental housing. We refer to them as 'happy renters'. ii) Those with $d = r$ and $z = 2$ are renting, but suffer a utility cost relative to owning. We refer to them as 'unhappy renters'. iii) Those with $d = o$ and $z = 1$ are owning but would not suffer a utility cost if they were renters. We refer to them as 'unhappy owners'. iv) Those with $d = o$ and $z = 2$ are owning and would suffer a utility cost if they were renters. We refer to them as 'happy owners'.

The rental market functions perfectly: a household can always find a rental house at a fixed exogenous rental rate. The market for owner housing, in contrast, is characterized by matching frictions. In order to trade, a buyer must first meet a potential seller and vice versa.

We assume that all unhappy renters and unhappy owners participate in the housing market, that is, they search for a house to buy or put their house for sale, while happy renters and happy owners do not.[7] Unhappy renters would like to buy to avoid the utility cost of rental housing. Unhappy owners would like to sell because of the cost of housing. This is because the equilibrium user cost of owner housing (capital and maintenance costs) will be higher than the rent since all households value owner housing at least as much as rental housing (given non-housing consumption) and some households strictly prefer owner housing to rental housing. Therefore, the unhappy owners pay the higher cost of owner housing but would receive the same utility flow from rental housing.[8]

Each period, households receive wage income εw_z, where $\varepsilon \in \{\varepsilon_1, ..., \varepsilon_{n_\varepsilon}\}$ is an iid income shock

[6] We could assume that all households suffer some utility cost from living in a rental house as opposed to a (larger) owner house. What matters here is that some households value owner houses more than others.

[7] The participation decision could be endogenized by assuming that there is a fixed cost of entering the market. Happy owners and happy renters are unlikely to gain from trade. See Diaz and Jerez (2013) for a similar discussion.

[8] Hence, the label 'unhappy'.

and w_z the average wage rate of those with tenure preference z. Probability of income shock ε_i is φ_i. By allowing the wage rate to depend on the tenure preference, we can capture the fact that owners have on average higher income than renters.[9] As we discuss below, this helps in replicating certain features of the empirical asset distribution which are important for the results. In addition, the advantage of having the persistent income shock being perfectly correlated with the tenure preference is that we do not have to introduce an additional state variable.

We think of the income and tenure preference shocks as imperfectly capturing certain relevant life cycle aspects. The story we have in mind is that young households first rent their house. As they get older, their income increases and they may also have children, which leads them to prefer a larger house and consider becoming home owners.

In each period, timing is the following. First, potential buyers (unhappy renters) and potential sellers (unhappy owners) are randomly matched and can meet at most one trading partner. Upon having met, they bargain over the price. If there exists a price that makes trade mutually beneficial, trade takes place and the price is determined by Nash bargaining with equal bargaining powers. The price will depend on the seller's and buyer's continuation values, which in turn depend on their asset positions. Next, unsuccessful matches break down and the transactions of successful matches take place. Buyers move to owner housing and sellers move to rental housing.[10] The renters pay the rent and the owners the maintenance cost. Finally, all households decide on non-housing consumption and financial saving or borrowing.

The periodic utility of the household is given by $u(c, z, d)$ where c denotes non-housing consumption. The interest rate is $R - 1$. Each household's financial asset position, a, evolves as

$$a' = Rs + \varepsilon' w',$$

where s denotes financial saving or borrowing and primes indicate next period values. In what follows, we refer to a as 'financial wealth'.

[9] We relate the earnings differences to the tenure preference, instead of the occupancy state, because we do not want the households to buy a house in order to attain higher earnings. In the equilibrium of the calibrated model, almost all households with tenure preference $z = 1$ are renters and almost all households with $z = 2$ are owners.

[10] We abstract from own-to-own trades. According to Wheaton and Lee (2009), in the US housing market, there are generally more purchases of homes by renters or new households than there are by existing owners. Having both own-to-own trades and rent-to-own trades would substantially complicate the model. See Anenberg and Bayer (2013) for a model where the choice of whether to first buy a new house or sell the current one is endogenous.

Borrowing is limited by a borrowing constraint. We require that $s \geq \underline{s}^d$ for $d = r, o$. We will later assume that $\underline{s}^r = 0$ and $\underline{s}^o < 0$, that is, only owners can borrow. These assumptions mean that home owners can costlessly refinance their mortgage.[11]

If a household does not buy or sell a house, its current non-housing consumption is

$$c = a - s - g, \tag{1}$$

where g is the direct cost of housing services. This cost equals the rent, $g = \upsilon$, for the renters and the maintenance cost, $g = \kappa$, for the owners.

If a renter buys a house with price p, its current non-housing consumption is

$$c = a - s - \kappa - (1 + \tau)p, \tag{2}$$

where $\tau \geq 0$ denotes a transaction tax.

Finally, if an owner sells a house, its current non-housing consumption is

$$c = a - s - \upsilon + p. \tag{3}$$

All households must be able to afford strictly positive non-housing consumption. If we denote a minimum consumption level by $c_{\min} > 0$ (close to zero), it directly follows from (2) that the maximum price that a buyer can pay is

$$p = \frac{a - \underline{s}^o - \kappa - c_{\min}}{1 + \tau}. \tag{4}$$

Similarly, from (3) it follows that the minimum price a seller needs to receive is

$$p = \underline{s}^r + \upsilon - a + c_{\min}. \tag{5}$$

2.2 Household problem and bargaining

We now define the household optimization problem recursively. Let $V^d(a, z)$ denote the value function before current period matches and $v^d(a, z)$ the value function conditional on not trading. The latter is determined as:

[11] Most mortgage contracts in Finland specify an amortization schedule and mortgage refinancing is relatively rare. However, mortgage contracts typically provide an option to pay interest only for several years and reverse mortgages are available.

$$v^d(a,z) = \max_{s \geq \underline{s}^d} \left\{ u(c,z,d) + \beta \sum_{j=1}^{2} P(j,z) \sum_{i=1}^{n_\varepsilon} \varphi_i V^d (Rs + \varepsilon_i w_j, j) \right\} \tag{6}$$
$$\text{subject to (1)}$$

where $\beta < 1$ is the subjective discount factor, $z = 1, 2$ and $d = r, o$. We use $s^d(a,z)$ to denote the associated savings policy.

Because happy renters and happy owners do not participate in the housing market

$$V^r(a,1) = v^r(a,1) \tag{7}$$
$$V^o(a,2) = v^o(a,2). \tag{8}$$

For unhappy renters and unhappy owners, we have to take into account the value of being matched with a potential trading partner. Let $W^b(a,\widetilde{a})$ denote the value of a potential buyer (unhappy renter) with financial wealth a matched with a potential seller (unhappy owner) with financial wealth $\widetilde{a}$. Similarly, let $W^s(\widetilde{a},a)$ denote the value of a potential seller with financial wealth a matched with a potential buyer with financial wealth $\widetilde{a}$.

Finally, let us denote the population of households with financial wealth a, occupancy state d, and tenure preference state z by $\mu^d(a,z)$. The mass of potential sellers is $m^s = \int \mu^o(a,1)\, da$ and the mass of potential buyers is $m^b = \int \mu^r(a,2)\, da$.

We can now define $V^r(a,2)$ as

$$V^r(a,2) = \phi^s \int W^b(a,\widetilde{a}) \frac{\mu^o(\widetilde{a},1)}{m^s} d\widetilde{a} + (1-\phi^s)\, v^r(a,2), \tag{9}$$

where ϕ^s denotes the probability of meeting a potential seller. The first term is the expected value of a match weighted by the probability of being matched with a potential seller. The second term is the value of a renter not trading weighted by the probability of not being matched.

Similarly, we define $V^o(a,1)$ as

$$V^o(a,1) = \phi^b \int W^s(\widetilde{a},a) \frac{\mu^r(\widetilde{a},2)}{m^b} d\widetilde{a} + \left(1-\phi^b\right) v^o(a,1), \tag{10}$$

where ϕ^b denotes the probability of meeting a potential buyer.

In order to determine $W^b(.)$ and $W^s(.)$, we need to find out, for all possible matches, whether the match leads to trade and if so, at what price. This can be computationally very costly when we discretize the state space with a reasonably fine grid for financial wealth. However, the computational costs can be reduced drastically by exploiting the fact that the surplus from trade can be expressed using the no-trade value functions defined above. The benefit of this approach is that one does not have to solve the household optimization problems when determining $W^b(.)$ and $W^s(.)$.

Consider a potential buyer with financial wealth a who has met a potential seller and contemplates buying the house with price p. If it buys the house, it becomes an owner and faces the same problem as a happy owner with financial wealth equal to $a-(1+\tau)p$. If it does not buy, it's value is the same as that of an unmatched renter. Hence, its surplus from trade can be written as

$$S^b(a,p) = v^o(a-(1+\tau)p, 2) - v^r(a, 2). \tag{11}$$

In the same way, if a potential seller with financial wealth $\widetilde{a}$ sells its house with price p, it becomes a happy renter with financial wealth equal to $\widetilde{a}+p$. If it does not sell, its value is the same as that of an unmatched owner. Therefore, its surplus from trade is

$$S^s(\widetilde{a},p) = v^r(\widetilde{a}+p, 1) - v^o(\widetilde{a}, 1). \tag{12}$$

If there exists a price p such that $S^b(a,p) \geq 0$ and $S^s(\widetilde{a},p) \geq 0$, the match leads to trade and the equilibrium price is

$$\arg\max_p \left\{S^b(a,p)\, S^s(\widetilde{a},p)\right\}. \tag{13}$$

We denote the equilibrium price by $p(a,\widetilde{a})$, where the first argument is the buyer's financial wealth and the second argument is the seller's financial wealth. The appendix shows that if trade takes place, the Nash bargaining price is uniquely determined.

Finally, let $Tr(a,\widetilde{a})$ be an indicator function that equals one if trade takes place and zero otherwise, when the buyer's and seller's financial wealth positions are a and $\widetilde{a}$, respectively. Hence, Tr is defined as

$$Tr(a,\widetilde{a}) = \begin{cases} 1 \text{ if } \exists\, p \text{ s.t. } S^b(a,p) \geq 0 \text{ and } S^s(\widetilde{a},p) \geq 0 \\ 0, \text{ otherwise} \end{cases} \tag{14}$$

We can now define $W^b(a,\widetilde{a})$ and $W^s(a,\widetilde{a})$ as

$$W^b(a,\widetilde{a}) = \begin{cases} v^o\left(a-(1+\tau)\,p\left(a,\widetilde{a}\right),2\right) \text{ if } Tr\left(a,\widetilde{a}\right)=1 \\ v^r\left(a,2\right) \text{ if } Tr\left(a,\widetilde{a}\right)=0 \end{cases} \tag{15}$$

$$W^s(a,\widetilde{a}) = \begin{cases} v^r\left(\widetilde{a}+p\left(a,\widetilde{a}\right),1\right) \text{ if } Tr\left(a,\widetilde{a}\right)=1 \\ v^o\left(\widetilde{a},1\right) \text{ if } Tr\left(a,\widetilde{a}\right)=0 \end{cases}. \tag{16}$$

2.3 Matching

We follow the related literature in assuming that trading frictions can be represented by a matching function, which specifies the number of trading opportunities in a given period. Empirical evidence suggests that in labor-market applications matching technology features constant returns to scale (see for instance Petrongolo and Pissarides, 2001).[12] To our knowledge, there are no studies testing the constant returns to scale hypothesis in the housing market.[13]

We use the simplest possible specification. We have two cases depending on the relative masses of potential buyers, m^b, and sellers, m^s. If $m^s \leq m^b$, the probability of being matched with a potential seller, ϕ^s, and the probability of being matched with a potential buyer, ϕ^b, are

$$\phi^b = \chi \text{ and } \phi^s = \chi\frac{m^s}{m^b} \tag{17}$$

otherwise

$$\phi^b = \chi\frac{m^b}{m^s} \text{ and } \phi^s = \chi, \tag{18}$$

where $\chi \in (0,1]$ is a matching parameter. Given the masses of potential buyers and potential sellers, the higher is χ, the more matches there are every period. If $\chi = 1$, traders in the short side of the market are guaranteed to meet a potential trading partner each period.

In our benchmark calibration, the ownership rate is 50%, so that there are equal numbers of owners and renters. We also assume that the tenure preference transitions are symmetric, so

[12] If matching does not feature constant returns scale, the probability of a match depends not only on the composition of those in the market (sellers/buyers), but also on the amount of sellers and buyers in the market.

[13] For a thorough discussion on trading frictions in asset markets, see e.g. Rocheteau and Weill (2011) and Caplin and Leahy (2011).

that $P(1,2) = P(2,1)$. Therefore, the stationary tenure preference distribution is such that half of the households strictly prefers owner to rental housing. Under these assumptions, the mass of potential buyers equals the mass of potential sellers in a stationary equilibrium.[14] This means that $\phi^b = \phi^s = \chi$.

It is important to note, however, that these symmetry assumptions are not essential for the workings of our model. In the sensitivity analysis, we allow the ownership rate to differ from 50%, but retain the symmetric preference shocks. In this case, the ownership rate does not match the (stationary) tenure preference distribution and there is shortage or oversupply of owner housing relative to what the households prefer.[15] Therefore, the mass of potential buyers differs from the mass of potential sellers and, as a result, the matching probabilities are not both given by χ.

2.4 Stationary equilibrium

We consider a stationary equilibrium where the distribution of households over their asset, tenure preference, and occupancy states is constant over time. The interest, wage and rental rates as well as the shares of owner and rental households are exogenously given.

Definition 1 *The stationary equilibrium consists of value functions* $\left\{V^d(a,z), v^d(a,z), W^b(a,\widetilde{a}), W^s(a,\widetilde{a})\right\}$*, household savings function* $s^d(a,z)$*, prices* $p(a,\widetilde{a})$*, indicator function* $Tr(a,\widetilde{a})$*, matching probabilities* ϕ^b *and* ϕ^s*, and distribution* $\mu^d(a,z)$ *(containing the information of* m^b *and* m^s*) which satisfy*

Matching:

Given $\mu^d(a,z)$*,* ϕ^b *and* ϕ^s *are determined by (17) or (18).*

Household optimization and bargaining:

a) Given $V^d(a,z)$*,* $s^d(a,z)$ *solves (6) with* $v^d(a,z)$ *as the resulting value function.*

b) Given $v^d(a,z)$*, surpluses* $S^b(a,p)$ *and* $S^s(a,p)$ *are determined by (11) and (12). Given the surpluses,* $Tr(a,\widetilde{a})$ *is determined from (14). For pairs* $\{a,\widetilde{a}\}$ *such that* $Tr(a,\widetilde{a}) = 1$*,* $p(a,\widetilde{a})$ *is determined by (13). Given* $Tr(a,\widetilde{a})$ *and* $p(a,\widetilde{a})$*,* $W^b(a,\widetilde{a})$ *and* $W^s(a,\widetilde{a})$ *are determined by (15) and (16).*

[14] This is true even if the mass of potential buyers initially differs from the mass of potential sellers.

[15] Also, for any given ownership rate different from 50%, it is possible to specify an asymmetric tenure preference transition matrix so that the resulting stationary distribution of tenure preferences matches the ownership rate.

c) Given $v^d(a,z)$, $V^r(a,1)$ *and* $V^o(a,2)$ *are determined by (7) and (8). Given* $v^d(a,z)$, $W^b(a,\widetilde{a})$, $W^s(a,\widetilde{a})$, *and* $\mu^d(a,z)$, $V^r(a,2)$ *and* $V^o(a,1)$ *are determined by (9) and (10).*

Consistency:

$\mu^d(a,z)$ *is the time invariant distribution that follows from the household savings policy, the outcome of the Nash bargaining, the probabilities* $P(z',z)$ *and* φ_i *for all* $i = 1, 2, ..., n_\varepsilon$, *and the exogenously determined ownership rate.*

2.5 Solving the model

When making decisions, households need to take into account the distribution of potential trading partners. This is the key computational challenge in solving the model. For instance, a potential seller wants to consider the distribution of asset holdings for all potential buyers. This is because its surplus from a match depends on the asset position of the potential buyer. Therefore, the value of not selling today depends on the whole distribution of traders.

When solving the model, we thus need to find a distribution which is consistent with households' information about the distribution and the resulting household behavior. In practice, we iterate over the distribution. We first make an initial guess for the distribution. We then use that distribution to determine the matching probabilities and the value functions of the households that are not in the market (equations (9) and (10)). After that we solve recursively for all the value and policy functions. Finally, we simulate the model to find the associated stationary distribution. The resulting distribution provides us with a new guess.

In experimenting with very different initial guesses for the distribution, we found that this iteration converges quite nicely. In addition, the equilibrium was always independent of the initial guess. We discuss computational issues in more detail in the appendix.

3 Calibration

We base our calibration on the Wealth Survey that was conducted by Statistics Finland in 2004. The survey contains register data about the asset holdings and incomes of a representative sample of Finnish households. The register data are supplemented by survey information. In the survey, households were asked, among other things, to give an estimate of the current market value of their house and to report the length of stay in their current dwelling.

We consider only households where the age of the household head is between 25 and 60, in order to focus on the working age population. In addition, we only use data from Helsinki Metropolitan Area (HMA) because we wish to focus on a single housing and labor market.[16] We also exclude households living in service housing. These restrictions imply that we have a data set of about 600 households.

We set the model period to be 3 months. Having a shorter time period might be useful, for instance, in order to describe the distribution of selling times. On the other hand, shortening the model period would further increase the computational costs. We set the interest rate parameter at $R = 1.01$ implying an annual interest rate of about 4%.

We construct two variables for the analysis: 'house value' and 'financial wealth'. House value is the value of primary residence as estimated by the household. Financial wealth is the sum of all financial assets, quarterly after-tax return to financial assets, quarterly after-tax non-capital income, less mortgage debt and quarterly interest payments on it.

We consider the following utility function

$$u(c, z, d) = \frac{c^{1-\sigma}}{1-\sigma} - I(z, d) f,$$

where

$$I(z, d) = \begin{cases} 1 \text{ if } z = 2 \text{ and } d = r \\ 0 \text{ otherwise} \end{cases}.$$

Parameter $\sigma > 0$ measures risk-aversion ($\sigma = 1$ corresponds to log-utility) and f is the utility cost of living in rental housing when having a preference for owner housing. We set $\sigma = 2$, which is a relatively conventional value.

In our data set, the ownership rate is 45%.[17] However, in the benchmark calibration, we focus on the simple case where the ownership rate equals 50% and the tenure preference shocks are symmetric. As discussed in section 2.3, these assumptions imply that in the stationary equilibrium

[16] The Helsinki Metropolitan area consists of four municipalities (Helsinki, Espoo, Vantaa and Kauniainen) and roughly one fifth of the overall population of Finland.

[17] Based on our calculations using the Wealth Survey, the ownership rate is 67% in the whole of Finland. In HMA without the age restriction we use in calibrating the model, the ownership rate is 51%.

there is no shortage or oversupply of owner housing relative to household preferences. Moreover, we can directly control the matching probabilities ϕ^b and ϕ^s with the matching parameter χ.

In our data, the average length of stay in current house is roughly 7 years. Based on this and the assumption of symmetric tenure preference shocks, the tenure preference transitions are given by

$$P(z', z) = \begin{bmatrix} 0.967 & 0.033 \\ 0.033 & 0.967 \end{bmatrix}.$$

The income shock can take two values, that is $\varepsilon \in \{\varepsilon_1, \varepsilon_2\}$. We interpret the first shock as unemployment. The unemployed households receive an unemployment compensation. In Finland, most workers are covered by an earnings-related unemployment insurance scheme. During the first two years of unemployment, the replacement rate is typically about 50%. We therefore set

$$\varepsilon_1 = 0.5 \text{ and } \varepsilon_2 = 1.$$

We choose the probabilities of the income shocks so that the unemployment rate is 8%, which implies

$$\varphi_1 = 0.08 \text{ and } \varphi_2 = 0.92.$$

We allow the wage income to depend on the tenure preference. In the data, the mean after-tax non-capital income of renters is 58% of the mean income of owners. We therefore set $\frac{w_1}{w_2} = 0.58$. We normalize the wage rates so that the average after-tax non-capital income equals 1. This results in $w_1 = 0.76$ and $w_2 = 1.32$ and means that the average income of those preferring to rent is $(0.08 * 0.5 + 0.92) * 0.76 = 0.73$ and those preferring to own is $(0.08 * 0.5 + 0.92) * 1.32 = 1.27$. In what follows, we refer to the after-tax non-capital income as simply 'income'.

In the data, the median rent-to-income ratio is 0.27. Hence, we set the rent at $v = 0.20$ $(0.2/0.73 \approx 0.27)$. We set the transaction tax at $\tau = 0.016$.[18] We assume that households can only borrow against owner housing. Therefore, the borrowing constraint for renters is $\underline{s}^r = 0$.

[18] This was the tax rate for dwellings in apartment buildings in Finland up until 2013 when it was set to 2% of the transaction price.

We are then left with five parameters: owners' borrowing limit, $\underline{s}^o$, maintenance cost, κ, matching parameter, χ, discount factor, β, and utility cost, f. We set these parameters so that the model matches certain empirical targets. First, we want the model to feature a realistic average house price-to-average income ratio. In the data, the median ratio of house value to quarterly income among owners is 17.2. Given that the average income of those preferring to own is 1.27 in the model, the average house price in the model should be 21.8.

Second, we want to capture the role of borrowing constraints as realistically as possible. As we show below, the housing market outcomes in the model are sensitive to changes in traders' asset positions only when they are close to being borrowing constrained. We therefore wish to target the share of buyers that are likely to be borrowing constrained. Those buyers have little savings relative to the value of the house they are contemplating buying. After buying a house, they are highly leveraged.

The asset positions of renters in our data offer little guidance in this respect because the data do not reveal which renters are considering buying a house or the value of the house they would like to buy. Fortunately, we know the length of stay in current house for each household. Therefore, instead of looking at the asset positions of all renters, we look at the asset positions of those who recently bought a house. These recent buyers have had very little time to repay their mortgage and should therefore have a very similar financial position as right after having bought the house. We define recent buyers as home owners that have lived in their current house for up to two years. We then match the share of recent buyers with a financial wealth-to-house-value ratio less than -0.8. In the data, that share is approximately 25%.

Third, we want the model to feature a realistic average time-on-the-market, so that households in the model economy face a realistic trade-off between trading now and waiting for a better match. Based on Eerola and Lyytikäinen (2012), the average time-on-the-market has been 55 days between 2003 and 2011. This corresponds to 0.61 model periods.[19]

[19] In the model, we compute the average time-on-the-market by following households that have just become unhappy owners. In the model, transactions occur in the beginning of a period. Therefore, an unhappy renter that buys a house in a given period, avoids paying the utility cost associated with rental housing for the whole period. Accordingly, if a household sells its house in the same period it enters the housing market, the time-on-the-market is recorded as zero. If it sells in the next period, the time-on-the-market is recorded as 1 period, or 90 days, and so on. Time-on-the-market is not recorded if a household is hit by a new tenure preference shock before selling the

Fourth, we choose the borrowing limit for owners, $\underline{s}^o$, so that it reflects a realistic down payment requirement for mortgages. In 2010, about half of the housing loans for first time buyers exceeded 90% of the house value (Financial Supervisory Authority, 2011). We assume that owners can borrow up to 95% of the average house price. Finally, in our data, the average annual maintenance cost of owner-occupiers is 1.6% of the average house value. We use this information to pin down the maintenance cost κ.

To summarize, we choose β, f, χ, $\underline{s}^o$, and κ so as to match the following targets: i) Average house price equal to 21.8 (median house value-to-income ratio in the data), ii) share of recent buyers with financial wealth-to-house value ratio less than -0.8 equal to 0.25, iii) average time-on-the-market equal to 0.61 model periods, iv) owners can borrow up to 95% of the average house price, v) average annual maintenance cost is 1.6% of the average house price.

Given the targeted average house price, the last two targets directly imply $\underline{s}^o = -0.95 * 21.8 = -20.71$ and $\kappa = (0.016 * 21.8)/4 = 0.0872$. Targets i)-iii) in turn depend on all three remaining parameters, β, f, χ. With parameter values $\beta = 0.9865$, $f = 0.335$, and $\chi = 0.7$, the model closely matches also targets i)-iii).

Table 1 shows selected percentiles of the distribution of the financial wealth-to-house value ratio in the data and the model. For the table, we calculated, for each owner-occupier in the data and in the model, the financial wealth-to-house value ratio. This ratio is close to the usual loan-to-value ratio. In the data, 'recent buyers' refers to owners who have lived in their current house up to two years. In the model, it refers to households who have become owners within the last 8 model periods.

Table 1 here

The model roughly replicates the left tail of the two empirical distributions. In particular, the model is consistent with two important features of the data. First, a non-trivial share of all owner households are very highly leveraged.[20] Second, recent buyers are typically even more leveraged

house and withdraws the house from the market.

[20] Because of higher house prices, home owners living in the HMA are typically more leveraged than households living in other parts of Finland. Moreover, Finnish households in general have little private pension savings because the mandatory pension system is quite generous. However, in an international comparison, households in our data are unlikely to be exceptionally highly leveraged. For instance, according to the OECD, the aggregate gross

than other home owners suggesting that borrowing constraints are particularly relevant for the potential buyers. As we discuss below, the reason why recent buyers are more leveraged than other owners relates to the correlation between tenure preference and income.

To be sure, our model economy features much less dispersion in these financial wealth-to-house value ratios than the data. This is not surprising given that we abstract from e.g. life cycle features. However, as we show below, it is mainly the left tail of this distribution that matters for housing market outcomes in the model economy.

4 Results

4.1 Household policies and price determination

Let us first briefly discuss the household savings policy, illustrated by figure 1. In the figure, current financial wealth is on the horizontal axis.[21] The vertical axis shows the difference between the expected next period financial wealth (that is, $Rs^d(a, z) + E\varepsilon w$) and current financial wealth. If this difference is positive (negative), the household is expected to become wealthier (poorer). The left hand panel shows the savings policy for renters and the right hand panel that for owners separately for those on the market (unhappy owners and unhappy renters) and those not on the market (happy renters and happy owners).

Figure 1 here

For very low asset holdings, any increase in the current financial wealth is spent on non-housing consumption in the current period. Therefore, an increase in current financial wealth is associated with a one-to-one reduction in the difference between expected future financial wealth and current financial wealth. This happens as long as households are borrowing constrained. Borrowing

household debt-to-income ratio in 2004 was 82% in Finland, 104% in Germany, and 123% in the US. Since then, this ratio has increased in most OECD countries, including Finland. Cowell et al. (2012) compare household net worth distribution in 5 countries. Table 1 in their paper suggests that the left tail of this distribution is quite similar in Finland, US, UK, and Sweden.

[21] The lowest financial wealth levels in the figures correspond to the maximum and minimum prices defined in (4) and (5). See the appendix for details.

constrained owners borrow up to $-\underline{s}^o$ and borrowing constrained renters choose to save nothing ($\underline{s}^r = 0$). For those close enough to the borrowing constraint, the expected next period financial wealth is nevertheless higher than current financial wealth because financial wealth includes the wage income and the unemployment benefit.[22]

For a given level of financial wealth, unhappy renters and happy owners save more than happy renters or unhappy owners. This reflects the fact that unhappy renters and happy owners expect their income to decrease sometime in the future (as $w_2 > w_1$). Unhappy renters also expect to spend more on housing in the future since the user cost of owner housing is higher than that of rental housing.

Figure 2 illustrates how the Nash bargaining outcome depends on potential buyer's and seller's asset positions. The horizontal axis shows the ratio of buyer's or seller's financial wealth to the average house price. For sellers, this ratio is close to the usual loan-to-value ratio. The left hand panel plots the Nash bargaining price as a function of seller's asset position and the right hand panel as a function of buyer's asset position. Both panels show two different cases: one where the potential trading partner is relatively poor in terms of financial wealth and another where the potential trading partner is relatively wealthy. For some combinations of the seller's and buyer's financial wealth, a match does not result in trade.

Figure 2 here

Consider first the left hand side of the figure and the case of a relatively wealthy buyer. When the seller is close to the borrowing constraint, the Nash bargaining price is relatively low. Selling the house allows a highly leveraged owner to smooth consumption over time. For a given price, these households benefit more from trade than wealthier sellers. Therefore, the Nash product is maximized with a relatively low price. However, the need to sell for liquidity reasons diminishes quickly as we increase seller's financial wealth. This means that the outside option of the seller increases rapidly. Hence, for there to be trade, the price must also increase rapidly. Further away from the borrowing constraint, the price curve becomes almost flat. Wealthier sellers do not need

[22]For instance, the expected next period financial wealth for a happy renter with no savings is approximately 0.75. This is much higher than the lowest possible realization of the financial wealth level (i.e., no savings and the worst income shock).

to sell in order to smooth non-housing consumption. Therefore, they all face the same trade-off between selling today and waiting for a better match. Hence, the price does not depend on seller's asset position.

When looking at the case of a relatively poor buyer, one observes that trade only occurs if also the seller is relatively poor. Because of the borrowing constraint, a poor buyer is only able to trade if the price is relatively low. However, when faced with such a buyer, a wealthier seller, who does not have to sell for liquidity reasons, prefers to wait for a better match.

Similarly, the right hand side panel shows that when the buyer is relatively poor, trade only occurs if the seller is poor as well. Because of the borrowing constraint, a buyer with very little savings is unable to pay a price that would satisfy a wealthier seller. Because of the desire for consumption smoothing, the price increases rapidly with buyer's financial wealth at low asset levels. However, the price curve does not flatten out as in the left hand panel. A wealthier buyer is always willing to pay more than a poorer one in order to avoid the utility cost associated with rental housing today rather than later.

Figure 3 shows the combinations of buyer's and seller's asset positions (relative to the average house price) that result in trade. The figure only covers matches where traders are relatively poor. Even very poor buyers end up buying if matched with a very poor seller trading for liquidity reasons. As the seller's financial wealth increases, the potential buyer needs to be wealthier for the match to result in trade.

Figure 3 here

In the absence of matching frictions, all trades (within the same period or in the stationary equilibrium) would take place at the same market price and all households could count on being able to buy or sell at the prevailing market price. One important implication of matching frictions is that poor sellers that would like to sell quickly for liquidity reasons may not be able to sell or may have to sell at a relatively low price. In this sense, matching frictions make borrowing constraints more relevant for household welfare.

4.2 Frictions and housing market outcomes

In this section, we analyze how the housing market outcomes in the stationary equilibrium depend on the matching friction and the borrowing constraint. We vary one friction at a time, keeping all other parameters fixed, and recompute the stationary equilibrium. We first vary the matching parameter χ. We consider values $\chi = 1.0$ and $\chi = 0.4$ (benchmark: $\chi = 0.7$). We then tighten the borrowing constraint for owners by setting $\underline{s}^o = -18.53$ and $\underline{s}^o = -16.35$ (benchmark: -20.71). These numbers correspond to a borrowing limit that is 85% and 75% of the average house price in the benchmark calibration, respectively.

We report changes in the average house price and the average asset positions for owners and renters. We also consider the average time-on-the-market, the share of matches that result in trade, and the coefficient of variation of house prices.

The average time-on-the-market is a commonly used measure of housing market conditions. In the model, it also indirectly measures the welfare cost related to the misallocation of housing units because it reflects the share of households that pay the utility cost associated with rental housing. The utility cost is borne by unhappy renters each period they are unable to move to owner housing. In the absence of matching and credit frictions, no one would pay this cost. In the benchmark calibration, the share of households that pay the utility cost is 1.0%. This share changes almost one-to-one with the average time-on-the-market. There are two reasons why unhappy renters do not trade immediately. First, since $\chi < 1$, some potential buyers are not matched with a potential seller. Second, some matches do not result in trade. As we explain below, the main reason for this is the borrowing constraint. In the benchmark calibration, 13% of the matches do not result in trade.

Also price dispersion is closely linked to the frictions we are interested in. Since all owner houses are identical in the model, absent matching frictions, they would sell at the same price. If better matches are instantaneously available, all differences in prices stemming from the characteristics of the current trading partners must vanish. In other words, some matching frictions are needed to create any price dispersion. However, matching frictions alone are not able to generate price dispersion, if all matches are identical. If all potential future trading partners are alike and identical to the current trading partner, waiting for a new match can never be profitable. Therefore, in the model, any house price dispersion stems from matching frictions together with wealth heterogeneity.

In the stationary equilibrium of the benchmark calibration, the very lowest realized house price is 20.84 or about 4.5% below the average price. Hence, the model can account for non-trivial deviations from the average price. When looking at the effects of frictions on price dispersion, we use the coefficient of variation of house prices because it is a scale-neutral measure of dispersion. In the benchmark calibration, the coefficient of variation for realized house prices is 0.37%. The lowest house prices correspond to matches were *both* trading partners are close to the borrowing constraint. However, given the stationary asset distribution, such matches are very rare. Most transactions take place at a price that is very close to the average price. This explains why the coefficient of variation for realized house prices is relatively small.

Table 2 displays the results as percentage changes relative to the benchmark calibration. The first three columns report the relative changes in the average financial wealth of owners ($\overline{a}^o$) and renters ($\overline{a}^r$) and the average house price ($\overline{p}$). The last three columns report the relative changes in the average time-on-the-market (tom), the coefficient of variation of house prices ($cv(p)$), and the share of matches that result in trade (tr).

Table 2 here

Consider first the matching frictions. Changes in the matching parameter χ have virtually no effect on households' average financial asset holdings nor the average house price. Naturally, they do affect our measures of market inefficiency. Reducing matching frictions by increasing χ from 0.7 to 1.0 decreases the average time-on-the-market by 73%. This directly follows from buyers and sellers being more likely to be matched. There is a small countervailing effect, however, because now the share of matches that result in trade is smaller. This is because a reduction in matching frictions makes deferring trade less costly. Interestingly, this effect also shows up in reduced price dispersion (by some 25%). Because deferring trade is less costly, the bargaining outcome becomes less sensitive to the asset positions of the traders.

Increasing matching frictions has opposite effects: The average time-on-the-market goes up as trading opportunities are less frequent. However, at the same time, a larger share of matches leads to trade because waiting for a better match is more costly. This also means that a larger share of bargaining outcomes are influenced by the asset positions of the traders. Therefore, also price dispersion is larger.

Consider then the borrowing constraint. Not surprisingly, tightening the borrowing constraint increases households' average financial wealth. This is because more savings are required in order to be able to buy a house. The effects are relatively large, reflecting the fact that many home owners are close to the borrowing constraint in the benchmark calibration. For instance, lowering the maximum mortgage by about 10% (from 20.71 to 18.53) increases owners' average financial wealth by 18%. At the same time, a tighter borrowing constraint implies a lower average house price by 6%. The more drastic tightening of the borrowing constraint (lowering the maximum mortgage by some 20%) roughly doubles these effects.

Tightening the borrowing constraint leads to a substantially longer average time-on-the-market. Lowering the maximum mortgage by about 10% increases the average time-on-the-market by 75%, while the more drastic reduction increases it by 172%. The increase in the average time-on-the-market reflects the fact that a smaller share of matches result in trade. Tightening the borrowing constraint diminishes the surplus from trade for matches were the potential buyer is relatively poor. As a result, even though households are on average wealthier, there are more matches that do not lead to trade.

Tightening the borrowing constraint also increases the price dispersion. Lowering the maximum mortgage by about 10% or 20% increases the coefficient of variation of house prices by 31% and 63%, respectively. In the latter case, we also find that the very lowest realized house prices are 11% below the average price (compared to about 4% in the benchmark case). As the borrowing constraint is tightened, it becomes relevant to a larger share of potential buyers, even though renters' average financial wealth also increases. As a result, buyers end up trading only if they are matched with a seller that needs to sell for liquidity reasons. In those cases, the realized price is relatively low.

More generally, these results illustrate how credit frictions interact with the effects of matching frictions. Tightening the borrowing constraint increases the average time-on-the-market, much like increasing matching frictions would do. While borrowing constraints do not alter the frequency of finding a trading opportunity, they influence the share of successful matches. Moreover, while some matching frictions are needed to create any price dispersion between identical houses, tightening the borrowing constraint increases price dispersion substantially.

The intuition behind both the smaller share of successful matches and the increased price dispersion relates to the fact the bargaining outcome depends on traders' asset positions mainly through the borrowing constraint. When the borrowing constraint is very lax, all matched sellers and buyers face a similar trade-off between trading now and deferring trade. As a result, there is no reason to wait for a better match and trade takes place at (approximately) the same price in all matches. A tighter borrowing constraint creates heterogeneity in the match surplus because of liquidity concerns. As a result, fewer matches result in trade and the price dispersion (of identical houses) is larger.

4.3 Sensitivity analysis

In this section, we consider alternative parametrizations. Our main interest is in studying whether the above conclusions regarding the effects of the borrowing constraint are sensitive to changes in some key parameters. We vary the ownership rate. In addition, we consider lower risk aversion (logarithmic utility), and a somewhat lower discount factor than in the benchmark calibration.

When varying these parameters, we recalibrate the utility cost f so as to get the same average house price as in the benchmark calibration. We do not recalibrate other parameters. We first report how these changes affect housing market outcomes relative to the benchmark case. We then consider the effects of tightening the borrowing constraint in these alternative parametrizations.

In the benchmark calibration, the supply and demand for owner and rental houses is balanced in the sense that the (fixed) ownership rate equals the share of households that prefer owner to rental housing. Here we consider ownership rates of 45% and 55%. We retain the symmetric tenure preference shocks of the benchmark calibration. As a result, relative to the household preferences, there is now either a shortage or oversupply of owner houses. Moreover, the matching probabilities are no longer both directly given by χ.[23]

Table 3 displays changes in selected statistics relative to the benchmark calibration. The first row of the table relates to the case where the ownership rate is 45% and there are more buyers

[23] When we increase (decrease) the ownership rate, we increase (decrease) the supply of owner housing relative to what the households would prefer. Increasing (decreasing) the ownership rate without changing other parameters would decrease (increase) the average house price. Therefore, in order to target the same average house price, the mismatch cost parameter f must be higher (lower) than in the benchmark when the ownership rate is higher (lower) relative to the benchmark.

than sellers in the market. In this case, the probability of a potential buyer meeting a seller is relatively low (22%), whereas the probability of a seller meeting a potential buyer is the same as in the benchmark calibration (70%). Since buyers are less likely to meet a seller, they will accept bargaining outcomes that were not successful in the benchmark. Therefore, relative to the benchmark calibration, average time-on-the-market is shorter and price dispersion is larger but the differences are not substantial.[24]

Increasing the ownership rate to 55%, means that the probability of a seller being matched with a potential buyer is relatively low (21%) while the buyer's likelihood to meet a seller is the same as in the benchmark case. As a result, the average time-on-the-market is substantially longer. However, the low probability of meeting a buyer also means that deferring trade is more costly for the seller. Therefore, the seller is more willing to sell at a relatively low price when she is matched with a borrowing constrained buyer. As a result, both the share of matches that result in trade and price dispersion are larger.

The logarithmic utility function results in much lower average financial wealth than the benchmark calibration. Because households are less risk-averse in this case, being borrowing constrained is not as big a concern. The average time-on-the-market is virtually unchanged relative to the benchmark calibration. This reflects two opposite effects. On the one hand, the fact that households are less keen on smoothing consumption over time makes the borrowing constraint less relevant for the bargaining outcome. On the other hand, the fact that households are on average poorer makes it more likely that at least one of the traders is close to being borrowing constrained.

Finally, assuming a lower discount factor decreases the average financial wealth increasing the importance of the borrowing constraint. In this case, however, households are still equally concerned about consumption smoothing as in the benchmark calibration. As a result, the average time-on-the-market is longer and price dispersion larger than in the benchmark calibration.

Table 3 here

Table 4 shows the effect of a tightening of the borrowing constraint in the different calibrations.

[24] It should be noted, however, that even though the average time-on-the-market for the sellers is somewhat shorter than in the benchmark case, potential buyers may have to stay longer in the market than in the benchmark case, because they are less likely to meet a seller.

In each case, we lower the maximum mortgage by about 10%. For comparison, the table also repeats the effects of the same experiment in the benchmark calibration. Qualitatively, the effects are the same across all calibrations. Renters' and owners' average financial wealth, average time-on-the-market and price dispersion increase while the average house price and the share of matches that result in trade decrease. Quantitatively, when looking at the average time-on-the-market, the effects are large except when the ownership rate is 55%. In this case, however, the average time-on-the-market is very high to start with. The absolute increase is in fact quite similar in all cases. The effect on price dispersion does seem to depend on the ownership rate, but is very similar across all other cases. The effect on the share of matches that result in trade is remarkably similar in all cases.

Table 4 here

5 Discussion

We have developed a model of the housing market that features both credit and matching frictions. We described how the outcome of the bargaining process depends on buyer's and seller's asset positions and the borrowing constraint. In addition, we showed that the borrowing constraint works to magnify the effects of matching frictions. For instance, while some matching frictions are needed to generate any idiosyncratic price dispersion, tightening the borrowing constraint increases price dispersion substantially. This is because the borrowing constraint makes the outcome of the bargaining process more sensitive to traders' asset positions. Together with asset heterogeneity, the borrowing constraint also implies that some matches do not result in trade. Therefore, the average time-on-the-market is very sensitive to credit market conditions. More generally, tightening the borrowing constraint makes the housing market less liquid.

We view our model as a first step in the development of a theory of housing markets that takes into account both matching and credit frictions. The results of the present paper can be extended and complemented in several ways. For instance, credit frictions might become even more important for housing market outcomes if we allow for endogenous housing market participation together with 'thick-market effects' (as in Ngai and Tenreyro 2014).

In future work, it should also be possible to consider aggregate dynamics (as in, for instance, Díaz and Jerez 2013). One potentially very interesting question in this respect is the role of borrowing constraints for house price dynamics. Even a moderate fall in house prices may reduce the net worth of highly leveraged households drastically. Stein (1995) and Ortalo-Magné and Rady (2006) have described how such a reduction in households' net worth may feed back into house prices through household borrowing constraints and create a multiplier effect. However, in models where the spot market for housing works perfectly, borrowing constraints can influence house price dynamics substantially only if the share of borrowing constrained households is very large (see Eerola and Määttänen 2012). This is partly because, in these settings, households that are not borrowing constrained, will always take advantage of any future house price predictability that may be caused by borrowing constraints. Matching frictions, however, may limit the ability of non-constrained households to react to anticipated capital gains. Matching frictions might therefore make borrowing constraints more relevant for house price dynamics.

Appendix

Nash bargaining price

In this appendix, we show that the Nash bargaining price is unique. The value function of the household in occupancy state d and tenure preference state z with financial wealth a is

$$v^d(a,z) = \max_{s \geq \underline{s}^d} \left\{ u(c,z,d) + \beta \sum_{j=1}^{2} P(j,z) \sum_{i=1}^{n_\varepsilon} \varphi_i V^d(Rs + \varepsilon_i w_j, j) \right\}.$$

Denote the savings policy that solves the household problem by $s^d(a,z)$. The savings policy is determined by the first-order condition

$$-\frac{\partial u(c,z,d)}{\partial c} + \beta R \sum_{j=1}^{2} \sum_{i=1}^{n_\varepsilon} P(j,z) \varphi_i \frac{\partial V^d(Rs + \varepsilon_i w_j, j)}{\partial a'} + \mu^d = 0, \tag{A1}$$

where μ^d is the Kuhn-Tucker multiplier on the borrowing constraint $s \geq \underline{s}^d$.

Taking into account that households optimally choose savings after trade, we can write the surplus from trade for the potential buyer and the potential seller as

$$\begin{aligned} S^b(a,p) &= u\left(c^{trade}, 2, o\right) + \beta \sum_{j=1}^{2} \sum_{i=1}^{n_\varepsilon} P(j,2) \varphi_i V^o\left(Rs^o(a - (1+\tau)p, 2) + \varepsilon_i w_j, j\right) \\ &\quad - v^r(a,2) \\ S^s(\widetilde{a},p) &= u\left(\widetilde{c}^{trade}, 1, r\right) + \beta \sum_{j=1}^{2} \sum_{i=1}^{n_\varepsilon} P(j,1) \varphi_i V^r\left(Rs^r(\widetilde{a} + p, 1) + \varepsilon_i w_j, j\right) \\ &\quad - v^o(\widetilde{a},1) \end{aligned}$$

where

$$\begin{aligned} c^{trade} &= a - \kappa - (1+\tau)p - s^o(a - (1+\tau)p, 2) \\ &\quad \text{and} \\ \widetilde{c}^{trade} &= \widetilde{a} - \upsilon + p - s^r(\widetilde{a} + p, 1) \end{aligned}$$

Using the above expressions for the surpluses and taking into account condition (A1), the effect of price changes on the surplus of the buyer and the seller can be written as

$$
\begin{aligned}
\frac{\partial S^b(a,p)}{\partial p} &= -(1+\tau)\frac{\partial u\left(c^{trade},2,o\right)}{\partial c} \\
&\text{and} \\
\frac{\partial S^s(\widetilde{a},p)}{\partial p} &= \frac{\partial u\left(\widetilde{c}^{trade},1,r\right)}{\partial c}
\end{aligned} \tag{A2}
$$

The surplus from trade only depends on the price through its effect on current non-housing consumption. (The standard Kuhn-Tucker optimality conditions imply that $\mu^d > 0$ if the borrowing constraint is binding. In this case, however, $\frac{\partial s^d(a,z)}{\partial a} = 0$. If, in turn, the borrowing constraint is not binding, $\mu^d = 0$.)

Assume that $S^b(a,p) > 0$ and $S^s(\widetilde{a},p) > 0$. Then the Nash bargaining price p maximizes

$$
S(a,\widetilde{a},p) = S^b(a,p)\, S^s(\widetilde{a},p)\,.
$$

The first order condition for the optimal price is given by

$$
\frac{\partial S^b(a,p)}{\partial p} S^s(\widetilde{a},p) + \frac{\partial S^s(\widetilde{a},p)}{\partial p} S^b(a,p) = 0
$$

By using (A2) this can be written as

$$
-(1+\tau)\frac{\partial u\left(c^{trade},2,o\right)}{\partial c} S^s(\widetilde{a},p) + \frac{\partial u\left(\widetilde{c}^{trade},1,r\right)}{\partial c} S^b(a,p) = 0. \tag{A3}
$$

The second order condition is

$$
\begin{aligned}
\frac{\partial^2 S(a,\widetilde{a},p)}{\partial p \partial p} = {} & \frac{\partial^2 u\left(\widetilde{c}^{trade},1,r\right)}{\partial c \partial c}\left(1 - \frac{\partial s^r(\widetilde{a}+p,1)}{\partial a}\right) S^b(a,p) \\
& -2(1+\tau)\frac{\partial u\left(\widetilde{c}^{trade},1,r\right)}{\partial c}\frac{\partial u\left(c^{trade},2,o\right)}{\partial c} \\
& +(1+\tau)^2 \frac{\partial^2 u\left(c^{trade},2,o\right)}{\partial c \partial c}\left(1 - \frac{\partial s^o(a-(1+\tau)p,2)}{\partial a}\right) S^s(\widetilde{a},p)
\end{aligned}
$$

Together with $1-\frac{\partial s^r(\widetilde{a}+p,1)}{\partial a} > 0$ and $1-\frac{\partial s^o(a-(1+\tau)p,2)}{\partial a} > 0$, this implies that $\frac{\partial^2 S(a,\widetilde{a},p)}{\partial p \partial p} < 0$. Therefore, whenever trade is mutually beneficial, (A3) determines a unique equilibrium price.

Computational issues

We use the following algorithm to solve the model: i) Guess distribution $\mu^d(a,z)$ and determine the matching probabilities ϕ^s and ϕ^b. ii) Solve for the value and policy functions using value function iteration. iii) Simulate to find the resulting stationary distribution. iv) Update the guess for distribution. v) Repeat i)-iv) until the distribution has converged.

In step ii), given a guess for $V^d(a,z)$, we first solve for $v^d(a,z)$ from (6). We then determine $Tr(a,\widetilde{a})$ and $p(a,\widetilde{a})$. It is clear that $S^b(a,p)$ is decreasing and $S^s(a,p)$ is increasing in price: other things equal, the buyer's surplus from trade is always smaller and the seller's larger the higher the price. We therefore begin by calculating prices $\overline{p}^b$ and $\underline{p}^s$ such that $S^b\left(a,\overline{p}^b\right)=0$ and $S^s\left(a,\underline{p}^s\right)=0$. If $\overline{p}^b<\underline{p}^s$, there is no price that would render trade mutually beneficial. If instead $\overline{p}^b\geq\underline{p}^s$, we know that trade takes place. In this case, we find $p(a,\widetilde{a})\in[\underline{p}^s,\overline{p}^b]$ by solving (13), which is a one dimensional maximization problem. Given $Tr(a,\widetilde{a})$ and $p(a,\widetilde{a})$, we first determine $W^b(a,\widetilde{a})$ and $W^s(a,\widetilde{a})$ from (15) and (16). We then solve $V^d(a,z)$ for $d=r,o$ and $z=1,2$ from (7), (8), (9), and (10).

Of course, we need to use discrete grids of possible financial wealth levels for both owners and renters. We use cubic splines to interpolate value functions $V^d(a,z)$ and $v^d(a,z)$ between grid points. Since the match values $W^b(a,\widetilde{a})$ and $W^s(a,\widetilde{a})$ feature kinks around asset levels where trade becomes mutually beneficial, we apply linear interpolation to them.

For a given match and a given price, we compute the surplus from trade using value functions $v^d(a,z)$ according to (11) and (12). The minimum financial wealth levels that we may need to consider correspond to the maximum and minimum prices defined in (4) and (5). The minimum financial wealth is $\underline{s}^r+\upsilon+c_{\min}$ for renters and $\underline{s}^o+\kappa+c_{\min}$ for owners. We assume $c_{\min}=0.01$. In the benchmark calibration, these limits are approximately 0.21 and -20.61, respectively. These limits provide the lower bounds for the financial wealth grids. We set the maximum financial wealth levels in the benchmark at 51.8 for renters and at 30 for owners. There is no mass close to these limits in the stationary distribution. The difference between these limits corresponds to the average house price.

We approximate the distribution by a discrete density function. The financial wealth of a household in occupancy state d is forced to belong to a set $A^d=\{a_1^d,a_2^d,...,a_m^d\}$. As usual, we use a lottery to force next period financial wealth to be on the grid A^d (see algorithm 7.2.3 in Heer and Maussner, 2010).

In step iii), we first determine savings policy for all unmatched households as well as the outcome of the bargaining process and the associated savings policy for all possible matches. That is, we determine, among other things, $Tr\left(a_j^r, a_k^o\right)$ and $p\left(a_j^r, a_k^o\right)$ for all $j = 1, 2, .., m$ and $k = 1, 2, ..., m$. Since $Tr\left(a, \widetilde{a}\right)$ is a discrete function and the price is not defined everywhere, we do not interpolate these functions, but solve for the outcome of the bargaining process in the same way as in step ii).

We then determine three transition probability matrices. The first one determines transition probabilities from a given current state (a, d, z) to different next period states for unmatched households. The next period financial wealth is determined by the savings policy and the income shock. With two income shocks and two tenure preference states (and the lottery), an unmatched household in a given state may generally move to 8 different states. The second matrix determines probabilities with which a potential buyer (unhappy renter) with a given financial wealth $a \in A^r$ that is matched with a potential seller with a given financial wealth $\widetilde{a} \in A^o$ moves to different next period states. Given the match, there are again generally 8 different states to which the household can move. Similarly, the third matrix determines the probabilities at which a potential seller that is matched with a given potential buyer moves to different next period states. Given these transition probability matrices and an initial density function, we iterate over the density function to find the stationary distribution. At this stage, we need to take into account the probabilities of different matches which are in turn determined by the density function. For instance, of unhappy renters in state $\left(a_j^r, r, 2\right)$ that are matched with a potential seller, fraction $\mu^o\left(a_k^o, 1\right) / \sum_{l=1}^{m} \mu^o\left(a_l^o, 1\right)$ are matched with a potential seller with financial wealth equal to a_k^o.

The results reported here have been computed using 150 non-linearly spaced gridpoints for financial wealth in the value function and 200 non-linearly spaced gridpoints for financial wealth in the density function. Before we simulate to find the stationary distribution in step iii), we need to determine the outcome of the bargaining process for 200^2 combinations of seller's and buyer's financial wealth. Further increasing the number of gridpoints had virtually no impact on the reported statistics of the benchmark calibration.

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	Owners, data		Owners, model	
Percentile	All	Recent buyers	All	Recent buyers
5th	-0.85	-0.93	-0.85	-0.88
10th	-0.69	-0.87	-0.82	-0.85
25th	-0.40	-0.80	-0.72	-0.82
50th	-0.01	-0.50	-0.58	-0.76
95th	0.69	0.29	-0.09	-0.29

Table 1: Distribution of financial wealth-to-house value ratio in the data and in the model.

Note: The table shows the financial wealth-to-house value ratio for all households in the model and our data. In the data, 'recent buyers' refers to owners who have lived in their current house up to two years. In the model, it refers to households who have become owners within the last 8 model periods.

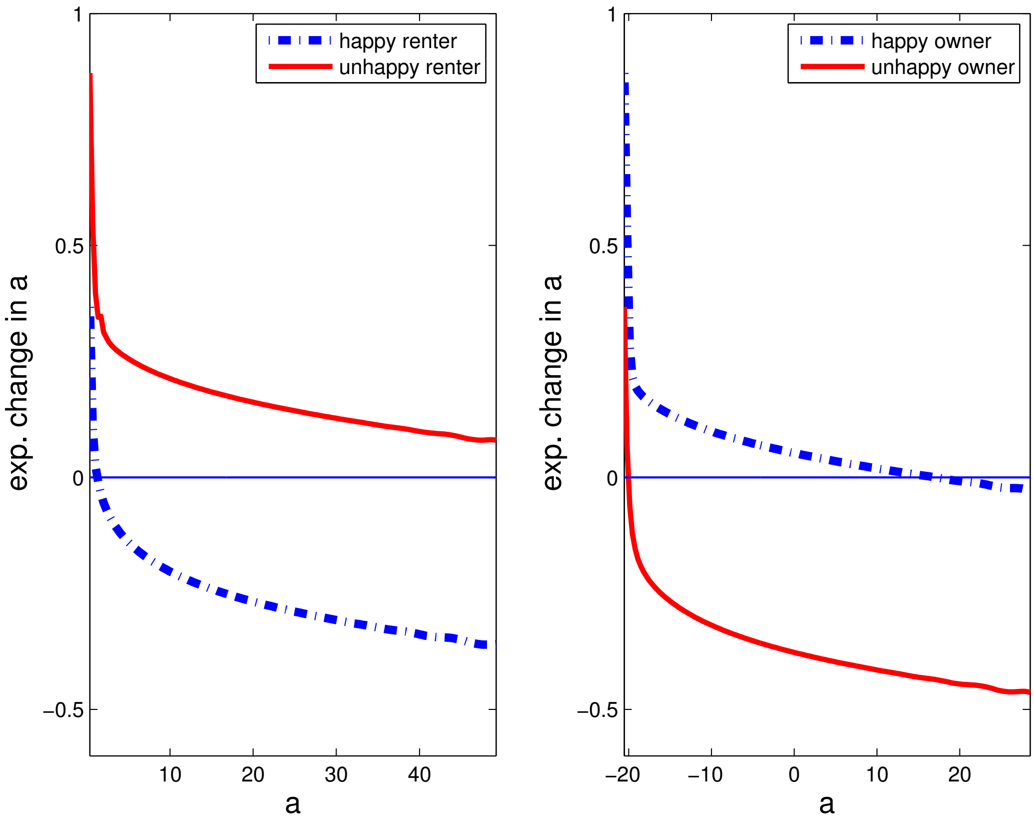

Figure 1: Renters' (left) and owners' (right) savings policy.

Note: The figure plots the difference between the expected next period financial wealth and current financial wealth as a function of current financial wealth (a).

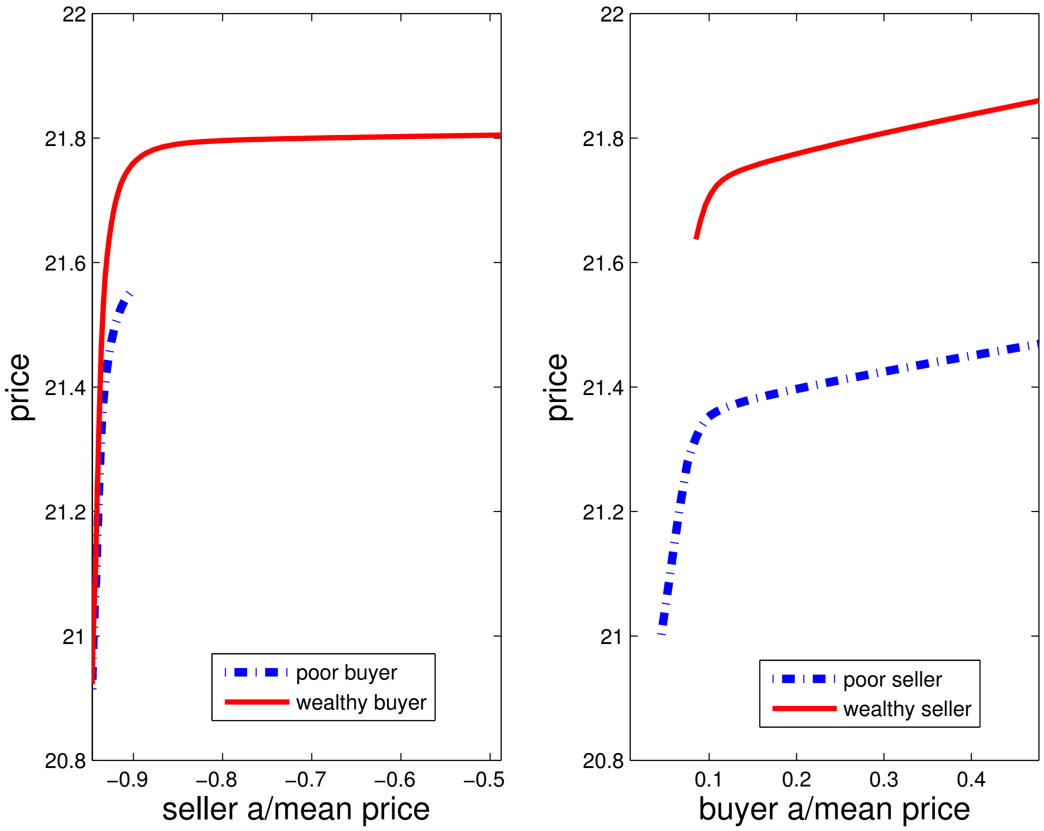

Figure 2: Price as a function of seller's (left) and buyer's (right) asset position.

Note: Asset positions are described with the financial wealth-to-average house price ratio.

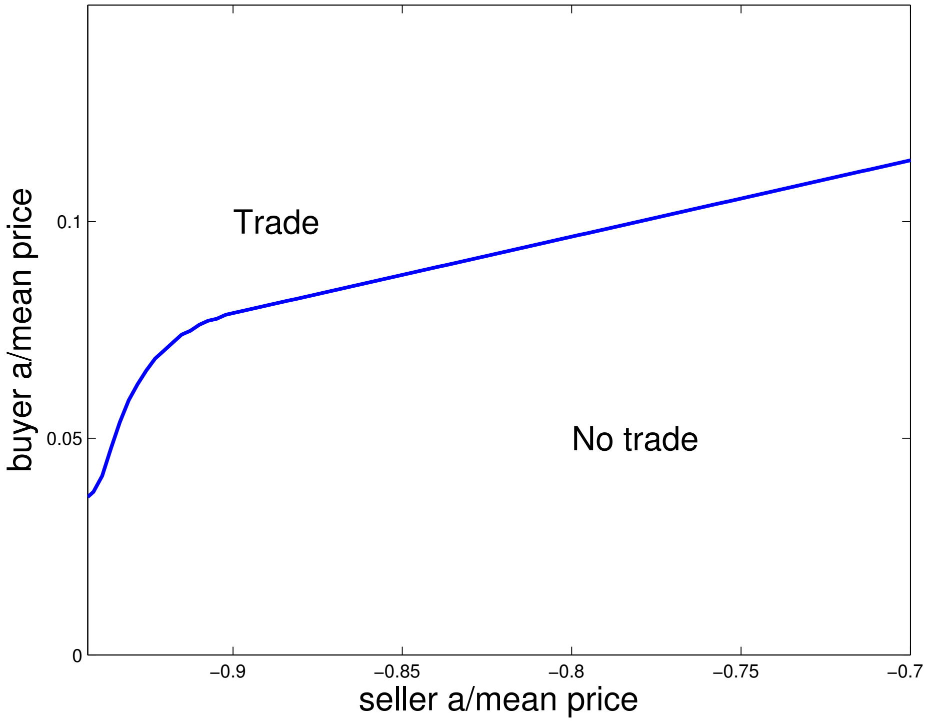

Figure 3: Matches that result in trade.

Note: Given seller's asset position, the figure shows the asset position of the poorest buyer with which the seller would trade. Asset positions are described with the financial wealth-to-average house price ratio.

	$\overline{a}^o$	$\overline{a}^r$	$\overline{p}$	tom	$cv(p)$	tr
Matching probability						
$\chi = 1.0$	1	2	-1	-73	-25	-2
$\chi = 0.4$	0	-2	1	166	56	4
Borrowing constraint						
$\underline{s}^o = -18.53$	18	8	-6	75	31	-23
$\underline{s}^o = -16.53$	37	17	-11	172	63	-42

Table 2: Percentage changes in selected statistics relative to the benchmark calibration.

Note: In the table, $\overline{a}^o$ and $\overline{a}^r$ denote the average asset holdings of owners and renters, respectively, and $\overline{p}$ denotes the average price. The measures of market inefficiency are average time-on-the-market (tom), coefficient of variation of house prices ($cv(p)$), and share of matches that lead to trade (tr). All figures in the table refer to percentage changes relative to the benchmark calibration where $\chi = 0.7$ and $\underline{s}^o = -20.71$. Owners' average financial wealth is negative. The table shows the change relative to the absolute value of average financial wealth.

	$\overline{a}^o$	$\overline{a}^r$	$\overline{p}$	tom	$cv(p)$	tr
Ownership rate 45%, $f = 0.19$	6	4	0	-9	18	4
Ownership rate 55%, $f = 0.74$	-1.2	-6.6	0	431	135	12
$\sigma = 1,\ f = 0.31$	-33	-49	0	1	-18	0
$\beta = 0.983,\ f = 0.39$	-28	-44	0	19	19	-7

Table 3: Percentage changes in selected statistics relative to the benchmark calibration.

Note: In the table, $\overline{a}^o$ and $\overline{a}^r$ denote the average asset holdings of owners and renters, respectively, and $\overline{p}$ denotes the average price. The measures of market inefficiency are average time-on-the-market (tom), coefficient of variation of house prices ($cv\,(p)$), and share of matches that lead to trade (tr). All figures in the table show the percentage changes relative to the benchmark calibration where the ownership rate is 50%, $\sigma = 2$ and $f = 0.335$. Owners' average financial wealth is negative. The table shows the change relative to the absolute value of average financial wealth. The utility cost parameter f has been recalibrated so that the average house price is the same as in the benchmark calibration.

	$\overline{a}^o$	$\overline{a}^r r$	$\overline{p}$	tom	$cv(p)$	tr
Benchmark calibration	18	8	-6	75	31	-23
Ownership rate 45%, $f = 0.19$	15	4	-4	68	9	-21
Ownership rate 55%, $f = 0.74$	17	17	-3	12	30	-24
$\sigma = 1,\ f = 0.31$	15	16	-7	65	30	-21
$\beta = 0.983,\ f = 0.39$	15	9	-7	70	33	-24

Table 4: Percentage changes in selected statistics following a tightening of the borrowing constraint in different cases.

Note: In the table, $\overline{a}^o$ and $\overline{a}^r$ denote the average asset holdings of owners and renters, respectively, and $\overline{p}$ denotes the average price. The measures of market inefficiency are average time-on-the-market (tom), coefficient of variation of house prices ($cv\,(p)$), and share of matches that lead to trade (tr). All numbers in the table show the effect (percentage changes) of lowering the maximum mortgage by about 10% relative to the case where $\underline{s}^o = -20.71$. Owners' average financial wealth is negative. The table shows the change relative to the absolute value of average financial wealth. The utility cost parameter f has been recalibrated so that the average house price is the same as in the benchmark calibration.

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ISBN 978-952-323-067-5 , ISSN 1456-6184, online