Journal of Monetary Economics 76 (2015) 107–123

Contents lists available at ScienceDirect

Journal of Monetary Economics

journal homepage: www.elsevier.com/locate/jme

Homeownership and the scarcity of rentals

Jonathan Halket [a,b,c,*], Matteo Pignatti Morano di Custoza [d,e]

[a] Department of Economics, University of Essex, Wivenhoe Park, Colchester CO3 4SQ, United Kingdom
[b] Institute For Fiscal Studies, United Kingdom
[c] CeMMAP, United Kingdom
[d] Confindustria Research Department, Italy
[e] CeLEG, LUISS G.Carli, Italy

ARTICLE INFO

Article history:
Received 11 November 2014
Received in revised form
20 August 2015
Accepted 21 August 2015
Available online 6 September 2015

Keywords:
Adverse selection
Competitive search
Homeownership

ABSTRACT

The provision of owner-occupied versus rental houses is modeled as a competitive search economy where households have private information over their expected duration. With public information, households with low vacancy hazard rates pay lower rents and search in thicker rental markets. With private information, rentals are under-provided to long-duration households to discourage short-duration households from searching there. Ownership is attractive in part because it cures the private information problem. Using a novel data set of rental listings, we show that homeownership rates are high where rent-to-price ratios are low but rentals are scarce and that long-duration households sort into scarce rental markets. These patterns are consistent with the model only under private information.

1. Introduction

Why do some households buy their home while others rent? There is a long list of plausible frictions that may create meaningful differences in the value of owning versus renting a home to a household. Many of the frictions that favor renting, such as the higher transactions costs of buying and selling a house and the downpayment constraints in the mortgage market, appear in one form or another in nearly all life cycle models with a homeownership choice.[1] There is no such consensus on the frictions that favor owning, in part because they are under-modeled and under-measured.

One oft mooted friction is that rentals are scarce in some parts of the market. Some studies that have inserted this friction in a reduced-form manner into their models (e.g. by imposing that large houses are only supplied on the owner-occupied market) have been otherwise successful at explaining changes in homeownership rates over the life cycle (Chambers et al., 2009a), over time (Chambers et al., 2009b; Fisher and Gervais, 2011), and across locations (Amior and Halket, 2014), among others.[2] *In these models*, absent the friction, homeownership rates would be much too low; the data

* Corresponding author at: Department of Economics, University of Essex, Wivenhoe Park, Colchester, CO3 4SQ, United Kingdom. Tel.: +44 1206 872394.
E-mail addresses: jonathan@halket.com (J. Halket), m.pignatti@confindustria.it (M. Pignatti Morano di Custoza).

[1] E.g. Amior and Halket (2014), Campbell and Cocco (2007), Chambers et al. (2009a,b), Cocco (2005), Diaz and Luengo-Prado (2008), Fisher and Gervais (2011), Gervais (2002), Halket and Vasudev (2014), Iacoviello and Pavan (2013), Kiyotaki et al. (2011), Li and Yao (2007), Rios-Rull and Sanchez-Marcos (2008).

[2] Some other models simply assume a "warm glow" to owning (Iacoviello and Pavan, 2013; Kiyotaki et al., 2011). One class of frictions that may work both ways is risk in the housing market, as in Sinai and Souleles (2005). Tax wedges may encourage ownership (Diaz and Luengo-Prado, 2008; Gervais, 2002) but would be welfare distorting absent some other reason to own. Some theories have a user cost premium of renting over owning, perhaps due to excessive utilization of housing services on the part of renters (as in Henderson and Ioannides, 1983).

http://dx.doi.org/10.1016/j.jmoneco.2015.08.003
0304-3932/

would reject the models. In addition to being empirically necessary for many models, rental scarcity in some segments of the market is also casually intuitive: in parts of the market where homeownership rates are high, rentals are indeed few in number. This of course is tautological.

In this paper we build and examine the evidence for the first theory of homeownership in which rental scarcity is an equilibrium outcome rather than an input. Since owning and renting are just labels for different (perhaps many different) contracts to provide housing services, we model the homeownership decision and the availability of rental housing as outcomes of a contracting problem and a search problem. Houses are ex ante identical and households differ only according to their cost of owning and their expected duration of stay in a house, which may be private information.[3] Homeowners (which may be households or landlords) post contracts for housing services which specify a (potentially type-dependent) price for housing services as well as whether, after eventual separation, the current owner or the eventual occupant is responsible for finding the next tenant (a "rental" or "owning" contract, respectively).

Within the housing market in this economy, households can direct their search to a specific type of contract (so that each type of contract is its own "submarket") and are bilaterally matched to houses within that submarket subject to the frictions from competitive search theory (Moen, 1997; Shimer, 1996). In equilibrium, the vacancy rate associated with a particular contract adjusts so that the expected return of posting any contract is the same.

Our main results are twofold. First, when households' expected durations in a house are unobservable, an incentive problem in rental markets distorts market tightnesses[4] compared to the public information benchmark. In the economy where households' expected durations are public information, households with low vacancy hazard rates (long-duration households) pay lower rental rates and search in less tight submarkets than households with high hazard rates. However, when expected durations are private information, long-duration households search in tighter submarkets than short-duration households, and thus spend more time on average searching for a house (per separation spell), but pay even lower rental rates once matched. (The unique equilibrium is separating.) The intuition for the result is that in equilibrium housing is under-provided to long-duration households so as to discourage short-duration households from searching there. In this sense, private information causes housing scarcity in some rental submarkets.

In our economy, owning a house solves the private information problem as households internalize their separation hazards in their optimal search problems. However, owning comes at some heterogeneous exogenous cost (a reduced-form way to model the various more well-understood frictions in the owner-occupied market). Our second result is that households that expect to stay in their house long enough are more likely to choose to own rather than rent. The distortions from the incentive problem in the rental market pile-up: the deviations from the public information benchmark due to private information are larger in markets where the long-duration households search. Meanwhile an owning contract is always incentive compatible. If a household has a high enough expected duration, the distortions in the rental market due to the information problem are more likely to dominate her idiosyncratic cost of owning so that she prefers to own.

In addition to providing an equilibrium theory of homeownership, our theory also explains some perhaps puzzling stylized facts we obtain from a unique data set. We use a large, novel data set of for-rent and for-sale listings on Craigslist to show that, within a market (such as a city), the parts of the market (i.e. "submarket") where homeownership rates are high are also the parts where rentals are relatively cheap. This correlation, which is consistent with findings from Verbrugge (2008), Verbrugge and Poole (2010) and Bracke (2013) using alternative data sets and markets, is at first counter-intuitive. If the rent-to-price ratio is exogenous to household demand for homeownership, then one might expect homeownership rates to be higher in submarkets where the ratio is higher, not lower.

The solution is the correct notion of scarcity. Our data show that vacant rentals in submarkets with low rent-to-price ratios disappear from the market quickly, the submarkets where homeownership is high. In other words, households are more likely to search for owner-occupied housing not when the relative price of an equivalent rental is high, but rather when an equivalent rental is hard to find. Crucially, the data allow us to measure scarcity by measuring how quickly vacant homes are filled and not just by the equilibrium supply of rental housing in a submarket. To our knowledge, this is the first data on rental vacancies where a within-market analysis of the variation in submarket rental vacancy duration is possible.

The data also show that households that have relatively long expected durations in their homes tend to live in the submarkets where rentals are scarce. Given the costs of vacancy for landlords, long-duration households should be appealing tenants and yet the data indicates that rental housing for them is harder to find. Our model shows that this is consistent with a private information problem: only then does our equilibrium yield that rentals are relatively cheap where they are scarce. Moreover this same private information friction endogenously provides that long-duration households search in the scarce markets and also that more of these same households prefer to own. Furthermore, in equilibrium, free entry implies that submarkets with scarce rentals must have low rents. So rent-to-price ratios are low where homeownership rates are high, as in the data.[5]

[3] There is a long literature looking at mobility and homeownership choices. Deng et al. (2003) and Gabriel and Nothaft (2001) find considerable variation across households and Metropolitan Statistical Areas in rental vacancy rates and durations. Boehm et al. (1991), Cameron and Tracy (1997), Haurin and Gill (2002) and Kan (2000) all find relationships between mobility hazards and homeownership.

[4] Markets are less tight if households on average take less time to find a house, or equivalently if landlords take longer on average to fill a vacancy.

[5] Variations in households' marginal rates of substitution across submarkets could also potentially explain the correlation between expected duration and ownership rates (as in Sinai and Souleles, 2005) but only if the marginal rates of transformation between rental and owner-occupied housing varied similarly across submarkets. In our paper, rent-to-price ratios vary even though the marginal rates of transformation are constant.

We calibrate our model to match some of the key moments in the data and find that the elasticity of the matching function is quite low. This implies that the private information problem leads to a ten percent reduction in the surplus created by rental housing for most households. The costs of owning can in turn be quite high and still many households would be willing to own. Or additionally, in a final extension to the model, we show that high expected duration types may be willing to search for rental contracts with higher initial rental payments as a way of screening lower expected duration types.

To be clear, we intend for this to be the beginning, not the end, of research which uses contracting problems in rental markets to construct equilibria consistent with the data on homeownership rates and prices in various markets. There are many pet theories on why so many people choose to own; each may play some role in partly explaining why ownership occurs.

We are following a growing literature by looking at housing in a search or matching framework (e.g. Albrecht et al., 2007, 2010; Caplin and Leahy, 2011; Head et al., 2014; Ngai and Tenreyro, 2014; Piazzesi and Schneider, 2009; Wheaton, 1990). To our knowledge, we are the first to look at both renting and owning in such a framework and the first to look jointly at renting and owning with adverse selection.[6] Piskorski and Tchistyi (2010, 2011) examine optimal mortgage design in owner-occupied markets (contracts for loans backed by housing services). Our work looks at contracts to supply housing services when there are search frictions and asymmetric information and thus extends the work of Guerrieri et al. (2010) to include dynamic contracts in a competitive search equilibrium with adverse selection.[7] In our equilibrium, contracts can be dynamic while the markets themselves are in steady-state.[8] Concurrently and complementarily, Chang (2011) and Guerrieri and Shimer (2014) examine environments where the markets can change dynamically, however all contracts are one-time exchanges (purchases and sales of assets).

The remainder of this paper is as follows. Section 2 examines market tightnesses and prices in rental and owner-occupied markets using data from Craigslist. Section 3 presents the model, first with just renting in public and then private information and then finally the equilibrium with both owning and renting. Section 4 numerically calibrates the model and Section 5 extends the model to fully optimal dynamic contracts. Section 6 concludes. Most proofs are in the Appendix.

2. Rental markets in the data

We merge data from the 2000 and 2010 U.S. Census and 2011 American Community Survey (ACS) with a novel data set constructed from rental and for-sale advertisements posted on Craistlist.org. The Craigslist data contain over 2.29 million for-sale postings and 3.16 million for-rent postings collected from the Craigslist.org RSS feed of listings for each metropolitan area that Craigslist covered at that time in the USA. The data were collected from postings starting on January 2, 2010 until June 27, 2012. Every post on the feed that had a listed street address was stored. Craigslist stopped including the street address in the RSS feed in July, 2012. In addition to the street address, our data contain an asking price or rent, an advertised number of bedrooms, the date of the posting as well as the URL of the posting and sometimes contain additional information such as the number of bathrooms, whether the residence is a single-family home, and some contact information for the listing agent.[9]

Craigslist lists' postings in order of recency which means that searchers on Craigslist see recent postings first when browsing. Therefore landlords (sellers) have an incentive to re-post their advertisement in order to move it to the top of the listings if they are still looking for perspective tenants (buyers). We will use the time between first and last postings for a particular home as our measure of its market tightness: on average, homes for rent or sale in a tight market should have short times between first and last postings. Time between postings is clearly an imperfect measure of how long the home is actually vacant and/or vacancy costs to the landlord. We assume in this section that the average vacancy costs per vacant spell in a particular submarket are proportional to the length time between a vacancy's first and last posting.

In order to determine a vacancy's first and last posting, we must first match houses across listings. We use the following algorithm to match houses. We separately sort both the rental and for-sale data by date. We assume that a listing is a new listing and not a continuation of a pre-existing listing if there is not an existing listing for an earlier date at the same address posted within 31 days of this listing and with an asking rent (price) within 15% of the pre-existing listing. Matching postings using the date and price of the posting is necessary because unfortunately not every listing contains an apartment number even when the home is clearly an apartment and there are several instances where multiple apartments in the same building seem to be concurrently for rent (or sale). Merlo and Ortalo-Magn (2004) find that listing prices forecast well

[6] Hubert (1995) and Miceli and Sirmans (1999) have models with renters and adverse selection in which long-term tenants have declining rent schedules while Barker (2003) shows that if households have inelastic demand for housing, those that expect to stay longer do not usually get discounts on their rent. Brueckner (1994) presents a model with adverse selection and evidence that banks use menus of mortgage points and interest rates to obtain information on a household's expected mobility.

[7] Delacroix and Shi (2013) and Albrecht et al. (2010) have adverse selection problems where the side posting the price has full information. Here, as in Guerrieri et al. (2010), the side directing its search has the superior information.

[8] We are therefore abstracting away from the interesting housing dynamics discussed in Head et al. (2014), Ngai and Tenreyro (2014), among others.

[9] To the best of our knowledge, our data set contains all postings on Craigslist with a listed address during the time period except for listings that were rapidly removed by Craiglist.org or the posting author.

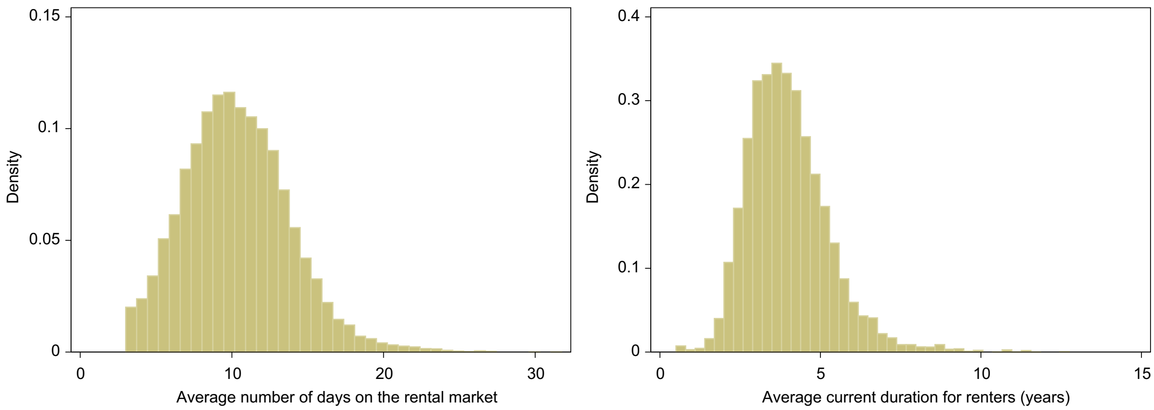

Fig. 1. Histograms of time on the market for rentals in Craigslist data and current duration for renters.

contracted sales prices for the for-sale market. In what follows we use the last posted rent or sale price as our estimate of the contracted price.

Using our matched data, we construct a measure of how long each home is on the market, T_i, by using the time span in days between its first and last postings plus three days:

$$T_i = lastdate_i - firstdate_i + 3$$

The three additional days are used so that homes only listed once are still "on the market" for some time period. Our results are robust to changes in this length of time.[10] The average number of days between postings for the same home in our rental data is 6 days and 8 days in the for-sale market.

In this section, our notion of a submarket is all housing for rent or sale within a zip code with the same number of bedrooms. Piazzesi et al. (2015), using data on for-sale search queries from the San Francisco Bay Area, similarly partition their markets into submarkets based on zip codes and number of bathrooms.[11] US zip codes are five digit post codes that tend to be cardinally geographically clustered. For instance, all zip codes with 100 as the first three digits (three digit zip) are located in New York City. In this section then a "market" is a collection of submarkets with the same number of bedrooms and the same first three digits in their zip code. For measures of rent-to-price ratios, we create rental and sale price indices for each zip code by number of bedroom cell by taking the mean rental or sale price for that cell and then taking the ratio of the mean rent to mean price as the rent-to-price ratio for that cell.[12] We keep only those cells for which we have at least 10 unique rental and 10 unique for-sale listings in our sample.

From the 2010 Census, we have zip code level measures of the number of occupied rentals and owner-occupied homes, the numbers of vacant properties for-rent and for-sale (though these properties usually must be vacant for over six months to be recorded as vacant), and the proportion of households with head of house age 35 or over. The 2000 Census contains information about the prior moving dates of households (conditional on tenure). From the ACS, we have median income in each zip code and homeownership rates by number of bedrooms for each zip code.

We use two different proxies for average expected duration, both conditional on tenure: the proportion of households in the submarket with a head of the house 35 years old or over (*proportion over 35*), and the average time since last move for renters (*current duration*).[13] Age is positively correlated with expected duration (since uncertainty over income and family prospects falls with age, see Halket and Vasudev, 2014), so the proportion over 35 in a submarket will be positively correlated with the average expected duration of households in the submarket. Meanwhile (ex post) actual duration is almost certainly positively correlated with a household's (ex ante) expected duration. Fig. 1 shows the densities by cell of various dimensions of the rental market.

We are interested in variation within a market at the submarket level. In the model that follows, households choose a submarket from within a market to direct their search to. Our theory connects households' expected duration in a home

[10] In particular, one might worry that in markets with few Craigslist postings, landlords would need to re-post their advertisement less often and thus that in these markets we should consider them "on the market" for longer than three days after their last posting. In one robustness exercise, we adjusted the additional days we add so that they vary by market (but not submarket) so that markets with few postings on Craigslist per day have more additional days; our results did not change. Furthermore, some rental listings may not be genuine vacancies but rather may just be a stock ad used by a real estate agency fishing for customers to call them. Others may be a stock ad used by a management company for a building with multiple vacancies in its building. To account for these possibilities as best as possible, we censor our data by dropping any listing which we record as $T_i > 75$. The results presented below are robust to alternative censoring thresholds as well as alternative windows for matching listings. Using the 75 day threshold, 3% of our sample postings are dropped.

[11] They also partition based on price to attempt to capture residual quality.

[12] In the Appendix, we do a robustness check using rent-to-price ratios from Zillow.com.

[13] The 2000 Census gives the number of renters that have moved into their current home in the last year, between 1 and 5 years ago, etc. We use the midpoint of each cell and take the average.

Table 1
Regressions of prices on vacancy durations and durations in home.

	Rent	Rent	Rent	Price	Price	Price
Time rent	0.025*					
	(0.010)					
Time sale				0.078**		
				(0.029)		
Prop over 35 yr		−0.195**			0.475*	
		(0.024)			(0.273)	
Duration in home			−0.036**			0.124*
			(0.014)			(0.059)
Median inc	0.359**	0.364**	0.352**	0.740**	0.721**	0.780**
	(0.015)	(0.015)	(0.016)	(0.031)	(0.031)	(0.043)
R^2	0.89	0.89	0.89	0.79	0.79	0.79
N	12,542	12,542	12,116	10,821	10,821	10,425

All variables are in logs and all regressions include dummies for each market. *Time rent* (*time sale*) is the T_i conditional on being for-rent (for-sale). *Rent* (*price*) is the final listed rent (price) for the property. *Prop over 35 yr* is the proportion of households in the zip code with head of house age 35 or over that are renting (owning) for the rent (price) regressions. Likewise *duration in home* is the duration for renter (owner-occupiers) for the rent (price) regressions. SEs, clustered by market, in parentheses.
N is the number of submarkets included in each regression.

* $p < 0.05$.

** $p < 0.01$.

with the submarkets they choose to search and live in and with rental rates and the availability of rental homes. The distribution of expected durations in a market is treated as exogenous, but submarket choice (and therefore the average expected duration in a submarket), price and availability are all endogenous outcomes. Given that, the regression results presented below should be thought of as evidence of correlations between market outcomes and not anything causal and the standard errors taken with a grain of salt.

There are several other caveats worth mentioning. The Craigslist listings are not random selections from their various markets, particularly in the for-sale markets. Furthermore, we cluster the standard errors at the market level and include dummies for at the market and number of bedrooms level but do not otherwise account for spatially correlated errors. All of our results are robust to clustering and including dummies at the county or city level instead.

Omitted variables are also likely an issue. We include median income in the zip in our regressions to try and capture some of the differences in unobserved housing quality across submarkets. Of course, neither age nor perhaps realized duration is orthogonal to income. Furthermore expected duration is correlated with tenure decisions due to the high transaction costs of homeownership. So the homeownership rate results below should be taken with an additional grain of salt.

Finally, our partitions of markets and submarkets are somewhat arbitrary: our theory has nothing to say about whether or why contracts sort along geographic dimensions nor does it shed any light as to the geographic size of a submarket. In reality, there may be several heterogeneous submarkets within each zip $\times$ bedroom cell and some submarkets may potentially overlap across cells. Piazzesi et al. (2015) find multiple for-sale submarkets within individual zip codes and that households typically search in multiple zip codes. In this case the elasticities presented in the tables here would then likely understate the true elasticities.

Table 1 shows that, in our data, both rental and sale prices are lowest in the submarkets where (respectively) rental and sale time on markets are lowest; a relationship which will follow naturally from the free entry conditions in our model. For instance, landlords must be compensated with higher rents when renting in submarkets where houses stay vacant for longer. Fig. 2 (upper right) shows the same correlation between rent-to-price ratios and rental vacancy rates using only data on 2 bedrooms houses in King County (Seattle–Tacoma–Bellevue, Washington MSA).[14] Table 1 also shows that younger households as well as households with shorter current durations searched in submarkets with higher rental prices but lower sales prices. Rent-to-price ratios in the submarkets where these households search are therefore higher. Despite the fact that rentals are expensive relative to prices, though, homeownership rates tend to be lower in these same submarkets (Table 2 and, for Seattle, Fig. 2 – upper left). Verbrugge (2008), Verbrugge and Poole (2010) and Bracke (2013) find similar correlations between rent-to-price ratios and homeownership rates, the latter even after controlling for potential unobserved heterogeneity.

From Table 2, households with lower expected durations search for rentals in submarkets where time on the market is longer, while time on the for-sale submarket is hardly different. Guasch and Marshall (1985) find a similar correlation between rental vacancy hazards and rental vacancy durations in a cross-section of Philadelphia rental housing. As we will now show, a negative correlation between expected duration and time on the market is not consistent with a competitive

[14] The Seattle MSA has the largest number of rental listings in our data. Each point represents a submarket with 2 bedrooms in King County. Rent-to-price ratios are the mean rent in that submarket (e.g. the mean over 2 bedroom listings in zip code 98001) divided by the mean price in that submarket in our Craigslist data.

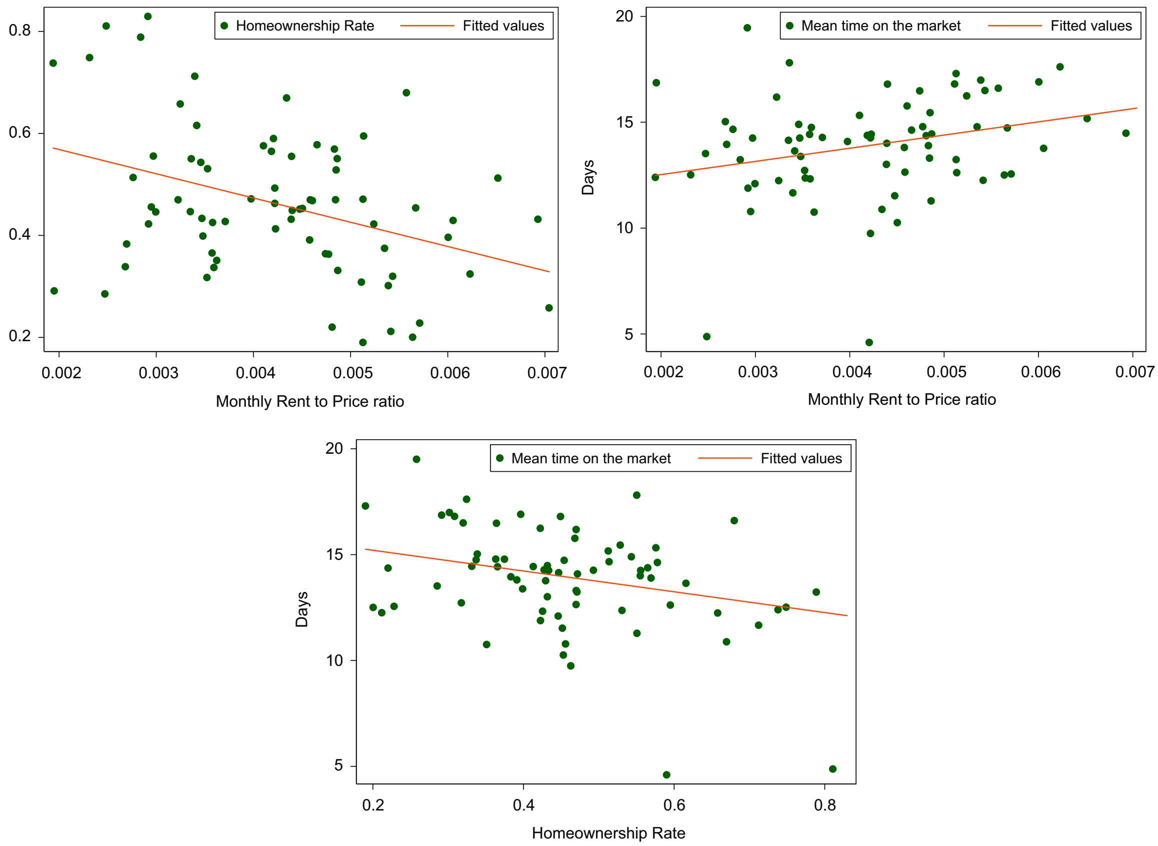

Fig. 2. King county. Rent-to-price ratios and time on the rental market are the ratio of the mean rent to mean price and mean number of days that a property is posted for rent for two bedroom houses in a zip code in King County, Washington using the Craigslist data. Homeownership rates are from the Census data at the same bedroom × zip code level.

Table 2
Regressions of vacancy duration and homeownership rates on durations in home.

	Time rent	Time rent	Time sale	Time sale	Homeownership	Homeownership
Prop over 35 yr	−0.059**		−0.084		0.767**	
	(0.018)		(0.075)		(0.087)	
Duration in home		−0.071**		0.002		0.360**
		(0.013)		(0.016)		(0.045)
Median inc	−0.015	−0.029*	−0.000	−0.000	0.267**	0.379**
	(0.009)	(0.010)	(0.012)	(0.014)	(0.029)	(0.021)
R^2	0.32	0.33	0.35	0.35	0.82	0.82
N	12,542	12,116	10,822	10,426	13,080	12,655

See notes to Table 1. For the homeownership regressions, *prop over 35 yr* and *duration in home* are the submarket averages unconditional on tenure.

search equilibrium with public information. Instead, the data show that landlords match quickly with long duration households, which will be consistent with the presence of private information.

3. Model

In this section we develop a model of competitive search with adverse selection as in Guerrieri et al. (2010). We build on their work in several ways. Our model is dynamic which, among other things, endogenizes the stock of households searching at any given time. It also allows us to endogenize the differences in the value of the asset to the different searchers through differences in the expected duration of the match. This in turn means that different households can have the same preference orderings over contracts conditional on matching but different preference orderings over contracts while still searching. So both the contract terms and the associated equilibrium market tightnesses may be needed to screen households.

3.1. Preferences and technology

Time is continuous and the horizon is infinite. There is a measure one of households indexed by their type $i \in \mathbb{I} = \{1, 2, \ldots, I\}$ and a large set of landlords or, synonymously, builders. Let π_i be the fraction of households of type i in the population, for all i. If a landlord decides to participate in the market, she pays a cost H in units of utility to build a house but then houses are costless to maintain; if she does not participate, she gets a payoff equal to 0. Households receive a flow utility of h when they occupy a house and 0 when they do not. Households and landlords each discount at the same rate $\rho < h/H$.

Households that are currently occupying a house separate with it at a hazard rate $\gamma: \mathbb{I} \to \Gamma \subset \mathbb{R}_+$, at which point a separated household no longer receives any utility from living in that particular house. Without loss of generality, we assume that γ is strictly decreasing in type. We will often refer to a household of type i as having a hazard $\gamma_i = \gamma(i)$. We denote $\bar{\gamma} \equiv \gamma_1$ and $\underline{\gamma} \equiv \lim_{i \to I} \gamma_i$ so that $\Gamma = [\underline{\gamma}, \bar{\gamma}]$.

For simplicity, we will first model an economy with only renting. The qualitative differences between the competitive equilibrium with public versus private information will remain unchanged when later we add in owner-occupation.

3.2. The rental market

A rental contract $w \in \mathrm{W}$ specifies a flow rent, possibly contingent on type, paid by the household to the landlord if matched. The contract ends in the case of separation. For simplicity, we will restrict our attention to rental contracts with a fixed flow rent. Barker (2003) and Guasch and Marshall (1987) find that most rental contracts do not have a duration-of-stay discount. In Section 5 we extend the setting to fully dynamic contracts with risk-averse households and show that our results still follow even with endogenous duration-of-stay discounts.

We consider two cases. In the first, a household's type is publicly observable and so contracts are also free to have type-specific rents. However, we will show that in equilibrium, only one type is lured by each contract. In the second case, a household's type is private information. In this case, by the revelation principle, we assume that landlords post a contract which contains direct revelation mechanisms for each type, without loss of generality. Following Guerrieri et al. (2010), we will show that we can assume without loss of generality that landlords post contracts with type-independent mechanisms. More precisely, in the private information case the equilibrium with contracts is payoff equivalent to the equilibrium with degenerate mechanisms offering the same rent to each household, which enables us to simplify the notation greatly.[15] Because in equilibrium each type of household directs its search to at most one type of rental contract (and later when we add owning, at most one type of owning contract), we will call a submarket all houses with a renting and/or owning contract that attracts a particular type of household. That is, we will have one submarket for each i.

The matching process between households and landlords is frictional. At any given time landlords post a single contract at zero cost and households direct their search to the most attractive contracts.[16]

Associated with any contract w, let u be the measure of households directing their search to w and v be the measure of landlords posting w. Define $\theta = u/v$ as the market tightness associated with contract w, $\theta: \mathrm{W} \to \mathbb{R}_+$. Households find a house at rate $\alpha_h(\theta)$ where $\alpha_h: \mathbb{R}_+ \to \mathbb{R}_+$ and α_h is decreasing in θ. Landlords fill a vacancy at rate $\alpha_l(\theta)$, where $\alpha_l: \mathbb{R}_+ \to \mathbb{R}_+$ is increasing in θ. We assume that $\alpha_l(\theta) = \theta \alpha_h(\theta)$, that is equivalent to constant returns to scale in matching, and $\alpha_h(0) = \alpha_l(\infty) = \infty$ and $\alpha_h(\infty) = \alpha_l(0) = 0$. We assume that the elasticity of $\alpha_l(\theta)$, $\varepsilon(\theta) \equiv (\theta/\alpha_l(\theta)) d\alpha_l(\theta)/d\theta$ is constant: $\varepsilon(\theta) = \varepsilon$.

Let $\psi_i(w)$ be the share of households of type i applying to any given contract w, so that $\psi(w) = \{\psi_1(w), \psi_2(w), \ldots, \psi_I(w)\} \in \Delta^I$, where Δ^I is the I-dimensional unit simplex, $\psi: \mathrm{W} \to \Delta^I$. The market tightness $\theta(w)$ and the share of households applying to w, $\psi(w)$ are determined in equilibrium.

Let $V_r(\gamma_i, r, \theta)$ and $Z_r(\gamma_i, r, \theta)$ be the expected values of living in a house and searching for a house,[17] respectively, to the households of type i applying to any given contract, w with rental payment for that type of r. $\theta = \theta(w)$ is the market tightness associated with the contract w. Then

$$\rho V_r(\gamma_i, r, \theta) = h - r + \gamma_i (Z_r(\gamma_i, r, \theta) - V_r(\gamma_i, r, \theta)) \tag{1}$$

$$\rho Z_r(\gamma_i, r, \theta) = \frac{\alpha_l(\theta)}{\theta} (V_r(\gamma_i, r, \theta) - Z_r(\gamma_i, r, \theta)) \tag{2}$$

Let $Y_r(\gamma_i, r, \theta)$ and $X_r(w, \theta)$ be the expected values of an occupied house when matched with a type i and a vacant house, respectively, to the landlord:

---

[15] This esthetic feature is not true in the setting with fully-dynamic contracts in Section 5; which is the main reason why we deal with it separately (see our discussion of Lemma 4).

[16] Matching is bilateral, thus every household can only apply to one contract, but she can use mixed strategies.

[17] These are the values of searching and living in the same market, repeatedly *ad infinitum*.

$$\rho Y_r(\gamma_i, r, \theta) = r + \gamma_i(X_r(w, \theta) - Y_r(\gamma_i, r, \theta))$$
$$\rho X_r(w, \theta) = \alpha_l(\theta) \sum_{i \in \mathbb{I}} \psi_i(w)(Y_r(\gamma_i, r_i, \theta) - X_r(w, \theta))$$

where $\psi_i(w)$ is the share of households of type i applying to the contract w, specifying rent r_i for that type, and θ is the market tightness associated with that contract.

Solving for the flow value of searching $\rho Z_r(\gamma_i, r, \theta)$ and posting $\rho X_r(w)$ gives

$$\rho Z_r(\gamma_i, r, \theta) = \frac{\alpha_l(\theta)}{\theta(\rho + \gamma_i) + \alpha_l(\theta)}(h - r) \tag{3}$$

$$\rho X_r(w, \theta) = \left(1 + \alpha_l(\theta) \sum_{i \in \mathbb{I}} \frac{\psi_i(w)}{\rho + \gamma_i}\right)^{-1} \alpha_l(\theta) \sum_{i \in \mathbb{I}} \frac{\psi_i(w) r_i}{\rho + \gamma_i} \tag{4}$$

Notice that $\rho Z_r(\gamma_i, r, \theta) < 0$ if $r > h$, $\forall\, i$ and $\forall\, \theta > 0$, thus no household would apply to a contract that imposes a flow rent r higher than the flow utility from housing h. Similarly, $X_r(w, \theta) < H$ if $r_i < \rho H$ for all i for which $\psi_i(w)\theta > 0$.

3.3. Equilibrium with public information

Definition 1. A steady-state competitive search equilibrium with renting and public information is a vector $\{Z_r^{*i}\}_{i \in \mathbb{I}}$, a set of contracts $\mathrm{W}_r^* \subseteq \mathrm{W}^{\mathbb{I}}$ each of which specifies a rent r_i for each $i \in \mathbb{I}$, a function $\theta_r^*\colon \mathrm{W}^{\mathbb{I}} \to \mathbb{R}_+$, a measure λ on $\mathrm{W}^{\mathbb{I}}$ with support W_r^*, and a function $\psi\colon \mathrm{W}^{\mathbb{I}} \to \Delta^I$ satisfying, for each $i \in \mathbb{I}$:

(i) Landlords' profit maximization and free entry:

$$\left(1 + \alpha_l(\theta_r^*(w)) \sum_{i \in \mathbb{I}} \frac{\psi_i(w)}{\rho + \gamma_i}\right)^{-1} \alpha_l(\theta_r^*(w)) \sum_{i \in \mathbb{I}} \frac{\psi_i(w) r_i}{\rho + \gamma_i} \le \rho H$$

with equality if $w \in \mathrm{W}_r^*$.

(ii) Households' optimal search:

Let $\displaystyle Z_r^{*i} \equiv \max_{w' \in \mathrm{W}_r^*} \frac{1}{\rho} \frac{\alpha_l(\theta_r^*(w'))}{\theta_r^*(w')(\rho + \gamma_i) + \alpha_l(\theta_r^*(w'))}(h - r_i')$

Then $\forall\, w \in \mathrm{W}^{\mathbb{I}}$

$$Z_r^{*i} \ge \frac{1}{\rho} \frac{\alpha_l(\theta_r^*(w))}{\theta_r^*(w)(\rho + \gamma_i) + \alpha_l(\theta_r^*(w))}(h - r_i)$$

with equality if $\theta_r^*(w) > 0$ and $\psi_i(w) > 0$.

(iii) Market clearing:

$$\int_{\mathrm{W}_r^*} \psi_i(w)\left(\theta_r^*(w) + \frac{\alpha_l(\theta_r^*(w))}{\gamma_i}\right) d\lambda(w) = \pi_i, \quad \forall\, i \in \mathbb{I}$$

The equilibrium definition imposes restrictions on the off-equilibrium beliefs of the landlords. The optimal search value of any type-i household is defined over the set of contracts posted in equilibrium W_r^* only, but under any deviating contract $w' \notin \mathrm{W}_r^*$, landlords expect market tightness $\theta_r^*(w')$ to adjust to make all types of households weakly worse off.

We can distinguish competitive equilibria according to whether there are contracts which attract more than one type in equilibrium.

Definition 2. A *separating competitive equilibrium* is any competitive equilibrium where for all $w \in \mathrm{W}_r^*$ and for all i, $\psi_i(w) > 0$ implies $\psi_i(w) = 1$. A *pooling equilibrium* is any competitive equilibrium that is not separating. Two competitive equilibria (indexed by A and B) are *allocatively equivalent* if for all $i \in \mathbb{I}$ and $w^A \in \mathrm{W}_r^{*A}$, $\psi_i(w^A) > 0$ implies that there exists a $w^B \in \mathrm{W}_r^{*B}$ with $\psi_i(w^B) > 0$ such that $r_i^A = r_i^B$ and $\theta_r^{*A}(w^A) = \theta_r^{*B}(w^B)$ and vice versa.

Lemma 1. *If there exists a pooling competitive equilibrium with public information, then there exists an allocatively equivalent separating competitive equilibrium.*

Proof. See Appendix.

So, rents and market tightnesses for each type do not vary across different competitive equilibria. In separating competitive equilibria, the market endogenously segments into submarkets, one for any different type i of households. Thus without loss of generality we can assume that a contract w in a separating competitive equilibrium contains a menu of rents where there is only one rent $r_i < h$ and thereafter label $w = r_i$. This also pins down the measure of landlords posting the contract w to households of type i, given by $v(w) = \gamma_i \pi_i / (\alpha_l(\theta_r^*(w)) + \gamma_i \theta_r^*(w))$.

3.3.1. Characterization

A necessary and sufficient condition for a separating competitive search equilibrium is the following[18]:

Proposition 1. *For any type i of households, a posted contract* w_r^{*i} *and the associated market tightness* $\theta_r^{*i} \equiv \theta_r^*(w_r^{*i})$ *are part of an equilibrium allocation if and only if they solve the following constrained maximization problem,* R_i:

$$\max_{w_i,\theta_i} \quad \frac{\alpha_l(\theta_i)}{\theta_i(\rho+\gamma_i)+\alpha_l(\theta_i)}(h-w_i)$$
$$\text{s.t.} \quad \frac{\alpha_l(\theta_i)}{\rho+\gamma_i+\alpha_l(\theta_i)} w_i \geq \rho H$$

The equilibrium allocation maximizes the expected value of search of any type-i household conditional on the firms making non-negative profits.

Proposition 2. A solution to R_i exists for each i. The solution is unique.

Proof. See Appendix.

Lemma 2. *In the solution to* $R = \{R_i\}_{i \in \mathbb{I}}$, *for all* $i, j \in \mathbb{I}$ *with* $i \neq j$, $\theta_r^{*i} \neq \theta_r^{*j}$

Proof. Using the constraint with equality to substitute for w_r^{*i}, the first order condition implies the following equilibrium condition for the market tightness:

$$\frac{h}{\rho H} = 1 + \frac{1}{\theta_r^{*i}} \frac{\varepsilon}{1-\varepsilon} + \frac{\rho+\gamma_i}{\alpha_l(\theta_r^{*i})(1-\varepsilon)} \tag{5}$$

The implicit solution for θ_r^{*i} is strictly increasing in γ_i.□

Lemma 3. *Any competitive equilibrium with public information is a separating competitive equilibrium.*

Proof. Follows immediately from Lemmas 1 and 2 and Proposition 1.□

The equilibrium values of the flow rent w_r^{*i} and the household's expected value ρZ_r^{*i} are given by

$$w_r^{*i} = \frac{\rho+\gamma_i+\alpha_l(\theta_r^{*i})}{\alpha_l(\theta_r^{*i})}\rho H$$
$$\rho Z_r^{*i} = \frac{1}{\theta_r^{*i}} \frac{\varepsilon}{1-\varepsilon}\rho H$$

We have the following comparative static results as γ_i varies:

Result 1. *In equilibrium, as the separation hazard* γ_i *increases*:

(i) *the market tightness* θ_r^{*i} *increases*;
(ii) *the flow rent* w_r^{*i} *increases*;
(iii) *the expected value to households* Z_r^{*i} *decreases*.

Proof. See Appendix.

Thus, households with lower expected durations have lower surpluses from matching with a house and thus face tighter markets and higher rents once matched and as a consequence have lower search values. Searching for a new tenant is costly, so more surplus is created when a landlord is matched with a high expected duration tenant. In equilibrium, absent other frictions, this extra surplus should be allocated towards some combination of lower rents and more houses, decreasing both the cost of housing and search costs for households. That is, absent other frictions, long duration households should find housing faster and landlords should take longer to match with long duration households.

[18] See e.g. Acemoglu and Shimer (1999) for a proof, with one caveat to the proof of sufficiency: in our setting, even if mechanisms in W_r^* are separating, other mechanisms in $W^{\mathbb{I}}$ can be pooling. It is straightforward to use the argument in the proof of Lemma 1 to show that if the sufficiency conditions are met for a separating competitive search equilibrium with separating-only mechanisms then they will be met here too.

3.4. Renting with private information

The equilibrium allocation in the public information case implies that every type $j < I$ strictly prefers to search in a higher ($i > j$) type's market if she was offered the higher type's contracted rent. In this subsection, we assume that the type of the household, i, is known only by the household. So, the public information allocation will not be incentive compatible under private information.

A mechanism in this setting would be a set of rents $\{r\}_{i \in \mathbb{I}}$. However, from the household's value of being matched (1), it is clear that the only mechanism compatible with truth telling offers the same rent to any reported type.

Lemma 4. *A contract is incentive compatible if and only if it offers the same rent to any reported type.*

Proof. Follows from the household's value of being matched to a contract.□

So we can safely associate any incentive compatible contract w with its associated rent (and thus can assume $w \in [\rho H, h]$).[19]

Lemma 5. *Sorting*: $\forall\, i$, $w \in [\rho H, h]$, $\theta \geq 0$, *and* $\epsilon > 0$, *there exists a couple* $(w', \theta') \in B_\epsilon(w, \theta(w))$, *with* $w' < w$ *and* $\theta' > \theta$, *such that*

$$Z_r(\gamma_j, w', \theta') > Z_r(\gamma_j, w, \theta), \quad \forall\, \gamma_j \leq \gamma_i \quad \textit{and}$$

$$Z_r(\gamma_j, w', \theta') < Z_r(\gamma_j, w, \theta), \quad \forall\, \gamma_j > \gamma_i$$

Proof. Follows from Eq. (3).□

The sorting lemma is similar to a standard "single-crossing conditions."[20] Given θ, different types do not have different preference orderings over w with private information. Sorting is only achieved through a local perturbation of both the rent and market tightness. We can now define the equilibrium, following and extending the definition in Guerrieri et al. (2010) to a dynamic setting.

Definition 3. A steady-state competitive search equilibrium with renting and private information is a vector $\{Z_p^{*i}\}_{i \in \mathbb{I}}$, a set of rents (i.e. incentive compatible contracts) $W_p^* \subseteq [\rho H, h]^{\mathbb{I}}$, a measure λ on $[\rho H, h]$ with support W_p^*, a function $\theta_p^*: [\rho H, h] \to \mathbb{R}_+$ and a function $\psi: [\rho H, h] \to \Delta^I$ satisfying:

(i) landlords' profit maximization and free entry: for any $w \in [\rho H, h]$

$$\left[1 + \left(\alpha_l(\theta_p^*(w)) \sum_{i \in \mathbb{I}} \frac{\psi_i(w)}{\rho + \gamma_i}\right)^{-1}\right]^{-1} w \leq \rho H$$

with equality if $w \in W_p^*$.

(ii) households' optimal search: Let

$$Z_p^{*i} \equiv \max_{w' \in W_p^*} \frac{1}{\rho} \frac{\alpha_l(\theta_p^*(w'))}{\theta_p^*(w')(\rho + \gamma_i) + \alpha_l(\theta_p^*(w'))}(h - w')$$

Then $\forall\, w \in [\rho H, h]$ and $\forall\, \gamma_i$

$$Z_p^{*i} \geq \frac{1}{\rho} \frac{\alpha_l(\theta_p^*(w))}{\theta_p^*(w)(\rho + \gamma_i) + \alpha_l(\theta_p^*(w))}(h - w)$$

with equality if $\theta_p^*(w) > 0$ and $\psi_i(w) > 0$.

(iii) market clearing:

$$\int_{W_p^*} \psi_i(w)(\theta_p^*(w) + \frac{\alpha_l(\theta_p^*(w))}{\gamma_i}) d\lambda(w) = \pi_i, \quad \forall\, i$$

As in the public information case, the equilibrium definition imposes conditions on the off-equilibrium beliefs of the landlords. Heuristically, a landlord considering whether to post a deviating contract w' imagines an initial market tightness $\theta = 0$. If no household is willing to apply, then $\theta = 0$ and the deviation is not profitable. Otherwise, some households apply,

[19] Lemma 4 relies on our restriction of the rental contract space to constant rent profiles. When we relax this assumption, as Section 5, the lemma no longer holds. However Lemma 4 is not necessary for a separating equilibrium and it is straightforward to see that such an equilibrium exists in Section 5's relaxed setting. We also show there that this setting can generate "length of stay" discounts in rents (e.g. a downward sloping rent profile with respect to actual duration).

[20] It is slightly different. See Guerrieri et al. (2010) for an elaboration.

increasing market tightness θ, until only one type of household i is indifferent about the deviating w' and all others j (weakly) prefer their equilibrium contracts. This in turn pins down the share ψ_i of households applying to that contract.

3.4.1. Equilibrium and characterization

The characterization of the equilibrium with private information is equivalent to the public information equilibrium with an extra incentive compatibility constraint that imposes that no other types of households j are attracted to the contract w_i. In the next proposition, we show that at the optimum, for all $i>1$, only the marginal incentive compatibility constraints $IC(i-1,i)$ bind: every type $(i-1)$ is indifferent between his own contract and the contract offered to the type i with marginally higher expected duration.

Proposition 3. *Let the problem* (PR) *be defined by the following constrained maximization problem* (PR_i), *for any* $i \in \mathbb{I}$:

$$\max_{\theta \in \mathbb{R}_+, w \in \mathbb{R}_+} \quad Z_r(\gamma_i, w, \theta)$$

$$\text{s.t.} \quad \frac{\alpha_l(\theta)}{\rho+\gamma_i+\alpha_l(\theta)} w \ge \rho H$$

$$\text{and} \quad Z_r(\gamma_j, w, \theta) \le Z_r(\gamma_j, w_p^{*j}, \theta_p^{*j}) \quad \text{for all } j \ne i \ \ [IC(j,i)]$$

where w_p^{*i}, θ_p^{*i} *is an optimal solution for i.*

The solution of (PR) *exists and is unique. Moreover, only the marginal incentive compatibility constraints* $IC(i-1,i)$ *bind, for all* $i>1$:

$$Z_r(\gamma_{i-1}, w_p^{*i}, \theta_p^{*i}) = Z_r(\gamma_{i-1}, w_p^{*,i-1}, \theta_p^{*,i-1}) \quad \text{and}$$

$$Z_r(\gamma_j, w_p^{*i}, \theta_p^{*i}) < Z_r(\gamma_j, w_p^{*j}, \theta_p^{*j}) \quad \forall \ j \ne i, i-1$$

Proof. See Appendix.

Thus, for the type with the highest separation hazard, $\gamma_1 = \bar{\gamma}$, the equilibrium allocation is the same as the one with public information. Then, the problem is solved iteratively for all other types:

(i) For $i=1$, w_p^{*1} and θ_p^{*1} solve R_1
(ii) For each $i>1$, w_p^{*i} and θ_p^{*i} are the solutions to

$$\max_{\theta \in \mathbb{R}_+, w \in \mathbb{R}_+} \quad Z_r(\gamma_i, w, \theta)$$

$$\text{s.t.} \quad \frac{\alpha_l(\theta)}{\rho+\gamma_i+\alpha_l(\theta)} w \ge \rho H$$

$$\text{and} \quad Z_r(\gamma_{i-1}, w_p^{*i}, \theta_p^{*i}) \le Z_r(\gamma_{i-1}, w_p^{*,i-1}, \theta_p^{*,i-1})$$

We are now ready to prove the existence and uniqueness of the equilibrium and characterize the equilibrium allocation:

Proposition 4. There exists a unique separating equilibrium. A set of contracts $\{w_p^{*i}\}_{\mathbb{I}}$, $w_p^{*i} \in [\rho H, h]$ and market tightnesses $\{\theta_p^{*i}\}_{\mathbb{I}}$, $\theta_p^{*i} \equiv \theta_p^*(w_p^{*i}) \equiv \theta_i$ associated with their respective types γ_i are part of the equilibrium allocation if and only if they solve the problem PR.

Proof. See Appendix.

We have the following comparative static results as γ_i varies.

Result 2. *In equilibrium, as the separation hazard* γ_i *increases*:

(i) *the market tightness* θ_p^{*i} *decreases*;
(ii) *the flow rent* w_p^{*i} *increases*;
(iii) *the expected value to households* Z_p^{*i} *decreases*;
(iv) *the vacancy rate*, $v_p^{*i}/(\pi_i - u_p^{*i} - v_p^{*i})$ *increases*;

Proof. See Appendix.

Result 2 is similar to result 1 except that, contrary to the public information case, low-γ types search in tighter rather than looser rental submarkets in equilibrium. These types pay even lower rents if matched. In this way landlords are able to optimally (with the least cost) separate types of households by posting contracts w_p^{*i} lower than the first-best optimum w_r^{*i} to those that expect to stay longer, in return for a higher market tightness θ_p^{*i}.

The intuition for the result is that households that expect to stay longer are less affected by a higher market tightness (and thus longer expected search times) because they expect to separate from the house and "pay" the search cost less frequently. On the other hand, those that expect to stay longer are more affected by a lower rent w because they expect to be matched a higher fraction of time for any given market tightness θ. The combination of these two factors implies that the second best allocation dictates tighter markets for those that expect to stay longer, contrary to the first best allocation. These tighter markets imply a lower vacancy rate (defined as vacancies per unit of housing).

3.5. Owning market

An owning contract simply specifies an up-front payment P paid by the household to the seller, which may vary across submarkets. Households derive the same flow utility h if they own or rent the house, and landlords (i.e. builders) pay the same building cost H.

As will become clear below, absent some further friction, owning would efficiently solve the private information problem and all houses would be owner-occupied.[21] To provide heterogeneity, we assume that there is an extra friction for owner-occupies which is heterogeneous in the population.[22] We assume that each household draws a "friction" $\chi \in [\underline{\chi}, \overline{\chi}] \subset \mathbb{R}_+$ from a probability distribution F, which is a fixed effect for the household. For simplicity, we assume that χ is independent of type i and that the friction additively taxes the value of searching and living in a house. Independence could be easily relaxed while additivity means that, for each type i, there will be at most one owning contract that in equilibrium attracts searchers, which eases notation.[23]

Builders only have to sell a new house. It is important to notice that sellers posting an owning contract are not concerned about the buyer's type, regardless of whether this information is private or public. A household that buys the house, an owner, fully internalizes the expected search cost eventually paid in the case of separation, contrary to a renter. The builder's expected value of posting an owning contract for sale at price P with implied tightness θ is simply given by

$$X_o(P, \theta) = \frac{\alpha_l(\theta)}{\rho + \alpha_l(\theta)} P \tag{6}$$

Notice that (6) is independent of γ_i. In equilibrium $X_o(P, \theta) = H$ for any owning submarket with positive ownership rates. This will immediately imply that sale prices are negatively correlated with market tightnesses across submarkets.

The values of searching as a buyer and living in a submarket with owner-occupied market tightness θ and price P for a household of type i and cost χ, respectively, are given by

$$\rho Z_o(\gamma_i, P, \theta, \chi) = \alpha_h(\theta)(V_o(\gamma_i, P, \theta, \chi) - Z_o(\gamma_i, P, \theta, \chi) - P) - \chi$$
$$\rho V_o(\gamma_i, P, \theta, \chi) = h + \gamma_i(X(P, \theta) + Z_o(\gamma_i, P, \theta, \chi) - V_o(\gamma_i, P, \theta, \chi)) - \chi$$

Solving for the flow value of searching as a buyer gives

$$\rho Z_o(\gamma_i, P, \theta, \chi) = \rho Z_r(\gamma_i, r_i, \theta) - \chi$$

where $r_i = P(\rho + \gamma_i + \alpha_l(\theta))/(\rho + \alpha_l(\theta))$.

3.6. Equilibrium with both renting and owning

In the appendix, we formally define a competitive equilibrium with private information and both renting and owning. The market endogenously segments into submarkets and we can characterize the equilibrium allocation using an equivalent constrained maximization problem. The equilibrium with both renting and owning can be characterized by the iterative solutions to a problem analogous to the one with only renting[24]:

[21] The $i=1$ type would be indifferent between owning and renting.

[22] There are plenty of potential candidate frictions. For instance, a (possibly heterogeneous) "financing cost" or additional transactions costs. See Halket and Pignatti (2012) for an example where the friction is sequential search for owner-occupiers.

[23] Fixed types and χs are not essential. For instance, we could allow a household's type i and χ to change whenever it received a separation shock. The economy would be quantitatively exactly the same as long as the distribution over types and χ remained constant.

[24] We omit the proof, however it too is similar to the case with only renting.

$$Z_{po}^{*i}(\chi) \equiv \max_{\{rent,own\}} \left\{ \tilde{Z}_p^i \equiv \max_{\tilde{\theta}_p^i \in \mathbb{R}_+, w_i \in [\rho H, h]} Z_r(\gamma_i, w_i, \tilde{\theta}_p^i), \max_{\theta_o^i \in \mathbb{R}_+, P_i \in [H, h/\rho]} Z_o(\gamma_i, P_i, \theta_o^i, 0) - \chi \right\}$$

$$\text{s.t.} \quad \frac{\alpha_l(\tilde{\theta}_p^i)}{\rho + \gamma_i + \alpha_l(\tilde{\theta}_p^i)} w_i \geq \rho H$$

$$P_i = \frac{\rho + \alpha_l(\theta_o^i)}{\alpha_l(\theta_o^i)} H$$

$$Z_{po}^{*i-1}(\overline{\chi}) \geq Z_r(\gamma_{i-1}, w_i, \tilde{\theta}_p^i) \quad \text{for all } i > 1$$

Result 3. *The proportion of type i that are homeowners is increasing in i and thus expected duration.*

Proof. See Appendix.

As the equilibrium is separating, submarkets contain only one type. Result 3 says that submarkets with high duration types will have higher ownership rates on average. The equilibrium in the private information rental market for the highest-γ type is the same as in the public information case. For households with lower γ's, the equilibrium in the (private information) rental market is increasingly distorted with respect to the first best (public information) equilibrium. This immediately implies that the type-specific cutoff $\chi^\dagger$ such that $\tilde{Z}_p^i = Z_o^{*i}(\chi^\dagger)$ is increasing in *i*. The optimal market tightness conditional on owning for each type, θ_o^{*i}, is identical to the optimal tightness in that type's rental market with public information, θ_r^{*i}.

Homeownership rates increase in expected duration solely because the rental frictions modeled here are endogenously increasing in expected duration. If we relaxed the assumption that the distribution of χ was independent of *i*, it would be natural to assume that those with higher expected durations also had lower homeownership frictions. For instance, an exogenous transaction costs to buying a house would work in such a manner. In such cases, this would *reinforce* Result 3.

4. Calibration

As we know from the theoretical results above, for any parametrization, the model with private information gives the following qualitative patterns: (a) rentals have a lower time on the market in submarkets with lower rents, (b) households with high expected durations that search for rentals search for ones with low times on the market and lower rents; (c) households with high expected durations search in for-sale markets with higher prices if they search for owner-occupied housing; and (d) areas with high ownership rates also have low rent-to-price ratios. These are qualitatively consistent with our findings from the data. In this section, we match the model quantitatively to the data and measure the welfare loss due to private information.

A key parameter governing the size of the welfare loss due to the private information problem is the elasticity of the matching function, ε. In the equilibrium with private information, the matching probability, α_h, of long duration types declines so as to screen those with shorter expected durations. Long duration types receive even lower rents (relative to the public information benchmark) though. What determines the size of the welfare loss is how big a decrease in rents the longer duration type households receive in exchange for a given change in their matching probability. A low elasticity means that α_l changes relatively little in response to a change in α_h and therefore (using the landlords zero-profit condition) rents change relatively little as well. In this section, we calibrate the model to match the estimated elasticity of vacancy duration with respect to expected occupancy duration from Section 2 as well as other moments. We find that the data implies a very low value of ε.

We set the interest rate, $\rho=0.03$, in line with estimates of the ex ante real interest rate on the 10-year U.S. Treasury Bonds, as in Campbell et al. (2009). Given ρ, only the ratio h/H matters for relative rents, prices and market tightnesses. The median duration of stay for renters in the U.S. is about 2 years (Hansen, 1998; Deng et al., 2003). We set $\overline{\gamma} = 1$ so that the worst type of household expects to stay 1 year.[25,26]

We assume the matching function is Cobb–Douglas: $m(u, v) = ku^{\varepsilon}v^{1-\varepsilon}$. The disutility to owning, χ, only affects homeownership rates and has no effect on vacancy rates or prices in owning or renting markets. Furthermore, our model is about rental frictions and has little to say about the frictions on the owner-occupied side of the market. For simplicity then we assume it is distributed uniformly on $[0, .15Z_r^{*1}]$.

We calibrate the three remaining parameters, k, ε and h/H, to match three moments in the data: the rent-to-price ratio, the average duration of rental vacancies and the elasticity of rental vacancy duration with respect to expected duration. Gabriel and

[25] Hansen (1998) finds that over 75% of current renters have lived in their current residence for at least a year. We could of course include atypical “renters” as well, such as short-term business travelers. Hotels and “executive rentals” do fit our qualitative theory after all; they rent out at high nightly rates but are relatively easy for tenants to secure. However they are not in our Craigslist data so we do not include them here.

[26] We assume $\{\gamma_i\}_{i=1}^{I=\infty}$ is dense in Γ.

Table 3
Moments in data and model.

Moment	Data	Model (Private)	Model (Public)
r/p	3.5%	3.25%	3.3%
Avg(θ)	1.5 months	1.45 months	6 days
$\frac{\partial \ln \theta}{\partial (1/\gamma)}$	-0.07	-0.09	>0

r/p, Avg(θ) and $\partial \ln \theta / \partial (1/\gamma)$ are the rent-to-price ratio, the average vacancy duration and the elasticity of vacancies with respect to expected duration, respectively. See text for complete details.

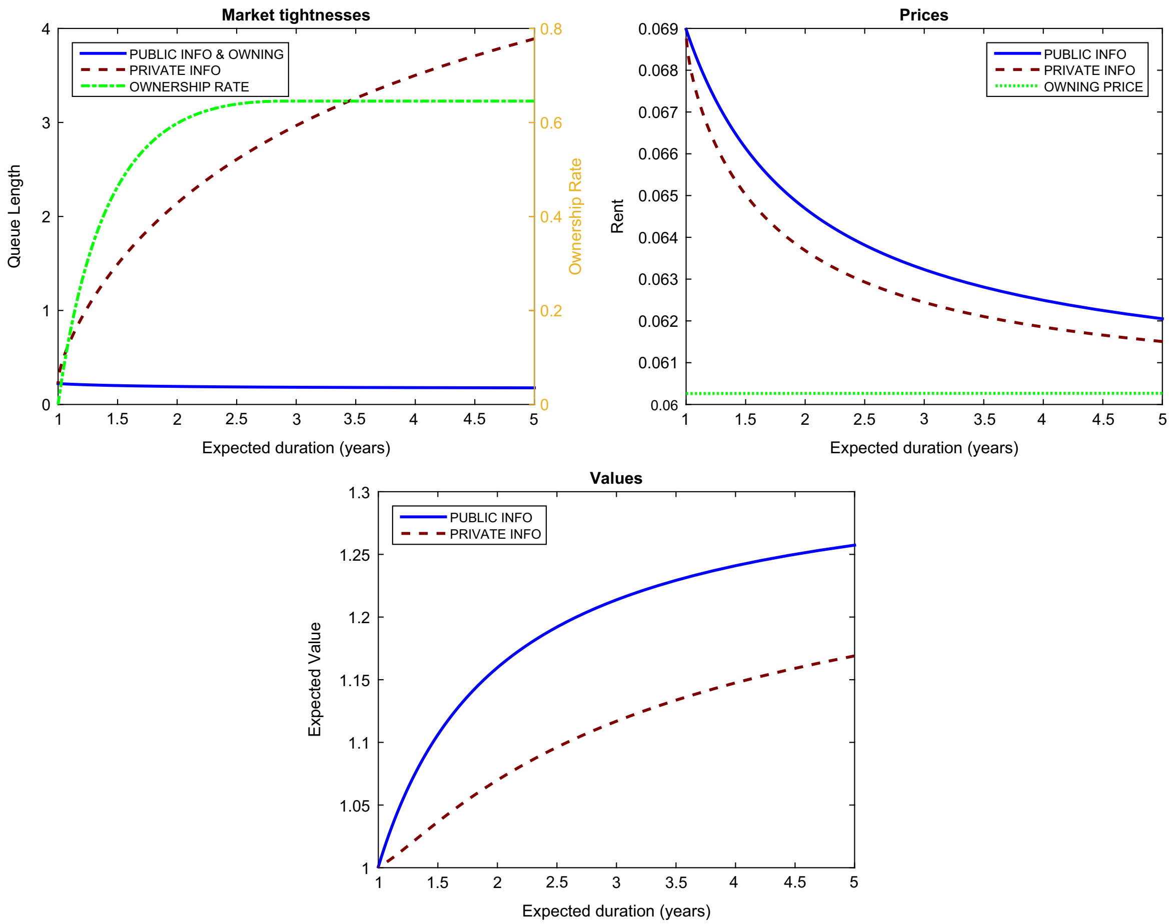

Fig. 3. Market tightness, prices and values.

Nothaft (2001) report average vacancy durations of between 1.5 and 2 months in the U.S. Our estimate of the elasticity from Section 2 is about -0.07 depending on which proxy for expected duration is used. We match these to the model using the expected rental vacancy duration and its elasticity for the submarket that corresponds to the median renter, $\gamma = 0.5$. Campbell et al. (2009) find an average (annual) rent-to-price ratio of about 5% in their U.S. sample.[27] However, rent-to-price ratios in the data implicitly account also for maintenance, which we abstract from. Halket and Vasudev (2014) report maintenance of about 1.5%, so we target a model rent-to-price ratio of 3.5%. The rent-to-price ratio varies across submarkets, so again we target the ratio at $\gamma = 0.5$. As it turns out, given the low estimate of ε, the rent-to-price ratio is between 3% and 4% for all submarkets. We compute the model moments at each point $(k, \varepsilon, h/H) \in [1, 2, \ldots, 20] \times [0.05, 0.1, \ldots, 1] \times [0.04, 0.05, \ldots, 0.15]$ and choose the point that minimizes the sum over the three moments of squared difference between the model and the data.[28]

[27] Rent-to-prices of course can vary considerably over time as interest rates, risk-premia, expected capital gains or other factors change.
[28] The optimal point in the grid does not vary with alternative weights on the moments.

We find that $k=8$, $\varepsilon=0.1$ and $h/H=0.05$. At these parameter values, the average rental vacancy duration in the $\gamma=0.5$ submarket is 1.45 months, the elasticity is -0.09 and the rent-to-price ratio is 3.25%. Table 3 reports the moments from the matched moments in the data and the model with private information, as well as the moment values under a public information counterfactual. The left panel of Fig. 3 plots the market tightness, or queue length, and the homeownership rate and the center panel plots the flow rent (or flow equivalent housing price) as a function of γ in the three economies: renting with public information, renting with private information and owning.

The queue length increases as γ increases very slightly in the case of renting with public information and in the owning economy, while it decreases as γ increases in the renting economy with private information. As we have already proven, renting with public information cannot *qualitatively* match the negative estimated elasticity of vacancy durations with respect to expected duration found in Table 2. Interestingly, with the very low calibrated value of ε, the elasticity of vacancy durations in the owning market is positive but nearly zero, which is also what we find in the data.

In both renting economies, the flow rent increases with γ: it increases faster in the private information case to offset the positive effect of the longer queue length faced by low γ-types on landlords' profits. The housing price in the owning economy markets, expressed in flow terms (ρP), decreases slightly as γ increases; prices are lower in markets where houses sell quickly, as follows from the free entry condition for the owning market.

Finally, the right panel of Fig. 3 shows the expected value of searching for a house as a function of γ when renting with public information and renting with private information. The expected value of renting is always higher with public information rather than private (they coincide for the highest value of γ). The expected value increases as γ decreases in both markets but it increases less in the private information renting market. Quantitatively, with the low elasticity, the expected welfare loss of renting due private information is about 10% for all households with expected durations longer than 2 years. Those households with low enough χ are able to ameliorate this loss by owning though. In the next section, we discuss how duration dependent rental payments can also help ameliorate this welfare loss.

5. Fully optimal rental contracts under private information

The welfare loss due to private information could be more efficiently ameliorated if rental contracts themselves could be written in such a way as to affect the off-equilibrium value of searching for the low duration types without affecting the equilibrium value of searching for higher types. That is, a planner could raise welfare by only lowering the off-equilibrium value of low duration households deviating into higher duration households' markets. In turns out, this is exactly what happens in a competitive equilibrium when we allow fully optimal, duration dependent contracts. In these contracts yield the same allocation and welfare as the competitive equilibrium with public information if households are risk-neutral. If households are risk averse then duration dependency does not generally obviate the private information problem.

We make two changes to the model: (a) limited commitment: households and landlords cannot make transfers to each other once a separation shock is received (though this is implicit in the preceding sections above) and (b) households are risk averse over their rent payments. Formally we assume that households still receive flow utility h from being well-matched to their current house. But now we assume that they receive disutility $u(r_t)$ from paying a flow rent r_t at time t, where $u(0)=0$, $u'>0$, $u''>0$.

Incentive compatible equilibrium rental contracts will now be functions $w(t)$ which depend on the duration of the match, t, and, implicitly, on not receiving a separation shock. Equilibrium contracts will still be separating and the equilibrium can still be characterized in a way similar to the private rental economy above (that is, a version of Proposition 4 holds here). So we skip straight to the characterization and focus on the case with renting only.

We can write the value of search for a household:

$$Z_{r2}(\gamma_i, w, \theta) = E[U|\gamma_i]\frac{\alpha_h(\theta)(\rho+\gamma_i)}{\rho(\alpha_h(\theta)+\rho+\gamma_i)} \tag{7}$$

where

$$E[U|\gamma_i] = \int_0^\infty e^{-(\rho+\gamma_i)t}\gamma_i(h-u(w(t)))\,dt. \tag{8}$$

Similarly we can write the value of search for the landlord:

$$X_{r2}(\gamma_i, w, \theta) = E[R|\gamma_i]\frac{\alpha_l(\theta)(\rho+\gamma_i)}{\rho(\alpha_l(\theta)+\rho+\gamma_i)} \tag{9}$$

where

$$E[R|\gamma_i] = \int_0^\infty e^{-(\rho+\gamma_i)t}\gamma_i w(t)\,dt. \tag{10}$$

Let the problem $(PR2)$ be defined by the following constrained maximization problem $(PR2_i)$, for any $i \in \mathbb{I}$:

$$\max_{\theta, w(t)} \quad Z_{r2}(\gamma_i, w, \theta)$$
$$\text{s.t.} \quad X_{r2}(\gamma_i, w, \theta) \geq H$$
$$\text{and} \quad Z_{r2}(\gamma_j, w, \theta) \leq Z_{r2}(\gamma_j, w_p^{*j}, \theta_p^{*j}) \text{ for all } j \neq i \qquad [IC(j, i)]$$

where w_p^{*j}, θ_p^{*j} is an optimal solution for j.

To see how this equilibrium is characterized, we can examine how the optimal solution for w depends on t, conditional on some θ (using that the incentive compatibility constraint binds for the next worse type):

$$\max_{w(t)} \quad \int_0^\infty e^{-(\rho+\gamma_i)t}\gamma_i(h - u(w(t)))\,dt$$
$$\text{s.t.} \quad \int_0^\infty e^{-(\rho+\gamma_i)t}\gamma_i w(t)\,dt \geq \frac{\rho(\alpha_l(\theta) + \rho + \gamma_i)}{\alpha_l(\theta)(\rho + \gamma_i)}H$$
$$\text{and} \quad \int_0^\infty e^{-(\rho+\gamma_j)t}\gamma_j(h - u(w(t)))\,dt \leq \frac{\rho(\alpha_h(\theta) + \rho + \gamma_j)}{\alpha_h(\theta)(\rho + \gamma_j)}Z_{r2}(\gamma_j, w_p^{*j}, \theta_p^{*j}), \quad j = i - 1$$

The first-order condition with respect to $w(t)$ is

$$\left(1 - \lambda_2 \frac{\gamma_j}{\gamma_i} e^{-(\gamma_j - \gamma_i)t}\right)\frac{du}{dw(t)} = \lambda_1 \tag{11}$$

where λ_1 and λ_2 are the Lagrange multipliers for the zero profit and incentive compatibility conditions, respectively. Note if information is public then $\lambda_2 = 0$ and $du/dw(t) = \lambda_1$, which means the optimal contract is constant with respect to time and we have the same allocations as the public information rental economy in the body of the paper.

From (11), it is clear that $w(t)$ is everywhere continuous in t. Differentiating (11) with respect to t gives (when $\lambda_2 > 0$)

$$(\gamma_j - \gamma_i)\frac{du}{dw(t)} = \frac{d^2u}{dw(t)^2}\frac{dw(t)}{dt} \tag{12}$$

This yields $dw/dt < 0$ for all t.

So the optimal rental contract with private information is continuously declining with time. Tenants bear some risk by paying more of the expected value of the contract sooner. Bearing this risk helps screen short durations types as they (effectively) discount the future more. However high early payments imply a lower expected value of search than the public information case. Thus there are competing tools to screen low duration searchers: high early payments and higher market tightnesses. The welfare loss due to high early payments is increasing in risk aversion. So, for sufficiently high risk aversion, the "planner" will still optimally distort market tightnesses by tightening them for long duration types as well as use downward-tilting rent profiles.

6. Conclusion

Novel data on rental markets from Craigslist shows that submarkets with high duration households have lower rent-to-price ratios, higher ownership rates and tighter rental markets. To explain these patterns, we build a competitive search equilibrium model of housing tenure choices where households have private information over their expected duration. Owning a house solves the private information problem but at some heterogeneous cost. We show that both renting and owning markets endogenously segment into submarkets, one for every type of households.

In rental submarkets, households that expect to stay longer search in thinner markets in order to discourage more footloose households from searching in the same submarket. Relative to the first-best, the distortions in the rental market with private information increase with expected duration. As a result, more of the households that expect to stay longest in their houses will choose to own.

Scopes for extension include adding heterogeneity to the housing stock and using a life-cycle model to unify expected durations and the costs of owning using perhaps a borrowing constraint. As long as any mooted cost of owning does not increase too quickly with expected duration, those with the highest expected durations will choose to own.

Acknowledgments

This paper formerly circulated under "Housing Tenure Choices With Private Information." We thank the editor Boragan Aruoba, Melvyn Coles, Allen Head, Ricardo Lagos, Andreas Muller, Roland Rathelot, Morten Ravn, Thomas Sargent, Randy Wright, two anonymous referees and especially Gian Luca Violante for helpful comments. We are also grateful to seminar participants at the Atlanta, Boston and Cleveland Federal Reserves, Arizona State University, University of Toronto, Yeshiva University, Baruch College, New York University, Bank of Italy, Institute for Advanced Studies in Vienna, the Federal Reserve

Board, the University of Essex Search and Matching Workshop, Society for Economic Dynamics, Vienna Macro Cafe, Paris SAM, HULM-Atlanta and the Nordic Macroeconomics Conferences and to Patrick Killelea, who gathered the Craigslist data. Jonathan Halket thanks the ESRC for funding under Grant number PTA-026-27-2395 and through the ESRC Centre for Microdata Methods and Practice (CeMMAP) Grant number ES/I034021/1.

Appendix A. Supplementary data

Supplementary data associated with this paper can be found in the online version at http://dx.doi.org/10.1016/j.jmoneco.2015.08.003.

References

Acemoglu, D., Shimer, R., 1999. Efficient unemployment insurance. J. Polit. Econ. 107 (5), 893–928.
Albrecht, J., Anderson, A., Smith, E., Vroman, S., 2007. Opportunistic matching in the housing market. Int. Econ. Rev. 48 (2), 641–664.
Albrecht, J., Gautier, P.A., Vroman, S., 2010. Directed Search in the Housing Market. Tinbergen Institute Discussion Papers 10-005/3. Tinbergen Institute.
Amior, M., Halket, J., 2014. Do households use homeownership to insure themselves? evidence across u.s. cities. Quant. Econ. 5 (3).
Barker, D., 2003. Length of residence discounts, turnover, and demand elasticity. Should long-term tenants pay less than new tenants? J. Hous. Econ. 12 (1), 1–11.
Boehm, T.P., Herzog Jr., H.W., Schlottmann, A.M., 1991. Intra-urban mobility, migration and tenure choice. Rev. Econ. Stat. 73, 59–68.
Bracke, P., 2013. House prices and rents: Micro evidence from a matched dataset in central London, SERC Discussion Papers 0127, Spatial Economics Research Centre, LSE.
Brueckner, J.K., 1994. Borrower mobility, adverse selection, and mortgage points. J. Financ. Intermediation 3 (4), 416–441.
Cameron, S., Tracy, J., 1997. The Transition to Homeownership: The Importance of Early Career Concerns.
Campbell, J.Y., Cocco, J.F., 2007. How do house prices affect consumption? Evidence from micro data. J. Monet. Econ. 54 (3), 591–621.
Campbell, S.D., Davis, M.A., Gallin, J., Martin, R.F., 2009. What moves housing markets: a variance decomposition of the rent-price ratio. J. Urban Econ. 66 (2), 90–102.
Caplin, A., Leahy, J., 2011. Trading frictions and house price dynamics. J. Money Credit Bank. 43, 283–303.
Chambers, M., Garriga, C., Schlagenhauf, D., 2009a. The loan structure and housing tenure decisions in an equilibrium model of mortgage choice. Rev. Econ. Dyn. 12 (3), 444–468.
Chambers, M., Garriga, C., Schlagenhauf, D.E., 2009b. Accounting for changes in the homeownership rate. Int. Econ. Rev. 50 (3), 677–726.
Chang, B., 2011. Adverse Selection and Liquidity Distortion in Decentralized Markets, Discussion Papers 1513, Northwestern University, Center for Mathematical Studies in Economics and Management Science.
Cocco, J., 2005. Portfolio choice in the presence of housing. Rev. Financ. Stud. 18 (2), 535–567.
Delacroix, A., Shi, S., 2013. Pricing and signaling with frictions. J. Econ.Theory 148 (4), 1301–1332.
Deng, Y., Gabriel, S.A., Nothaft, F.E., 2003. Duration of residence in the rental housing market. J. Real Estate Finance Econ. 26 (2–3), 267–285.
Diaz, A., Luengo-Prado, M.J., 2008. On the user cost and homeownership. Rev. Econ. Dyn. 11 (3), 584–613.
Fisher, J.D.M., Gervais, M., 2011. Why has home ownership fallen among the young? Int. Econ. Rev. 52 (3), 883–912.
Gabriel, S.A., Nothaft, F.E., 2001. Rental housing markets, the incidence and duration of vacancy, and the natural vacancy rate. J. Urban Econ. 49 (1), 121–149.
Gervais, M., 2002. Housing taxation and capital accumulation. J. Monet. Econ. 49, 1461–1489.
Guasch, J.L., Marshall, R.C., 1987. A theoretical and empirical analysis of the length of residency discount in the rental housing market. J. Urban Econ. 22 (3), 291–311.
Guasch, J., Marshall, R.C., 1985. An analysis of vacancy patterns in the rental housing market. J. Urban Econ. 17 (2), 208–229.
Guerrieri, V., Shimer, R., 2014. Dynamic adverse selection: a theory of illiquidity, fire sales, and flight to quality. Am. Econ. Rev. 104 (7), 1875–1908.
Guerrieri, V., Shimer, R., Wright, R., 2010. Adverse selection in competitive search equilibrium. Econometrica 78 (6), 1823–1862.
Halket, J., Pignatti, M., 2012. Housing Tenure Choices with Private Information, Economics Discussion Papers 717, University of Essex, Department of Economics.
Halket, J., Vasudev, S., 2014. Saving up or settling down: Home ownership over the life cycle. Rev. Econ. Dyn. 17 (2), 345–366.
Hansen, K.A., 1998. Seasonality of Moves and Duration of Residence, no. 66. US Department of Commerce, Economics and Statistics Administration, Census Bureau.
Haurin, D.R., Gill, H.L., 2002. The impact of transaction costs and the expected length of stay on homeownership. J. Urban Econ. 51 (3), 563–584.
Head, A., Lloyd-Ellis, H., Sun, H., 2014. Search, liquidity, and the dynamics of house prices and construction. Am. Econ. Rev. 104 (4), 1172–1210.
Henderson, J.V., Ioannides, Y.M., 1983. A model of housing tenure choice. Am. Econ. Rev. 73 (1), 98–113.
Hubert, F., 1995. Contracting with costly tenants. Reg. Sci. Urban Econ. 25 (5), 631–654.
Iacoviello, M., Pavan, M., 2013. Housing and debt over the life cycle and over the business cycle. J. Monet. Econ. 60 (2), 221–238.
Kan, K., 2000. Dynamic modeling of housing tenure choice. J. Urban Econ. 48, 46–69. http://dx.doi.org//10.1006/juec.1999.2152.
Kiyotaki, N., Michaelides, A., Nikolov, K., 2011. Winners and losers in housing markets. J. Money Credit Bank. 43, 255–296.
Li, W., Yao, R., 2007. The life-cycle effects of house price changes. J. Money Credit Bank. 39 (6), 1375–1409.
Merlo, A., Ortalo-Magn, F., 2004. Bargaining over residential real estate: evidence from england. J. Urban Econ. 56 (2), 192–216.
Miceli, T.J., Sirmans, C.F., 1999. Tenant turnover, rental contracts, and self-selection. J. Hous. Econ. 8 (4), 301–311.
Moen, E.R., 1997. Competitive search equilibrium. J. Polit. Econ. 105 (2), 385–411.
Ngai, L.R., Tenreyro, S., 2014. Hot and cold seasons in the housing market. Am. Econ. Rev. 104 (12), 3991–4026.
Piazzesi, M., Schneider, M., 2009. Momentum traders in the housing market: survey evidence and a search model. Am. Econ. Rev. 99 (2), 406–411.
Piazzesi, M., Schneider, M., Stroebel, J., 2015. Segmented Housing Search. NBER Working Papers 20823. National Bureau of Economic Research, Inc.
Piskorski, T., Tchistyi, A., 2010. Optimal mortgage design. Rev. Financ. Stud. 23 (8), 3098–3140.
Piskorski, T., Tchistyi, A., 2011. Stochastic house appreciation and optimal mortgage lending. Rev. Financ. Stud. 24 (5), 1407–1446.
Rios-Rull, J.-V., Sanchez-Marcos, V., 2008. An aggregate economy with different size houses. J. Eur. Econ. Assoc. 6 (2–3), 705–714.
Shimer, R., 1996. Contracts in a frictional labor market. MIT mimeo.
Sinai, T., Souleles, N.S., 2005. Owner-occupied housing as a hedge against rent risk. Q. J. Econ. 120 (2), 763–789.
Verbrugge, R., 2008. The puzzling divergence of rents and user costs, 1980–2004. Rev. Income Wealth 54 (4), 671–699.
Verbrugge, R., Poole, R., 2010. Explaining the rento inflation divergence, 1999–2007. Real Estate Econ. 38 (4), 633–657.
Wheaton, W.C., 1990. Vacancy, search, and prices in a housing market matching model. J. Polit. Econ. 98 (6), 1270–1292.