Homeownership and the Scarcity of Rentals*

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Abstract

Using a novel data set of rental market listings, we find that homeownership rates are high where price-to-rent ratios are high but rental properties are scarce. We model the provision of owner-occupied versus rental housing services as a competitive search economy where households have private information over their expected duration. Owning is assumed inefficient but does solve the private information problem. With public information, households with low vacancy hazard rates pay lower rents and search in thicker markets. With private information, rentals are under-provided to long-duration households to discourage short-duration households from searching there. If households have high enough expected durations, rentals become scarce enough that they prefer to own. The data confirm that long-duration households sort into scarce rental markets, consistent with a private information problem.

Keywords: adverse selection, competitive search, housing tenure

JEL Classification: C78, R13, R21, R23.

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1 Introduction

We use a large, novel dataset of rental and for sale listings from Craigslist to show that, within a market (such as a city), the parts of the market (i.e. "submarkets") where homeownership rates are high are also the parts where rentals are relatively cheap but scarce. 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. 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. Crucially, the data allow us to measure scarcity by measuring how quickly vacant homes are filled and not just the supply of housing in a submarket.

Figure 1 illustrates the basic stylized correlations between rent-to-price ratios, homeownership rates and rental vacancy rates using the Seattle Area. In the figures, each dot is a submarket, which we define as housing with a particular number of bedrooms in a particular zip code. Rent-to-price ratios are the ratio of the mean rent to mean price in submarket (e.g. the mean over 2 bedroom listings in zip code 49820) using the Craigslist data (see below for complete description). Homeownership rates are from the Census at the same bedroom x zip code level. Time on the market is the average number of days that a rental property is posted for rent in our Craigslist data. Verbrugge (2008); Verbrugge and Poole (2010); Bracke (2013) find similar positive correlations between price-to-rent ratios and homeownership rates; the latter even after controlling for potential unobserved heterogeneity. The figures also show that rental properties stay on the market longer in high price-to-rent ratio submarkets and in submarkets where homeownership is low.

Using a competitive search model, we show that when households' expected durations are public information, rentals are counterfactually scarce in submarkets where short duration households search. However when expected durations are private information, an adverse selection problem causes rental housing to be scarce in submarkets where long duration households search and endogenously leads to high homeownership rates among these households even though price-to-rent ratios in their submarkets are also high.

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].

However, there is little consensus on the frictions that favor owning. Tax wedges may offer one

[1]e.g. Campbell and Cocco (2007); Chambers, Garriga and Schlagenhauf (2009*a*,*b*); Cocco (2005); Diaz and Luengo-Prado (2008); Fisher and Gervais (2007); Gervais (2002); Amior and Halket (2012); Iacoviello and Pavan (2009); Kiyotaki, Michaelides and Nikolov (2008); Li and Yao (2007); Rios-Rull and Sanchez-Marcos (2008)

motive for owning (as in Diaz and Luengo-Prado (2008); Gervais (2002)). Other, more "fundamental" frictions used in models include 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)), amplifications to the perceived volatility of rents (Berkovec and Fullerton (1992)), a housing ladder with only owner-occupied housing on the top rungs (Ortalo-Magne and Rady (2006); Rios-Rull and Sanchez-Marcos (2007)), and a warm glow to owning (Iacoviello and Pavan (2009); Kiyotaki et al. (2008)).[2] While "intuitive", it is not yet clear what the size and ultimate source of these various frictions are. Most, like differential housing supply and warm glows, are likely equilibrium outcomes rather than inputs.

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 an outcome of a contracting problem and a search problem. In the baseline model, 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 future 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) and Shimer (1996)). In equilibrium, vacancies in a particular submarket adjust so that the expected return to adding a new house in any submarket is the same.

Our main results are twofold. First, 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 markets than households with high hazard rates. However, when expected durations are private information, long-duration households search in tighter markets than short-duration households, thus they spend more time on average

[2]One class of frictions that may work both ways is risk in the housing market, as in Sinai and Souleles (2005).

[3]There is a long literature looking at mobility and homeownership choices. Deng, Gabriel and Nothaft (2003) and Gabriel and Nothaft (2001) find considerable variation across households and Metropolitan Statistical Areas in rental vacancy rates and durations. Boehm, Herzog Jr. and Schlottmann (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.

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 markets.

The data are consistent with the presence of an information problem. Under public information, submarkets with higher surplus matches (due to the high expected duration of the matches) should have lower queues for rental housing and lower rents. Instead the data show that while rents are lower, queues are higher in high surplus submarkets. To our knowledge, this is the first data on rental vacancies capable of affording a within market analysis of the variation in (sub)market tightnesses.

In our economy, owning a house solves the private information problem by internalizing the separation hazard in the optimal search problem of the household, but at some heterogenous cost. 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 implied by the incentive problem in the rental market pile-up: the deviations from first-best due to private information (compared to the public information benchmark) are larger in markets where the long-duration households search. Meanwhile the 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 dominate her cost of owning so that she prefers to own the house even though owning would otherwise be less efficient (in a first-best sense). This too is consistent with the correlations we find in the data.

A policy of rent control predictably leads to a lower supply of rental housing and tighter markets in the regulated market in both public and private information cases. With private information however, the effects on the regulated market spill into the unregulated market, leading to lower supply and tighter markets there as well. This happens even though there is no excess demand in any market (as in e.g. Fallis and Smith (1984)); all markets are in equilibrium. Instead, by worsening the allocation for low-duration households, rent control exacerbates the information problem, making it more costly for higher-duration households to screen the low-duration households.

In the final part of our paper, we give the economy access to a technology which permits the building of non-conforming, i.e. customized, houses; which we model as giving a higher utility flow at some cost to the matching probability. We show that customization appeals most to long-duration households. So, unlike rent control, the customization technology offers an additional way to relax the incentive compatibility constraints in the rental market; thus there may be "over-customization" in the rental market relative to the public information benchmark. And yet, since the appeals of owning and customization are each increasing in expected duration, more owners than renters may customize. If customization is observable to an econometrician using hedonics, than owner-occupiers will appear to live in houses with more amenities, otherwise they will appear to get a warm glow from owning (that is, they would appear to get a higher utility flow from the same observable set of house attributes).

We are following a growing literature by looking at housing in a search or matching framework (e.g. Albrecht, Anderson, Smith and Vroman (2007); Albrecht, Gautier and Vroman (2010); Caplin and Leahy (2008); Ngai and Tenreyro (2009); 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[5]. Our work looks at contracts to supply housing services[6] when there are search frictions and asymmetric information and thus extends the work of Guerrieri, Shimer and Wright (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. Concurrently and complementarily, Chang (2011) and Guerrieri and Shimer (2012) examine environments where the markets can change dynamically, however all contracts are one-time exchanges (purchases and sales of assets).

Variations in households' marginal rates of substitution across submarkets could potentially explain this correlation (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, price-to-rent ratios vary even though the marginal rates of transformation are constant.

Our work on customization is a sort of companion to House and Ozdenoren (2008). In their model of durable goods, goods that are more durable are endogenously more homogeneous due to resale concerns. They cite "McMansions" (which are predominately owner-occupied) as an example of a generic durable good. In our model, durable goods are endogenously heterogeneous or homogeneous based on the expected duration of the match (rather than the duration of the good). The typical owner-occupied house is actually relatively varied compared to rental housing in our economy since, endogenously, owner-occupiers expect to be matched longer with their house.

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 economies of renting with public and then private information; Section 4 presents the owning technology and the

[5]Hubert (1995); 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.

[6]and in this sense compliments the work on optimal mortgage design in owner-occupied markets (contracts for loans backed by housing services) by Piskorski and Tchistyi (2011, 2010)

[7]Delacroix and Shi (2007) 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.

equilibrium with owning and renting; Section 5 presents a numerical example and the effects of rent control while section 6 presents the customization technology. Section 7 concludes by commenting briefly on how our economy here could be extended to include optimal rental contracts. 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 span 2010-2011 and contain over 2.29 million for-sale postings and 3.16 million for-rent postings with listed addresses on Craigslist websites for metropolitan areas within the U.S.A. In addition to the street address, the data contain an asking price or rent, an advertised number of bedrooms and the date of the posting[8].

We match houses across listings according to the following algorithm. 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 percent of the pre-existing listing.[9] 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 a several (but not many) instances where multiple apartments in the same building are for rent/sale. In what follows we use the last posted rent or sale price as 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 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. 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.

Our notion of a submarket is all housing for rent (or sale) within a zip code with the same number of bedrooms. 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

[8] The data also contain 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] Our results are robust to changes in these numbers.

and then taking the ratio of those means as the rent-to-price ratio for that cell.

From the 2010 Census, we have zip code level measures of homeownership rates, 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 under age 35. 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.

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. So we treat all rentals located in a common three digit zip with the same number of bedrooms as being in the same market. A submarket within this market is then a particular zip code and number of bedrooms.

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 with the submarkets they choose to search and live in and with rental rates and the availability of rental homes. Expected duration is treated as exogenous, but location choice (and therefore the average expected duration in a location), 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. Our partitioning of markets and submarkets is somewhat arbitrary and we do not account for spatially correlated errors beyond clustering the standard errors at the zip level. Omitted variables are likely a huge problem. We use two different proxies for average expected duration: the proportion of households under 35 years old living in the area, and the average time since last move for renters[10]. Age is positively correlated with expected duration (since uncertainty over income and family prospects falls with age, see Halket and Vasudev (2013)), so the proportion under 35 will be negatively correlated with expected duration. Meanwhile (ex-post) actual duration is almost certainly positively correlated with (ex-ante) expected duration. We include median income in the zip in our regressions as unobserved quality and thus rents and prices is likely correlated with income. Of course, neither age nor perhaps realized duration is orthogonal to income. Furthermore expected duration is correlated with tenure decisions due to the high transactions costs of home ownership. So the

[10]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

	rent	rent	rent	price	price	price	rent/price	rent/price
time rent	0.022**							
	(0.005)							
time sale				0.047**				
				(0.009)				
prop under 35 yr		0.118**			-0.040**		0.052**	
		(0.009)			(0.013)		(0.011)	
duration in home			-0.080**			0.073*		-0.040**
			(0.011)			(0.030)		(0.015)
median inc	0.404**	0.375**	0.303**	0.734**	0.760**	0.890**	-0.313**	0.351**
	(0.011)	(0.012)	(0.011)	(0.018)	(0.017)	(0.026)	(0.014)	(0.013)

All variables are in logs and all regressions include dummies for zip000s and number of bedrooms. *time rent* (*time sale*) is the T_i conditional on being for-rent (for-sale). *prop under 35 yr* is the proportion of households in the zip code with head of house under age 35. SEs, clustered by zip000, in parentheses. ** $p < 0.01$, * $p < 0.05$.

tenure rate results below should be taken with an additional grain of salt.

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, in rental markets, landlords must be compensated with higher rents when renting in markets where houses stay vacant for longer. Table 1 also shows that households with lower expected durations search in submarkets with higher rental prices but lower sales prices. Unsurprisingly then, rent-to-price ratios in the submarkets where these households search tend to be higher. Despite the fact that rentals are expensive relative to prices, though, homeownership rates tend to be lower in these same submarkets (Table 2).

From Table 2, households with lower expected durations search in rental markets where time on the market is longer, while time on the for-sale market is hardly different. As we will show below, a negative correlation between expected duration and time on the market is not consistent with a competitive search equilibrium with public information. Searching for a new tenant is costly, so more surplus is created when a landlord is matched with a high expected duration tenant. In

Table 2: Regressions

	time rent	time rent	time sale	time sale	tenure	tenure
prop under 35 yr	0.058**		-0.010		-0.306**	
	(0.0076)		(0.018)		(0.011)	
duration in home		-0.116**		-0.018		0.271**
		(0.010)		(0.029)		(0.021)
median inc	0.017*	-0.021**	0.032*	0.029	0.455**	0.665**
	(0.008)	(0.007)	(0.013)	(0.015)	(0.015)	(0.012)

See notes to Table 1

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. Instead, the data show that landlords match quickly with long duration households. In what follows, we will argue that this is evidence for an extra private information friction.

3 Rental market

3.1 Preferences and technology

Time is continuous and the horizon is infinite. There is a measure one of households indexed by their type $i \in \mathbb{I} = \{1, 2, .., I\}$ and a large set of landlords or 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 doesn't 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 $\rho < 1$. We assume $h > \rho H$.

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. 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 $\Gamma = [\underline{\gamma}, \bar{\gamma}]$. We will also derive some analytical and computational results for the special case where $\{\gamma_i\}_{i=1}^{\infty}$ is dense in Γ. We refer to this special case as the differential-γ case.

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. We will restrict our attention to rental contracts with a fixed flow rent. Barker (2003) finds that most rental contracts do not have a duration-of-stay discount. Our model would yield similar qualitative features but would be far more complicated if we also imposed limited commitment constraints on both the household and landlord and a preference for smooth payments (perhaps due to borrowing constraints). In section 7, we offer some discussion of fully dynamic contracts.

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. This will eventually simplify the notation greatly.

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.[11]

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 $\alpha_l(\theta)$, $\varepsilon(\theta) \equiv \frac{\theta}{\alpha_l(\theta)} \frac{d\alpha_l(\theta)}{d\theta}$ 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 $\psi(w) = \{\psi_1(w), \psi_2(w), ..., \psi_I(w)\} \in \Delta^I$, 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

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

house[12], 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:

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

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:

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

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:

$$\rho Z_r(\gamma_i, r, \theta) = \frac{\alpha_l(\theta)}{\theta(\rho + \gamma_i) + \alpha_l(\theta)}(h - r) \tag{1}$$
$$\rho X_r(w, \theta) = \left(1 + \alpha_l(\theta) \sum_{i \in \mathbb{I}} \frac{\psi_i(w)}{\rho + \gamma_i}\right)^{-1} \alpha_l(\theta) \sum_{i \in \mathbb{I}} \frac{\psi_i(w) r_i}{\rho + \gamma_i} \tag{2}$$

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 $\psi_i(w)\theta > 0$.

3.2 Equilibrium with public information

A competitive search equilibrium satisfies the following conditions in every submarket: (i) landlords maximize expected profits; (ii) free entry (new entrants earn zero profits in expectation); (iii) households direct their search to the most convenient posted vacancy; (iv) $\theta = \theta(w)$ is consistent with rational expectations in equilibrium but also for any possible deviation w'.

More precisely, a landlord offering $w' \neq w$ expects that households apply until the market tightness θ' implies an expected value for the household equal to the outside option Z_r, that is taken as given by the (atomistic) firm. Formally:

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

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* $\mathrm{W}_\mathrm{r}^* \subseteq \mathrm{W}^\mathbb{I}$ *each of which specifies a rent* r_i *for each* $i \in \mathbb{I}$*, a function* $\theta_r^* : \mathrm{W}^\mathbb{I} \to \mathbb{R}_+$*, a measure* λ *on* $\mathrm{W}^\mathbb{I}$ *with support* W_r^**, and a function* $\psi : \mathrm{W}^\mathbb{I} \to \Delta^I$ *satisfying, for each* $i \in \mathbb{I}$*:*

(i) Landlords' profit maximization and free entry:

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

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

(ii) Households' optimal search:

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

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

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

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

(iii) market clearing:

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

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 $w' \notin \mathrm{W}_\mathrm{r}^*$, 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* $w \in \mathrm{W}_\mathrm{r}^*$ *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* $w^A \in \mathrm{W}_\mathrm{r}^{*\mathrm{A}}$*,* $\psi_i(w^A) > 0$ *implies there exists a* $w^B \in \mathrm{W}_\mathrm{r}^{*\mathrm{B}}$ *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. □

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 $v(w) = \frac{\gamma_i \pi_i}{\alpha_l(\theta_r^*(w)) + \gamma_i \theta_r^*(w)}$.

3.2.1 Characterization

A necessary and sufficient condition for a separating competitive search equilibrium is the following:[13]

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:*

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

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:

$$\frac{h}{\rho H} = 1 + \frac{1}{\theta_r^{*i}} \frac{\varepsilon}{1 - \varepsilon} + \frac{\rho + \gamma_i}{\alpha_l(\theta_r^{*i})(1 - \varepsilon)} \tag{3}$$

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

[13] 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 $\mathrm{W}^\mathbb{I}$ 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.

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 surplus from matching with a house and thus face tighter markets and higher rents once matched and as a consequence have lower search values.

Analytically, for the differential-γ case, by differentiating[14] the equilibrium condition (3) we obtain:

$$\frac{d\theta_r^*}{d\gamma} = \frac{1}{\varepsilon}\frac{\theta_r^{*2}}{\theta_r^*(\rho+\gamma) + \alpha_l(\theta_r^*)} > 0$$
$$\frac{dw_r^*}{d\gamma} = \frac{\rho H}{\theta_r^*(\rho+\gamma) + \alpha_l(\theta_r^*)} > 0$$
$$\frac{dZ_r^*}{d\gamma} = -Z_r^*\frac{\theta_r^*}{\varepsilon(\theta_r^*(\rho+\gamma) + \alpha_l(\theta_r^*))} < 0$$

[14]We need to explicitly define our notion of differentiation. Let $f : \mathbb{N} \to \mathbb{R}$ and $g : range(f) \to G \subseteq \mathbb{R}$. Define

$$\frac{\partial g}{\partial f}|_q = \lim_{q' \to q} \frac{g(q') - g(q)}{q' - q}$$

where $q, q' \in range(f)$. The total derivative is defined analogously.

3.3 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 section, 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 households value of being matched, 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 $w \in [\rho H, h]$).

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*

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

Proof. Follows from equation 1. □

The sorting lemma is sufficient to have a separating equilibrium and differs from the (assumed) condition in Guerrieri et al. (2010) in that it involves local perturbations in both the contract w and the market tightness θ. We 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) $\mathrm{W}_\mathrm{p}^* \subseteq [\rho H, h]^{\mathbb{I}}$, 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 $w \in \mathrm{W}_\mathrm{p}^*$.

(ii) households' optimal search: Let

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

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:

$$\int_{\mathrm{W}_\mathrm{p}^*} \psi_i(w)\left(\theta_p^*(w) + \frac{\alpha_l(\theta_p^*(w))}{\gamma_i}\right) d\lambda(w) = \pi_i \quad \forall i$$

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, 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.

3.3.1 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* $i \in \mathbb{I}$*:*

$$\begin{aligned} &\max_{\theta \in \mathbb{R}_+, w \in \mathbb{R}_+} Z_r(\gamma_i, w, \theta) \\ s.t. \quad &\frac{\alpha_l(\theta)}{\rho + \gamma_i + \alpha_l(\theta)} w \geq \rho H \\ \text{and} \quad &Z_r(\gamma_j, w, \theta) \leq Z_r(\gamma_j, w_p^{*j}, \theta_p^{*j}) \quad \text{for all } j \neq i \qquad [IC(j,i)] \end{aligned}$$

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 $i > 1$:

$$Z_r(\gamma_{i-1}, w_p^{*i}, \theta_p^{*i}) = Z_r(\gamma_{i-1}, w_p^{*,i-1}, \theta_p^{*,i-1}) \quad \textit{and}$$
$$Z_r(\gamma_j, w_p^{*i}, \theta_p^{*i}) < Z_r(\gamma_j, w_p^{*j}, \theta_p^{*j}) \quad \forall\, j \neq i, i-1$$

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

$$\begin{aligned} &\max_{\theta \in \mathbb{R}_+, w \in \mathbb{R}_+} Z_r(\gamma_i, w, \theta) \\ \text{s.t.} \quad &\frac{\alpha_l(\theta)}{\rho + \gamma_i + \alpha_l(\theta)} w \geq \rho H \\ \text{and} \quad &Z_r(\gamma_{i-1}, w_p^{*i}, \theta_p^{*i}) \leq Z_r(\gamma_{i-1}, w_p^{*,i-1}, \theta_p^{*,i-1}) \end{aligned}$$

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 $\{w_p^{*i}\}_{\mathbb{I}}, \quad w_p^{*i} \in [\rho H, h]$ and market tightnesses $\{\theta_p^{*i}\}_{\mathbb{I}}, \quad \theta_p^{*i} \equiv \theta_p^*(w_p^{*i}) \equiv \theta_i$ 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, $\frac{v_p^{*i}}{\pi_i - u_p^{*i} - v_p^{*i}}$ increases;

Proof. See Appendix. □

Analytically, for the differential-γ case, then:

$$\frac{d\theta_p^*}{d\gamma} = -\frac{1}{\rho+\gamma}\left[(1-\varepsilon)\frac{\rho Z_p^*}{\rho H} - \frac{\varepsilon}{\theta_p^*}\right]^{-1} < 0$$
$$\frac{dw_p^*}{d\gamma} = \frac{(1-\varepsilon)\rho Z_p^*}{\alpha_l(\theta_p^*)}\left[(1-\varepsilon)\frac{\rho Z_p^*}{\rho H} - \frac{\varepsilon}{\theta_p^*}\right]^{-1} > 0$$
$$\frac{dZ_p^*}{d\gamma} = -Z_p^*\frac{\theta_p^*}{\theta_p^*(\rho+\gamma)+\alpha_l(\theta_p^*)} < 0$$

Contrary to the public information case, low-γ types search in tighter markets in equilibrium, and pay 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}.

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).

4 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 markets would be owner-occupied markets[15]. To provide heterogeneity, we assume that there is an extra friction in the owning market which is heterogenous in the population[16]. 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 affects the value of searching and living

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

[16] 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 extra cost in the owning market is sequential search.

in a house. Independence could be easily relaxed while additivity means that there will be a single owning submarket for each type i, which eases notation.

Builders only have to sell a new house. It is important to notice that the owning market is not affected by the private information friction, because 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 in an owning market with tightness θ a contract for sale at price P is simply given by:

$$X_o(P,\theta) = \frac{\alpha_l(\theta)}{\rho + \alpha_l(\theta)} P \tag{4}$$

Notice that 4 is independent of γ_i. In equilibrium $X_o(P,\theta) = H$ for any owning submarket with positive ownership rates. This immediately implies that sale prices are negative correlated with market tightnesses.

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

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

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 $r_i = P\frac{\rho+\gamma_i+\alpha_l(\theta)}{\rho+\alpha_l(\theta)}$.

4.1 Equilibrium with only owning

Conditional on market tightnesses, neither builders nor owners when selling care about the types of the buyers in the market in which they have posted. So owning markets do not depend on whether households' types are public or private information. The equilibrium definition of an economy with only owning markets is similar to the equilibrium in economy with only rental markets with private information in that contracts (prices) are not type-specific: each submarket offers just one contract price (see Appendix for definition). The market endogenously segments into submarkets and we can characterize the equilibrium allocation using an equivalent constrained maximization problem.

As in the economies with renting, the equilibrium in the owning economy can be found by solving a constrained optimization problem iteratively by type.[17] The optimal market tightness conditional on owning for each type, θ_o^{*i}, is the same as the optimal tightness for the public renting market θ_r^{*i}.

[17] That is, a similar version of either Proposition 1 or 3 holds. Furthermore, it is also easy to show that a similar type of incentive compatibility constraint as the one in Proposition 3 never binds.

4.2 Equilibrium with both renting and owning

We are now ready to study the equilibrium problem in the housing market with private information.

Landlords/builders are free to enter in both the rental and the owning market. If they enter, they pay a building cost H and post a contract in one submarket. Households have private information over their mobility hazard rate γ and direct their search to their preferred postings.

In the appendix, we formally define a competitive equilibrium with private information and both renting and owning. The equilibrium with both renting and owning can be characterized by the iterative solutions to a problem analogous to those with only owning or renting[18]:

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

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

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

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

Result 3. *The proportion of type i that are homeowners is increasing in i*

Proof. See Appendix. □

The equilibrium in the private information rental market for the highest-γ type is the same as in the public information case while the maximands to the owning part of the characterization are identical to the solutions for the owning-only economy. 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.

5 Example and application to rent control

As a parametrization, we set $\rho = .05$, $h = .1$, $H = 1$, $\alpha_l = \theta^\varepsilon$ with $\varepsilon = .5$, and we allow for $\gamma \in [.2, .7]$, that is expected durations between 1.4 and 5 years, approximately and χ is distributed uniformly on $[0, .9Z_r^{*1}]$. Figure 3 plots the market tightness, or queue length, and the homeownership rate and figure 4 the flow rent (or housing price) as a function of γ in the three economies: renting with public information, renting with private information and owning.

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

The queue length increases as γ increases in the case of renting with public information and in the owning economy (and it is shorter in the latter case), while it decreases as γ increases in the renting economy with private information. 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 free entry condition for the owning market.

Finally, figure 5 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 value of renting with public information is always higher than the other cases (and it coincides with the private information renting 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.

As we know from the theoretical results above, for any parametrization, the model gives the same qualitative patterns that we have found in the data:

- Scarce rentals and low time on the market in submarkets with lower rents.
- Households with high expected durations search in rental markets with scarce housing and lower rents if they search for rental housing.
- Households with high expected durations search in for-sale markets with higher prices if they search for owner-occupied housing.
- Areas with high ownership rates also have low rent-to-price ratios.

Quantitatively, if we equate expected duration in the model with the average observed duration in the data, the model could generate a similar elasticity of time on the rental market with respect to expected duration by setting $\varepsilon = .1$.

5.1 Rent control

We continue the example by analyzing the same economy but with the addition of a very stylized rent control policy. Here rent control is just a simple rent ceiling (which we set to 90 percent of the highest rent in the uncontrolled economy). Figures 6, 7 and 8 show, respectively, the queue length, rents and expected value of searching in the controlled economy.

In the case of public information, the rent control policy distorts the markets for the shortest-duration households the most; their queues lengthen considerably and the supply of regulated rental housing falls, increasing the ownership rate only for those types whose rental submarkets have rents at the ceiling rate. All rental markets that had rents above the ceiling in the uncontrolled economy now have rents at the ceiling rate. However, because markets segment perfectly with public information, rent control does not affect the uncontrolled rental markets that already had low rents.

With private information, all rental markets are affected by the ceiling even though only the low-duration households have rents at the ceiling rate. That the controlled market affects the uncontrolled markets is not due to some households leaving the controlled market for an uncontrolled one, as in e.g. Fallis and Smith (1984) (where there is excess demand in the controlled market) and Weibull (1983) (where there is no excess demand) nor to misallocation of high-quality housing (as hinted at in Glaeser and Luttmer (2003) and examined more broadly for the case of China by Wang (2011)). Here, there is no excess demand; the controlled market is in "equilibrium", albeit an inefficient one[19]. Instead, rent control exacerbates the private information problem by making the low-duration households worse-off in their own market, tightening the incentive compatibility constraint. Queues in all rental markets are higher and the supply of rental housing is everywhere lower. The lower expected value of searching in the rental market also leads to more ownership, which, unlike in the case of public information, occurs with any binding rent ceiling.

Obviously rent control is not a welfare-improving policy in our economy. In fact, the Pareto optimal policy would be a system of market dependent lump-sum taxes and transfers to households that effectively shares the surplus that the longer-duration households have over the shorter-duration ones in the public information economy[20]. Rather than focusing on these policies though, we instead next endow the economy with a customization technology which in equilibrium helps screen low-duration types.

6 Customization

As we have seen, the private information problem can be decentralized in a rather easy way: some houses are for sale while other houses are for rent. It is "easy" for a household to direct its search in this case. In this section, we relax the assumption that all houses offer the same utility flow to all households and that this utility flow is observable prior to a match. There are generally many attributes, like specific location, the quality of the light in the house and so forth, that are

[19] There is no excess demand or supply at the controlled rent, and in that sense the controlled market is in equilibrium (as in Weibull (1983)). However landlords would enter into the market offering a higher rent and lower implied market tightness, if they could. Therefore neither the public nor private information controlled market allocations are competitive equilibriums as defined above. Rather they are competitive equilibriums to economies with the added restriction that $w \in [\rho H, \bar{w}]^{\mathbb{I}}$, where $\bar{w}$ is the rent ceiling.

[20] This optimum can potentially replicate the first best queues and rents if the masses of long-duration households are large enough.

often only observable in person. Tastes for these particular attributes can vary - some households value a quiet residential street more than others. To capture some of this, we add a customization technology similar to ones used in random-search models of housing (e.g. Arnott (1989); Igarashi (1991)). We assume that customization raises the flow utility that a household gets from the house at a cost of reduced matching.

Formally, a house can be customized or not. An uncustomized house gives a utility flow of h. A customized house has a variety τ located on a circle of circumference 1. Households have idiosyncratic tastes over varieties, denoted by ι and known only by the household. A household of taste ι living in a customized house of variety τ receives a utility flow of $h + c$ (with $c > 0$) if $d(\tau, \iota) < \frac{1}{2\delta}$, where $\delta > 1$, and receives a flow of 0 otherwise.[21]

Tastes are distributed uniformly over the population and independently of type i. We assume that a contract can specify whether or not a house has been customized but not the variety of customization. The variety of a particular house is not known to a prospective renter or owner until after the household is matched with the house. At this point the household observes the variety of the house and can then reject the match (and thus the contract) and continue to search.

Lastly, we assume that when houses are built, the builders know the measure of customized houses in the economy but do not observe the distribution of existing varieties. Thus builders pursue symmetric mixed strategies with regards to variety choice and the resulting distribution of varieties is uniform.

Our assumptions mean that: i) if a household chooses to search in a customized market, it will optimally choose to search there until it is matched with a house for which it is well-matched (i.e. gets $h + c$ utility flow from); ii) acceptable matches in a customized market with a mass of u searchers and a mass v postings will occur at a rate $m_c(u, v) = m(u, v)/\delta$.

6.1 Customization in rental markets

The flow value of searching in a customized rental market for a given γ_i, w and market tightness θ is given by $\rho Z_c(\gamma_i, w, \theta)$ (and likewise the flow value of vacancy is $\rho X_c(\gamma_i, w, \theta)$).[22]

$$\rho V_c(\gamma_i, w, \theta) = h + c - w + \gamma(Z_c(\gamma_i, w, \theta) - V_c(\gamma_i, w, \theta))$$
$$\rho Z_c(\gamma_i, w, \theta) = \frac{\alpha_l(\theta)}{\delta\theta}(V_c(\gamma_i, w, \theta) - Z_c(\gamma_i, w, \theta))$$

[21] $d : [0, 1) \times [0, 1) \to \mathbb{R}_+$ with $d(\tau, \iota) = \min\{|\tau - \iota|, 1 + \min\{\tau - \iota, \iota - \tau\}\}$

[22] To keep notation as light as possible, we note that only separating equilibria are possible here and drop X_c's dependency on Ψ

$$\rho Y_c(\gamma_i, w, \theta) = w + \gamma(X_c(\gamma_i, w, \theta) - Y_c(\gamma_i, w, \theta))$$
$$\rho X_c(\gamma_i, w, \theta) = \frac{\alpha_l(\theta)}{\delta}(Y_c(\gamma_i, w, \theta) - X_c(\gamma_i, w, \theta))$$

With public information, for any market that customizes, the equilibrium conditions for market tightness, rents and search value for each type ($\theta_{cr}^{*i}, w_{cr}^{*i}, Z_{cr}^{*i}$, respectively) are

$$\frac{h+c}{\rho H} = 1 + \frac{1}{\theta_{cr}^{*i}}\frac{\varepsilon}{1-\varepsilon} + \frac{\delta(\rho+\gamma_i)}{\alpha_l(\theta_{cr}^{*i})(1-\varepsilon)}$$
$$w_{cr}^{*i} = \frac{\delta(\rho+\gamma_i) + \alpha_l(\theta_{cr}^{*i})}{\alpha_l(\theta_{cr}^{*i})}\rho H$$
$$\rho Z_{cr}^{*i} = \frac{1}{\theta_{cr}^{*i}}\frac{\varepsilon}{1-\varepsilon}\rho H$$

Note that δ influences the flow value only through the equilibrium queue length.

The overall equilibrium value of search for a household with public information renting only but with the choice of customization is then the upper envelope of Z_{cr}^{*i} and Z_r^{*i}. Finally, customization with public information is a normal good in the sense that if any type prefers their customized market to their (shadow) uncustomized one, then all types with longer expected durations will also prefer their respective customized markets:

Result 4. *If there exists an $\tilde{i}$ such that $Z_{cr}^{*\tilde{i}} \geq Z_r^{*\tilde{i}}$, then $Z_{cr}^{*i} > Z_r^{*i}$ for all $i > \tilde{i}$.*

Proof. See Appendix. □

6.2 Customization in the owning market

The analysis of the owning market with customization is similar to the case without customization. For any type i, price P and market tightness θ:

$$\rho Z_{co}(\gamma_i, P, \theta, \chi) = \frac{\alpha_h(\theta)}{\delta}(V_{co}(\gamma_i, P, \theta, \chi) - Z_{co}(\gamma_i, P, \theta) - P) - \chi$$
$$\rho V_{co}(\gamma_i, P, \theta, \chi) = h + c + \gamma_i(X_{co}(P, \theta) + Z_{co}(\gamma_i, P, \theta, \chi) - V_{co}(\gamma_i, P, \theta, \chi)) - \chi$$

The market tightness in a given market is determined from the builders' zero profit condition:

$$\frac{\alpha_l(\theta)}{\rho\delta + \alpha_l(\theta)}P = X_{co}(P, \theta) = H$$

6.2.1 Customization with private information

The problem of customization when information is private follows similarly. We skip the definition of a competitive equilibrium and turn immediately to how to solve for its unique allocation.

Solving iteratively, for any type i, with θ_{cp}^{*i} and w_{cp}^{*i} the argmaxs for customized renting, θ_{up}^{*i} and w_{up}^{*i} the argmaxs for uncustomized renting, θ_{co}^{*i} and P_{co}^{*i} the argmaxs for customized owning, θ_{uo}^{*i} and P_{uo}^{*i} the argmaxs for uncustomized owning, and Z_{cu}^{*i} the maximum over all options:

$$
\begin{aligned}
Z_{cu}^{*i}(\chi) \equiv \max \Big\{ & \max_{\theta_{cp}\in\mathbb{R}_+, w_{cp}\in\mathbb{R}_+} Z_c(\gamma_i, w_{cp}, \theta_{cp}), \max_{\theta_{up}\in\mathbb{R}_+, w_{up}\in\mathbb{R}_+} Z_r(\gamma_i, w_{up}, \theta_{up}), \\
& \max_{\theta_{co}\in\mathbb{R}_+, P_{co}\in\mathbb{R}_+} Z_{co}(\gamma_i, P_{co}, \theta_{co}, 0) - \chi, \max_{\theta_{uo}\in\mathbb{R}_+, P_{uo}\in\mathbb{R}_+} Z_o(\gamma_i, P_{uo}, \theta_{uo}, 0) - \chi \Big\} \\
\text{s.t.} \quad & \frac{\alpha_l(\theta_{up})}{\rho + \gamma_i + \alpha_l(\theta_{up})} w_{up} \geq \rho H \\
& \frac{\alpha_l(\theta_{cp})}{\delta(\rho + \gamma_i) + \alpha_l(\theta_{cp})} w_{cp} \geq \rho H \\
& P_{co} \frac{\alpha_l(\theta_{co})}{\rho\delta + \alpha_l(\theta_{co})} = H \\
& P_{uo} \frac{\alpha_l(\theta_{uo})}{\rho + \alpha_l(\theta_{uo})} = H \\
& \quad Z_c(\gamma_j, w_c, \theta_c) \leq Z_{cu}^{*j}(\overline{\chi}) \quad \text{for all } j < i \\
& \quad Z_r(\gamma_j, w_u, \theta_u) \leq Z_{cu}^{*j}(\overline{\chi}) \quad \text{for all } j < i
\end{aligned}
$$

We analyze numerically some properties of the equilibrium in the following example.

6.3 Example continued

We continue the above example (without rent control) by adding $\delta = 1.35$ and $c = .01$. Figure 9 shows the value of searching in each rental market with private info, ρZ_{cp}^{*}, ρZ_{up}^{*}. There is a kink in ρZ_{cp}^{*} and the customized queue length path; the incentive compatibility constraint does not bind in customized market for the lowest types and thus queue lengths can fall as γ decreases for as long as the constraint doesn't bind (as in figure 10). However, these markets are non-existent in equilibrium as the values of searching in the customized markets are dominated by the uncustomized markets' values for these types.

For higher types the values of search in the uncustomized and customized markets are nearly the same (although the customized market is slightly better): for any type, slightly worse types are searching in their own customized markets where their search value is higher than it otherwise would be if there were only uncustomized markets. This relaxes the incentive compatibility constraint in the uncustomized market (relative to the case with only that market) nearly to the value of the customized market's one. However, the value of search in the uncustomized market is still slightly below because it is still harder to properly incentivize lower types in an uncustomized market and so distortions using the queue length are larger.

Figures 11, 12, 13 plot the upper envelopes over the values of customized versus uncustomized, and the queues and rents in all markets. There are several points worth noting.

First, private information leads to "over-customization" in the rental market: some markets are customized with private information where the types' corresponding market with public information would not customize. As in the simpler economy without customization but with private information, the market uses longer search times to screen away shorter duration households from the long duration households' markets. In the economy with the customization technology, there are two ways to lengthen search times: lengthen queues and customizing. So customization has two benefits with private information (higher flow utility and better screening) which leads it to be adopted for types that would not have adopted it under public information.

The cutoff γ such that owner-occupiers prefer customized houses is the same as the cutoff γ for renting with public information. This cutoff is lower than the cutoff in the renting market with private information. However ownership rates are higher for low γ types, so the proportion of customized houses in the owner-occupied markets may be higher than same proportion on the rental market. In this case the average homeowner gets a higher flow utility from living in his house $(h + c)$ than does the average renter and pays a higher price. An econometrician who did observe this customization would think that homeowners get a warm glow from owning.

7 Conclusion

We build a competitive search equilibrium model of housing tenure choices where households have private information over their expected duration, and we study the properties of rental and owning markets in a search equilibrium. 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 the rental markets, households that expect to stay longer search in thinner markets in order to discourage more footloose households from searching in the same market. 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.

Our novel data on rental markets corroborate the model. Submarkets with high duration households have higher price-to-rent ratios, higher ownership rates and tighter rental markets.

Rent control leads to distortions in both controlled and uncontrolled markets by exacerbating incentive compatibility constraints when information is private. A customization technology that raises the utility from housing at the cost of a lower probability of a match can help screen low-duration types. The extra screening leads to over-customization in the private information rental markets relative to the public information benchmark. However, since the appeal of customization is higher for households that expect to stay in their house longer, owner-occupiers may tend to customize more.

Though the rental contracts considered here are limited to constant, duration-independent rents, it would be relatively straightforward to consider duration-dependent contracts (and thus fully optimal) subject to additional limited participation constraints that, absent a separation shock, neither the landlord nor the household's continuation values in the contract fall below their outside options of search. Optimal duration-dependent contracts could achieve the first best as long as households remain risk-neutral. If households were risk-neutral, the optimal rent contract with private information would feature an upfront payment to the landlord followed by a constant rent $w = \rho H$. However, Barker (2003) finds little evidence for declining rent schedules. If households are risk-averse, we suggest (without proving) that the equilibrium contracts offered in such an economy may otherwise have many of the same qualitative features as those presented above.

Other scopes for extension include 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.

8 Appendix

Definition of Competitive Equilibrium With Only Owning

Definition 4. *A competitive search equilibrium with owning is a vector $\{Z_o^{*i}\}_{i\in\mathbb{I}}$, a set of prices $P^* = \{P^{*i}\}_{i\in\mathbb{I}} \in [H, h/\rho]^{\mathbb{I}}$, a measure λ on $[H, h/\rho]$ with support P^*, and functions $\theta_o^* : [H, h/\rho] \to \mathbb{R}_+$ and $\psi : [H, h/\rho] \to \Delta^I$ satisfying:*

(i) Builders' profit maximization and free entry:

$$\frac{\alpha_l(\theta_o^*(P))}{\rho + \alpha_l(\theta_o^*(P))} P \leq H$$

with equality if $P \in \mathrm{P}^*$.

(ii) Households' optimal search:

$$\text{Let} \quad Z_o^{*i} \equiv \max_{P' \in P^*} \frac{1}{\rho}\left(1 + \frac{\rho + \gamma_i}{\alpha_l(\theta_o^*(P'))/\theta_o^*(P')}\right)^{-1}\left[h - \left(1 + \frac{\gamma_i}{\rho + \alpha_l(\theta_o^*(P'))}\right)\rho P'\right]$$

Then $\forall P \in [H, h/\rho]$ and $i \in \mathbb{I}$

$$Z_o^{*i} \geq \frac{1}{\rho}\left(1 + \frac{\rho + \gamma_i}{\alpha_l(\theta_o^*(P))/\theta_o^*(P)}\right)^{-1}\left[h - \left(1 + \frac{\gamma_i}{\rho + \alpha_l(\theta_o^*(P))}\right)\rho P\right]$$

with equality if $\theta_o^*(P) > 0$ and $\psi_i(P) > 0$.

(iii) market clearing:

$$\int_{P^*} \psi_i(P)\theta_o^*(P) d\lambda(P) = \pi_i \quad \forall i$$

Definition of Competitive Equilibrium With Renting and Owning

Definition 5. *A competitive search equilibrium with renting, owning and private information is a set $\{Z_{po}^{*i}, Z_o^i, \tilde{Z}_p^i\}_{i\in\mathbb{I}}$ with $Z_{po}^{*i}, Z_o^i : [\underline{\chi}, \overline{\chi}] \to \mathbb{R}_{++}$ and $\tilde{Z}_p^i \in \mathbb{R}_{++}$, a set of incentive compatible rents $\tilde{\mathrm{W}}_{\mathrm{p}}^* \subseteq [\rho H, h]^{\mathbb{I}}$, a set of prices $P^* = \{P^{*i}\}_{i\in\mathbb{I}} \in [H, h/\rho]^{\mathbb{I}}$, a measure λ_r on $[\rho H, h]$ with support $\tilde{\mathrm{W}}_{\mathrm{p}}^*$, a measure λ_o on $[H, h/\rho]$ with support P^*, functions $\tilde{\theta}_p^* : [\rho H, h] \to \mathbb{R}_+$ and $\theta_o^* : [H, h/\rho] \to \mathbb{R}_+$ and functions $\psi_r : [\rho H, h] \to \Delta^{I\times[\underline{\chi}, \overline{\chi}]}$ and $\psi_o : [H, h/\rho] \to \Delta^{I\times[\underline{\chi}, \overline{\chi}]}$ satisfying:*

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

$$\left[1 + \left(\alpha_l(\tilde{\theta}_p^*(w)) \sum_{i\in\mathbb{I}} \frac{\int_{[\underline{\chi}, \overline{\chi}]} \psi_{r,(i,\chi)}(w) dF(\chi)}{\rho + \gamma_i}\right)^{-1}\right]^{-1} w \leq \rho H$$

with equality if $w \in \tilde{\mathrm{W}}_{\mathrm{p}}^*$.

(ii) Builders' profit maximization and free entry: for any $P \in [H, h/\rho]$

$$\frac{\alpha_l(\theta_o^*(P))}{\rho + \alpha_l(\theta_o^*(P))} P \leq H$$

with equality if $P \in P^*$.

(iii) Households' optimal search: Let

$$\tilde{Z}_p^i \equiv \max_{w' \in \tilde{\mathrm{W}}_{\mathrm{p}}^*} \frac{1}{\rho} \frac{\alpha_l(\tilde{\theta}_p^*(w'))}{\tilde{\theta}_p^*(w')(\rho + \gamma_i) + \alpha_l(\tilde{\theta}_p^*(w'))}(h - w')$$

$$Z_o^i \equiv \max_{P' \in P^*} \frac{1}{\rho}\left(1 + \frac{\rho + \gamma_i}{\alpha_l(\theta_o^*(P'))/\theta_o^*(P')}\right)^{-1}\left[h - \left(1 + \frac{\gamma_i}{\rho + \alpha_l(\theta_o^*(P'))}\right)\rho P'\right]$$

$$\text{and} \quad Z_{po}^{*i}(\chi) = \max\{Z_o^i - \chi, \tilde{Z}_p^i\} \;\forall\; i \in \mathbb{I}$$

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

$$Z_{po}^{*i}(\chi) \geq \frac{1}{\rho} \frac{\alpha_l(\tilde{\theta}_p^*(w))}{\tilde{\theta}_p^*(w)(\rho + \gamma_i) + \alpha_l(\tilde{\theta}_p^*(w))}(h - w)$$

with equality if $\tilde{\theta}_p^*(w) > 0$ and $\psi_{r,(i,\chi)}(w) > 0$. And $\forall P \in [H, h/\rho]$ and $\forall \gamma_i$

$$Z_{po}^{*i}(\chi) \geq \frac{1}{\rho}\left(1 + \frac{\rho + \gamma_i}{\alpha_l(\theta_o^*(P))/\theta_o^*(P)}\right)^{-1}\left[h - \left(1 + \frac{\gamma_i}{\rho + \alpha_l(\theta_o^*(P))}\right)\rho P\right] - \chi$$

with equality for $\chi = \underline{\chi}$ if $\theta_o^*(P) > 0$ and $\psi_{o,(i,\chi)}(P) > 0$.

(iv) market clearing:

$$\int_{\tilde{\mathrm{W}}_{\mathrm{p}}^*} \int_{[\underline{\chi}, \overline{\chi}]} \psi_{r,(i,\chi)}(w)\tilde{\theta}_p^*(w) dF(\chi) d\lambda_r(w) + \int_{P^*} \int_{[\underline{\chi}, \overline{\chi}]} \psi_{o,(i,\chi)}(P)\theta_o^*(P) dF(\chi) d\lambda_o(P) = \pi_i \quad \forall i$$

Proofs not in the main text

Proof of Lemma 1

Let w be any contract in any pooling equilibrium for which there exists $i \neq j$ and $\psi_i(w) > 0$, $\psi_j(w) > 0$. The landlord takes the expected values $\rho Z_r(\gamma_i, r_i, \theta(\mathrm{w}))$ and $\rho Z_r(\gamma_j, r_j, \theta(\mathrm{w}))$ of the two types as given.

A landlord cannot make strictly lower expected profits from either type. If she could, then a deviating contract would be the menu that does not offer an attractive rent to that type. By rational expectations, the expected queue length must be the same and so the landlord will make strictly higher expected profits, a contradiction. Therefore:

$$\frac{\alpha_l(\theta(\mathrm{w}))}{\rho+\gamma_i+\alpha_l(\theta(\mathrm{w}))} r_i = \frac{\alpha_l(\theta(\mathrm{w}))}{\rho+\gamma_j+\alpha_l(\theta(\mathrm{w}))} r_j = \rho H \tag{5}$$

The lemma follows trivially from there. □

Proof of Proposition 2

We want to prove the existence and uniqueness of the solution of the "unconstrained" maximization problem. We follow the following steps (and drop dependence on i)

The landlord's zero profit constraint (ZPC) constraint holds with equality for each type: Suppose not. We can increase Z by decreasing w and/or θ in a ball $B_\varepsilon(w_r^*, \theta_r^*)$ and still meet the constraint for ε small enough. Thus (w_r^*, θ_r^*) is not a maximum.

Existence. We can impose the ZPC with equality: $\theta_r^{zpc}(\gamma, w) = \alpha^{-1}\left(\frac{(\rho+\gamma)\rho H}{w-\rho H}\right)$. The maximization problem simplifies to: $\max_{w\in[\rho H,h]} Z_r^{zpc}(\gamma, w) = Z_r(\gamma, w, \theta_r^{zpc}(\gamma, w))$. Note that as $w \to \rho H$, $\theta_r^{zpc}(\gamma, w) \to \infty$ and $\frac{\alpha(\theta_r^{zpc})}{\theta_r^{zpc}}(\gamma, w) \to 0$, thus $Z_r^{zpc}(\gamma, w = \rho H) = 0$. The objective function is continuous and the constraint set is compact.

The solution is interior. From above, $Z_r^{zpc}(\gamma, w = \rho H) = 0$ and it is easy to show that $Z_r^{zpc}(\gamma, w = h) = 0$. Moreover, $Z_r^{zpc}(\gamma, w) > 0$ for all $w \in (\rho H, h)$.

Uniqueness. Analytically, it is easier to solve the equivalent problem $\max_{\theta\in\mathbb{R}_+} Z_r(\gamma, w_r^{zpc}(\gamma, \theta), \theta)$, where w_r^{zpc} satisfies the ZPC. The objective function is non-negative iff $\alpha \geq \frac{(\rho+\gamma)\rho H}{h-\rho H}$, or equivalently $\theta \geq \alpha^{-1}\left(\frac{(\rho+\gamma)\rho H}{h-\rho H}\right)$, and $\lim_{\theta\to\infty} Z_r(\gamma, w_r^{zpc}(\gamma, \theta), \theta) = 0$. Since the objective function is continuously differentiable on $\mathbb{R}_+$, the first-order condition is necessary for an optimum:

$$\frac{h}{\rho H} = 1 + \frac{1}{\theta_r^*}\frac{\varepsilon}{1-\varepsilon} + \frac{\rho+\gamma}{\alpha_l(\theta_r^*)(1-\varepsilon)} \tag{6}$$

The right-hand side of (6) is a decreasing, continuous, function in θ. Thus, there is only one solution θ^* of the maximization problem. □

Proof of Result 1

From (6), θ_r^* is increasing in γ, so from the zero-profit condition for landlords, w_r^* is increasing in γ. So Z_r^* is decreasing in γ. $\square$

Proof of Proposition 3

We go through the following steps:

The $IC(j,i)$ with $j > i$, never binds; a type with $\gamma_j < \gamma_i$ never wants to deviate to the i-contract. Any contract and associated market-tightness for a type i is also feasible for any type $j > i$.

For all $\{PR_i\}$, the ZPC binds and, for $i > 1$, at least one IC must bind.

By contradiction. Suppose not. If no constraint ever binds, then Z_p^{*i} is maximized by setting $w = \theta = 0$, but that violates the ZPC. If only the ZPC binds, then the problem is equivalent to the unconstrained one, but in that case the optimal contract associated with higher i (lower γ_i) is always preferred by all $j < i$, thus the IC is violated. If one $IC(j,i)$ binds but not the ZPC, then by the sorting condition we can pick a couple $(w, \theta) \in B_\varepsilon((w_p^{*i}, \theta_p^{*i}))$ such that the ZPC still holds and both types i and j are strictly better off, thus that is not a solution.

$\{PR_1\}$ is equivalent to the first best problem

Follows from the previous results.

There exists an unique solution to $\{PR_i\}$ for all $i > 1$. At the optimum, only the marginal IC is binding, $IC(i-1,i)$.

We prove this iteratively.

First step. The solution for $i = 1$ is the first best allocation: $Z_p^{*1} = Z_r^{*1}$, $\theta_p^{*1} = \theta_r^{*1}$ and $w_p^{*1} = w_r^{*1}$.

Iterative step. Consider the problem PR_i for type $i > 1$. We go through two sub-steps.

i Assume first that only the marginal IC is binding, $IC(i-1,i)$. By the previous analysis, this must be the case, in particular, for $i = 2$. The constrained optimum Z_p^{*i}, market tightness θ_p^{*i} and rent w_p^{*i} must satisfy the ZPC and $IC(i-1,i)$. Thus, θ_p^{*i} and w_p^{*i} satisfy the following non-linear system in θ and w:

$$X(\gamma_i, w, \theta) = H$$
$$Z_r(\gamma_{i-1}, w, \theta) = Z_p^{*(i-1)}$$

We can express w as a function of θ in both equations:

$$w = w_{zpc}(\gamma_i, \theta) = \left(1 + \frac{\rho + \gamma_i}{\alpha}\right)\rho H \tag{7}$$
$$w = w_{icc}(\gamma_{i-1}, \theta) = h - \left(1 + \frac{\rho + \gamma_{i-1}}{\alpha/\theta}\right)\rho Z_p^{*(i-1)} \tag{8}$$

Equation (8) is the indifference curve of type $(i-1)$ that by construction goes through the optimal point $(\theta_p^{*(i-1)}, w_p^{*(i-1)})$. Moreover, at $(\theta_p^{*(i-1)}, w_p^{*(i-1)})$ landlords make zero profits in the market for type $(i-1)$, thus they make strictly positive profits with households of type i. It implies that, at $\theta_p^{*(i-1)}$, the zero profit curve in the market for type i (7) is met for a lower value of the rent, $w < w_p^{*(i-1)}$. Thus:

$$w_{zpc}(\gamma_i, \theta_p^{*(i-1)}) < w_{icc}(\gamma_{i-1}, \theta_p^{*(i-1)})$$

At the limit, $w_{zpc} > w_{icc}$:

$$\lim_{\theta^{zp} \to 0} w^{zp} = \infty > h - \rho Z_r^{*1} = \lim_{\theta^{ic} \to 0} w^{ic}$$
$$\lim_{\theta^{zp} \to \infty} w^{zp} = \rho H > -\infty = \lim_{\theta^{ic} \to \infty} w^{ic}$$

Thus, they cross at least twice, one time on the left and one time on the right of the point $(\theta_p^{*(i-1)}, w_p^{*(i-1)})$.
It is easy to show that:

Result 5. *The expected value of a type i increases as θ increases on the indifference curve of a type j, with $i > j$ ($\gamma_i < \gamma_j$), and viceversa; moreover, the two types have the same expected values at $\theta = 0$.*

Intuitively, a higher market tightness affects more the type with higher moving probability. This implies that the expected value of type i is maximized at the crossing point with higher θ and lower w, and it is higher than the optimal expected value of type $(i-1)$:

$$\theta_p^{*i} > \theta_p^{*(i-1)}$$
$$w_p^{*i} < w_p^{*(i-1)}$$
$$Z_p^{*i} > Z_p^{*(i-1)}$$

This solves the problem for $i = 2$.

(ii) In general, we need to show that no other $IC(i-k, i)$ binds, with $i > 2$ and $k > 1$. Suppose by way of contradiction that it does bind. We can assume, from substep (i), that (only) the marginal incentive compatibility constraints bind for all $j < i$, in particular $IC(i-k, i-k+1)$. Thus, type $(i-k)$ is indifferent between the pairs $(\theta_p^{*(i-k)}, w_p^{*(i-k)})$, $(\theta_p^{*(i-k+1)}, w_p^{*(i-k+1)})$ and $(\theta_p^{*i}, w_p^{*i})$. Since the pair $(\theta_p^{*(i-k+1)}, w_p^{*(i-k+1)})$ is feasible for type i (the zero profit condition for type i is not binding), by result 5 type i chooses optimally a higher θ and lower w:

$$\theta_p^{*i} > \theta_p^{*(i-k+1)} > \theta_p^{*(i-k)}$$
$$w_p^{*i} < w_p^{*(i-k+1)} < w_p^{*(i-k)}$$

But then, by the same argument, type $(i-k+1)$ would prefer $(\theta_p^{*i}, w_p^{*i})$ to $(\theta_p^{*(i-k+1)}, w_p^{*(i-k+1)})$, violating the incentive compatibility constraint $IC(i-k+1, i)$. Thus $(\theta_p^{*i}, w_p^{*i})$ is not incentive compatible. A contradiction. □

Proof of Proposition 4

The proof is divided into two main parts. Part (1) proves that, if an allocation solves (PR), then there exists a competitive search equilibrium with that allocation. Part (2) proves that any equilibrium allocation solves (PR). From Proposition 3, it follows that the equilibrium exists and is unique.

Part (1)

The proof is by construction. Let $\{w_p^{*i}, \theta_p^{*i}\}_{\mathbb{I}}$ be a solution to the (PR) problem. Construct the candidate equilibrium allocation as follows:

$$Z_p^{*i} = Z_r(\gamma_i, w_p^{*i}, \theta_p^{*i}) \quad \forall i$$
$$W_p^* = \{w_p^{*i}\}_{\mathbb{I}}$$

Let the functions θ_p^* and Ψ be defined over the entire set $[\rho H, h]$ as follows:

$$\theta_p^*(w): \quad \frac{\alpha(\theta_p^*(w))}{\theta_p^*(w)} = \min_{j\in\mathbb{I}} \left[\frac{h-w}{\rho Z_p^{*j}} - 1\right]^{-1} (\rho + \gamma_j)$$
$$\psi_k(w) = 1 \quad \text{implies} \quad k = \arg\min_{j\in\mathbb{I}} \left[\frac{h-w}{\rho Z_p^{*j}} - 1\right]^{-1} (\rho + \gamma_j)$$

If there is more than one solution k that minimizes that equation, choose the largest one. The definition of the function $\Psi(w)$ then implies $\psi_j(w_i^*) = 0$ for all $j \neq k$. The expression for ρZ_p^{*i}

implies:

$$\theta_p^*(w_p^{*i}) = \theta_p^{*i} \quad \forall w_p^{*i} \in W_p^*$$
$$\psi_i(w_p^{*i}) = 1 \quad \forall w_p^{*i} \in W_p^*$$

The first equation is derived by noting that if the expression is minimized for $j \neq i$, then j strictly prefers the i-optimal contract to the j-optimal contract, a contradiction. The second equation follows, noting that, by the properties of the constrained optimum, the equation is minimized by i and $(i-1)$ only. Finally, the measure of landlords posting w_p^{*i} is consistent with market tightness $\Theta(w_p^{*i})$:

$$\lambda(w_p^{*i}) = \frac{\psi_i}{\theta_p^*(w_p^{*i}) + \frac{\alpha(\theta_p^*(w_p^{*i}))}{\gamma_i}} \quad \forall w_p^{*i} \in W_p^*$$

and $\lambda(w) = 0$ if $w \notin W_p^*$.

We prove that this allocation satisfies all the equilibrium conditions:
(i) Landlords' profit maximization and free entry.
By construction, the ZPC holds with equality $\forall w \in W_p^*$. Consider $w \notin W_p^*$, $w \in [\rho H, h]$ and assume, by contradiction:

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

This implies $\theta_p^*(w) > 0$ and there exists j with $\psi_j(w) > 0$ and

$$\left[1 + \frac{\rho + \gamma_j}{\alpha_l(\theta_p^*(w))}\right]^{-1} w > \rho H$$

By construction of $\Psi(w)$, $\psi_j(w) = 1$ and $\psi_k(w) = 0$ $\forall k \neq j$. Then, by construction of $\Theta(w)$:

$$\frac{\alpha(\theta_p^*(w))}{\theta_p^*(w)} = \left[\frac{h - w}{\rho Z_p^{*j}} - 1\right]^{-1} (\rho + \gamma_j) \leq \left[\frac{h - w}{\rho Z_p^{*k}} - 1\right]^{-1} (\rho + \gamma_k) \quad \forall k$$

And the inequality holds strictly for all $k > j$.
So, the couple $(w, \theta_p^*(w))$ satisfies all the constraints of the problem (P_j) and guarantees the optimal value Z_p^{*j} to j and strictly positive profits to landlords. By continuity and the sorting condition, there exists a couple $(w', \theta') \in B_\varepsilon(w, \theta_p^*(w))$, with $w' < w$ and $\theta' > \theta_p^*(w)$ such that $Z_r(\gamma_j, w', \theta') > Z_p^{*j}$ and the ZPC and IC's are satisfied. A contradiction.

(ii) Households' optimal search.
By construction, $Z_p^{*i} = \max_{w \in W_p^*} Z_r(\gamma_i, w, \theta_p^*(w))$, $\theta_p^*(w_p^{*i}) > 0$ and $\psi_i(w_p^{*i}) > 0$. Moreover, by the

construction of $\theta_p^*(w)$, for all $w \in [\rho H, h]$, $Z_p^{*i} \geq \frac{1}{\rho} \frac{\alpha_l(\theta_p^*(w))}{\theta_p^*(w)(\rho+\gamma_i)+\alpha_l(\theta_p^*(w))}(h-w)$.

(iii) Market clearing.

Follows directly by construction.

Part (2)

Part (i) of the equilibrium definition implies that $\theta_p^*(w) > 0$ for all $w \in W_p^*$, and part (iii) implies that for each i $\exists$ $w \in W_p^*$ such that $\psi_i(w) > 0$. It follows that, $\forall i$, $\exists$ $w \in W_p^*$ such that $\theta_p^*(w) > 0$ and $\psi_i(w) > 0$, thus from condition (ii) $Z_r(\gamma_i, w, \theta_p^*(w)) = Z_p^{*i}$.

We go through four steps to show that the equilibrium allocation solves the constrained maximization problem P_i, for all i:

(i) The ZPC is satisfied.

Let $w_p^{*i} \in W_p^*$ and $\theta_p^{*i} \equiv \theta_p^*(w_p^{*i})$, with $\psi_i(w_p^{*i}) > 0$. Suppose by contradiction that the ZPC is not satisfied:

$$\left[1 + \frac{\rho + \gamma_i}{\alpha_l(\theta_p^{*i})}\right]^{-1} w_p^{*i} < \rho H$$

Then, by equilibrium condition (i) and by noting that expected profits are decreasing in γ, there exists a $k > i$ such that:

$$\left[1 + \frac{\rho + \gamma_k}{\alpha_l(\theta_p^{*i})}\right]^{-1} w_p^{*i} < \rho H$$

By the sorting condition, $\exists$ $(\theta', w') \in B_\varepsilon$, with $\theta' > \theta$ and $w' < w$ s.th.:

$$\begin{aligned} Z_r(\gamma_j, w', \theta') &> Z_r(\gamma_j, w_p^{*i}, \theta_p^{*i}) \quad \forall j \geq k \\ Z_r(\gamma_j, w', \theta') &< Z_r(\gamma_j, w_p^{*i}, \theta_p^{*i}) \quad \forall j < k \end{aligned}$$

Thus, for all $j < k$, $Z_r(\gamma_j, w', \theta') < Z_r(\gamma_j, w_p^{*i}, \theta_p^{*i}) \leq Z_p^{*j}$ by equilibrium condition (ii). But then condition (ii) and $\theta' > 0$ imply $\psi_j(w') = 0$, $\forall$ $j < k$. It follows:

$$\left[1 + \left(\alpha_l(\theta') \sum_{i \in \mathbb{I}} \frac{\psi_i(w')}{\rho + \gamma_i}\right)^{-1}\right]^{-1} w' \geq \left[1 + \frac{\rho + \gamma_h}{\alpha_l(\theta')}\right]^{-1} w' > \rho H$$

where the last inequality holds for ε small enough. Thus, (w', θ') is a profitable deviation for the landlord. A contradiction.

(ii) IC's are satisfied.

Consider again $w_p^{*i} \in W_p^*$, $\theta_p^{*i} \equiv \theta_p^*(w_p^{*i}) > 0$ and $\psi_i(w_p^{*i}) > 0$. By equilibrium condition (ii), applied to all types j, it must be that:

$$Z_r(\gamma_j, w_p^{*i}, \theta_p^{*i}) \leq Z_p^{*j} \quad \forall j$$

Thus, the incentive compatibility constraints $IC(j,i)$ are satisfied $\forall j$.

(iii) The equilibrium value is equal to Z_p^{*i}, as defined in equilibrium condition (ii).

Again, it follows directly from condition (ii), since $\theta_p^*(w_p^{*i}) > 0$ and $\psi_i(w_p^{*i}) > 0$.

(iv) The equilibrium allocation solves P_i.

Let $\bar{Z}_r^i$ be the value from the competitive equilibrium allocation for each i. Suppose there exists a (w,θ) which respects the constraints for PR_i and is better: $X_r(w,\theta) \geq H$, $Z_r(\gamma_i, w, \theta) > \bar{Z}_r^i$ and $Z_r(\gamma_j, w, \theta) \leq \bar{Z}_r^j$ for $j < i$.

Take $w' \in B_\epsilon(w)$ such that $X_r(w',\theta) > X_r(w,\theta)$, $Z_r(\gamma_i, w', \theta) > \bar{Z}_r^i$ and $Z_r(\gamma_j, w', \theta) \leq \bar{Z}_r^j$ for $j < i$. There exists a $B_{\epsilon'}(w',\theta)$ such that for all $(\hat{w},\hat{\theta}) \in B_{\epsilon'}(w',\theta)$, $X_r(\hat{w},\hat{\theta}) > X_r(w,\theta)$ and $Z_r(\gamma_i, \hat{w}, \hat{\theta}) > \bar{Z}_r^i$.

By sorting (relative to (w',θ)), there exists $(w'',\tilde{\theta}) \in B_{\epsilon'}(w',\theta)$ such that $Z_r(\gamma_i, w'', \tilde{\theta}) > \bar{Z}_r^i$ and $Z_r(\gamma_j, w'', \tilde{\theta}) < \bar{Z}_r^j$ for $j < i$. Note that $w'' < w'$ and $\tilde{\theta} > \theta$.

The equilibrium θ for the rent w'' according to the competitive equilibrium: $\theta_p^*(w'') \geq \tilde{\theta}$. So $Z_r(\gamma_j, w'', \theta_p^*(w'')) < \bar{Z}_r^j$ for $j < i$ and $X_r(w'', \theta_p^*(w'')) \geq X_r(w'', \tilde{\theta}) \geq X_r(w', \theta) > H$. So the allocation which gave $\bar{Z}_r^i$ was not an equilibrium allocation. $\square$

Proof of Result 2

Start from the two equations for the constrained optimum and write them in Δ-form:

$$w(\gamma_{i+1} - \Delta) = \left(1 + \frac{\rho + \gamma_{i+1} - \Delta}{\alpha(\gamma_{i+1} - \Delta)}\right)\rho H$$
$$w(\gamma_{i+1} - \Delta) = h - \left(1 + \frac{\rho + \gamma_{i+1}}{\alpha(\gamma_{i+1} - \Delta)/\theta(\gamma_{i+1} - \Delta)}\right)\rho Z_p^{*(i+1)}$$

where $\alpha(\gamma_{i+1} - \Delta) = \alpha(\theta(\gamma_{i+1} - \Delta))$. We can then derive (dropping the subscripts $i+1$ and using the notation $\alpha_h = \alpha/\theta$):

$$\frac{w(\gamma) - w(\gamma - \Delta)}{\Delta} = \frac{\rho H}{\alpha(\gamma - \Delta)} - \frac{\alpha(\gamma) - \alpha(\gamma - \Delta)}{\Delta} \frac{\rho + \gamma}{\alpha(\gamma)\alpha(\gamma - \Delta)} \rho H$$
$$\frac{w(\gamma) - w(\gamma - \Delta)}{\Delta} = \frac{(\rho + \gamma)\rho Z_p^*}{\alpha_h(\gamma)\alpha_h(\gamma - \Delta)} \frac{\alpha_h(\gamma) - \alpha_h(\gamma - \Delta)}{\Delta}$$

Taking $\lim_{\Delta\to 0}$ and rearranging:

$$\frac{\partial w}{\partial \gamma} = \frac{\rho H}{\alpha}\left[1 - \varepsilon\frac{\frac{\partial \theta}{\partial \gamma}}{\theta}(\rho+\gamma)\right]$$
$$\frac{\partial w}{\partial \gamma} = -(\rho+\gamma)(1-\varepsilon)\frac{\frac{\partial \theta}{\partial \gamma}}{\alpha}\rho Z_p^*$$

Solving for θ' and w':

$$\frac{\partial \theta}{\partial \gamma} = -\frac{1}{\rho+\gamma}\left[(1-\varepsilon)\frac{\rho Z_p^{*(i+1)}}{\rho H} - \frac{\varepsilon}{\theta}\right]^{-1}$$
$$\frac{\partial w}{\partial \gamma} = \frac{(1-\varepsilon)\rho Z_p^*}{\alpha}\left[(1-\varepsilon)\frac{\rho Z_p^*}{\rho H} - \frac{\varepsilon}{\theta}\right]^{-1}$$

Thus:

$$\frac{\partial w}{\partial \theta} = -(\rho+\gamma)\frac{1-\varepsilon}{\alpha}\rho Z_p^* < 0$$

θ_p^* is increasing in γ implies:

$$\rho Z_p^* > \frac{1}{\theta_p^*}\frac{\varepsilon}{1-\varepsilon}\rho H$$

$$\frac{\partial \theta_p^*}{\partial \gamma} < 0 \quad \forall \gamma < \gamma_I$$
$$\frac{\partial w_p^*}{\partial \gamma} > 0 \quad \forall \gamma < \gamma_I$$

They go to ∞ for $\gamma = \gamma_I$. $\partial w/\partial \theta$ at the border is well defined:

$$\frac{\partial w_p^*}{\partial \theta_p^*} = -(\rho+\gamma)\frac{\varepsilon}{\theta_p^{*I}\alpha(\theta_p^{*I})}\rho H \quad \text{for } \gamma = \gamma_I$$

Lastly in steady state the number of vacancies created must equal the number filled, so that: $\frac{v_p^{*i}}{\pi_i - u_p^{*i} - v_p^{*i}} = \frac{\gamma_i}{\alpha_l(\theta_p^{*i})}$ $\square$

Proof of Result 3

For any given $\tilde{\gamma} \in \Gamma$, define the constant $k \equiv Z_r^*(\tilde{\gamma}) - \tilde{Z}_p^*(\tilde{\gamma})$. Note that the function $Z_r^* - k = \tilde{Z}_p^*$ at $\tilde{\gamma}$ and $\frac{d(Z_r^*-k)}{d\gamma} = \frac{dZ_r^*}{d\gamma}$. Also, $\forall \Delta > 0,\ Z_r^*(\tilde{\gamma}-\Delta) - k > \tilde{Z}_p^*(\tilde{\gamma}-\Delta)$. So $\frac{d\tilde{Z}_p^*}{d\gamma} > \frac{dZ_r^*}{d\gamma} = \frac{dZ_o^*}{d\gamma}$ $\square$

Proof of Result 4

From the first-order conditions for renting with and without customization, respectively:

$$\frac{d\theta_r^*}{d\gamma} = \left(\frac{\varepsilon(\rho+\gamma)}{\theta_r^*} + \frac{\varepsilon\alpha_l(\theta_r^*)}{(\theta_r^*)^2}\right)^{-1}$$

$$\frac{d\theta_{cr}^*}{d\gamma} = \left(\frac{\varepsilon(\rho+\gamma)}{\theta_{cr}^*} + \frac{\varepsilon\alpha_l(\theta_{cr}^*)}{\delta(\theta_{cr}^*)^2}\right)^{-1}$$

Suppose there exists a $\tilde{i}$ such that $Z_{cr}^{*\tilde{i}} = Z_r^{*\tilde{i}}$. Then $\theta_{cr}^{*\tilde{i}} = \theta_r^{*\tilde{i}}$ and (with slight abuse of notation) $\frac{d\theta_r^{*\tilde{i}}}{d\gamma} < \frac{d\theta_{cr}^{*\tilde{i}}}{d\gamma}$. Thus $\theta_r^*(\gamma)$ and $\theta_{cr}^*(\gamma)$ can cross at most once. □

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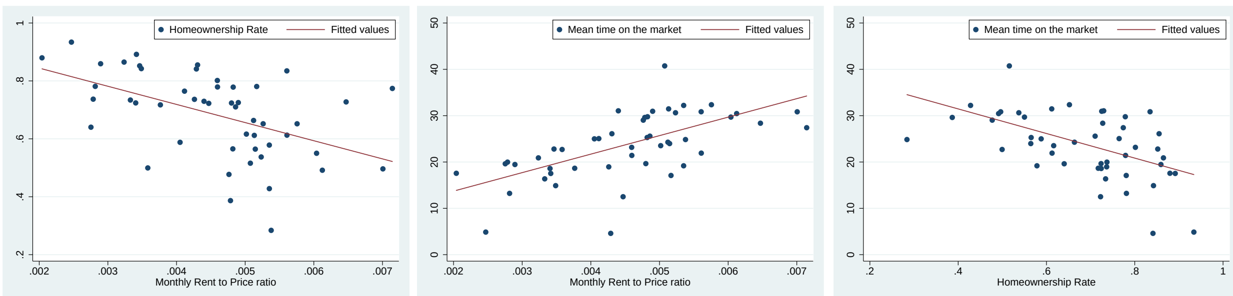
Figure 1: Greater Seattle Area



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 (e.g. the mean over 2 bedroom listings in zip code 49820) using the Craigslist data. Homeownership rates are from the Census data at the same bedroom x zip code level. The Greater Seattle Area refers to zip codes starting with 980.

Figure 2: Market tightness (queue length)

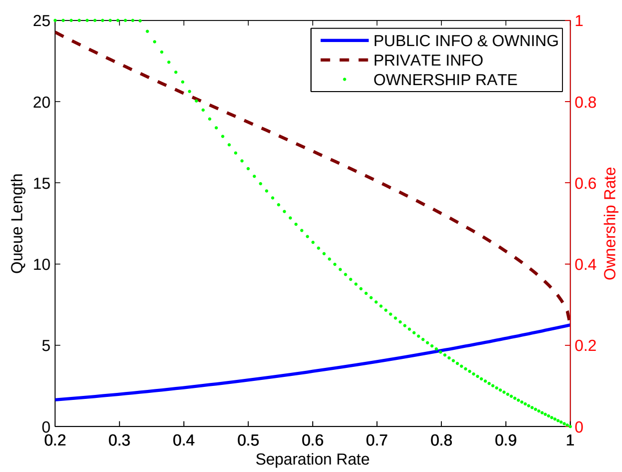


Figure 3: Market tightness (queue length)

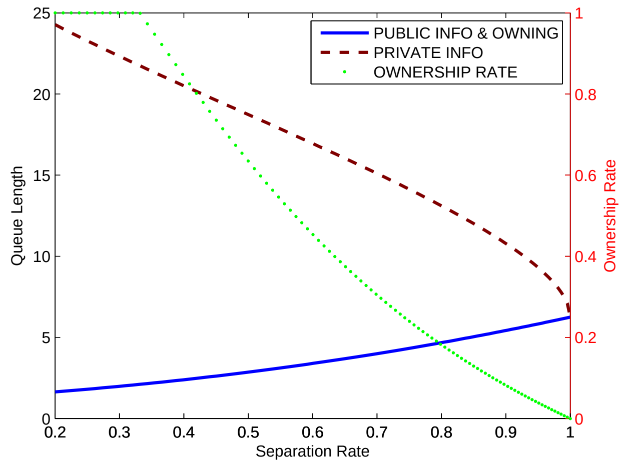


Figure 4: Flow rent

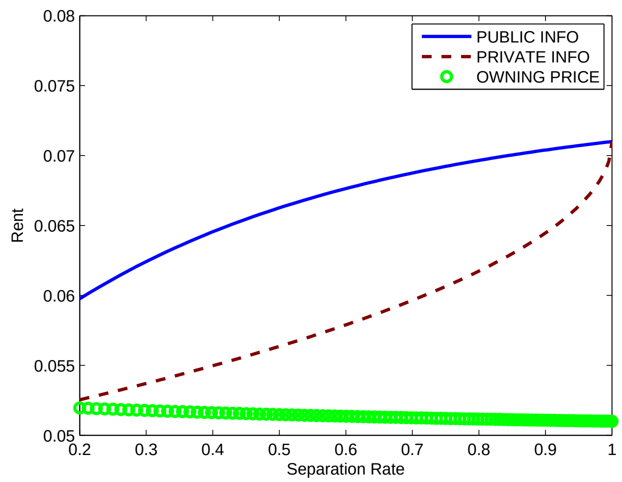


Figure 5: Expected value of searching in all markets

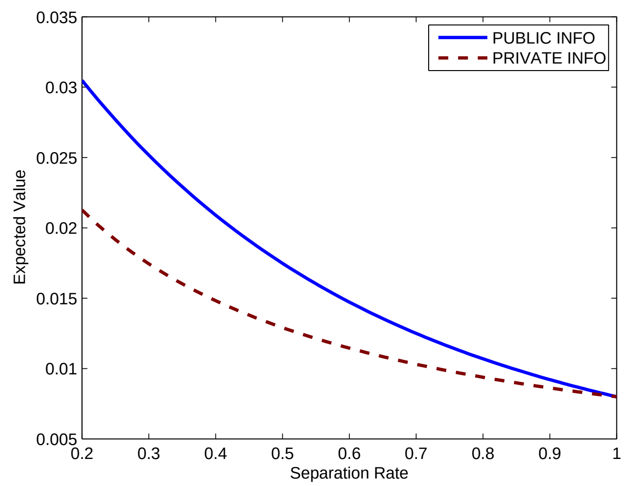


Figure 6: Market tightness with and without rent control (queue length)

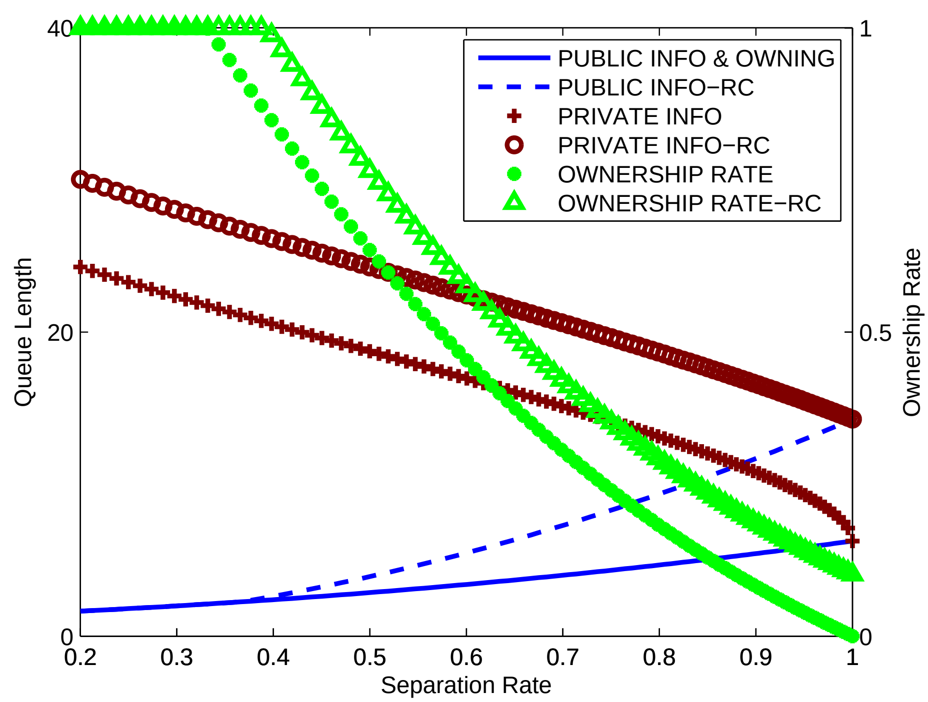


Figure 7: Flow rent with and without rent control

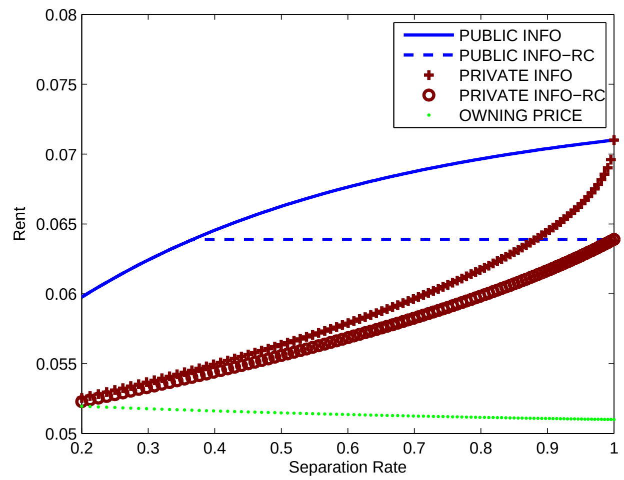


Figure 8: Expected value of searching in all markets with and without rent control

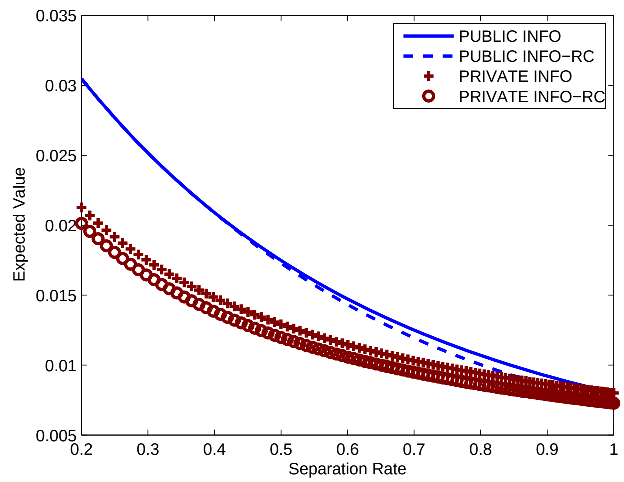


Figure 9: Flow value for renting with private information and option to customize

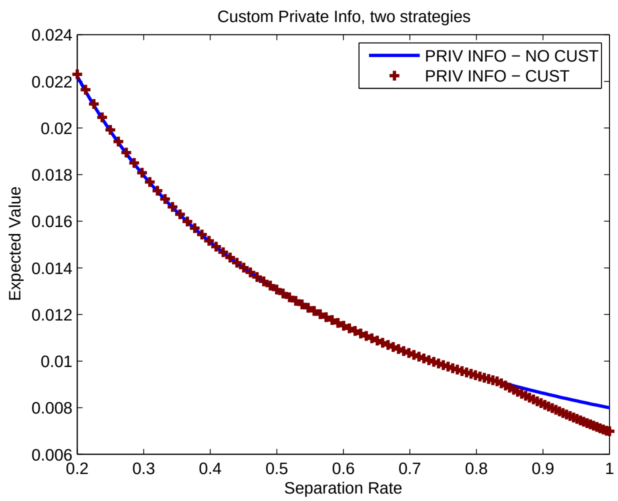


Figure 10: Market tightness (queue length) for renting with private information and option to customize

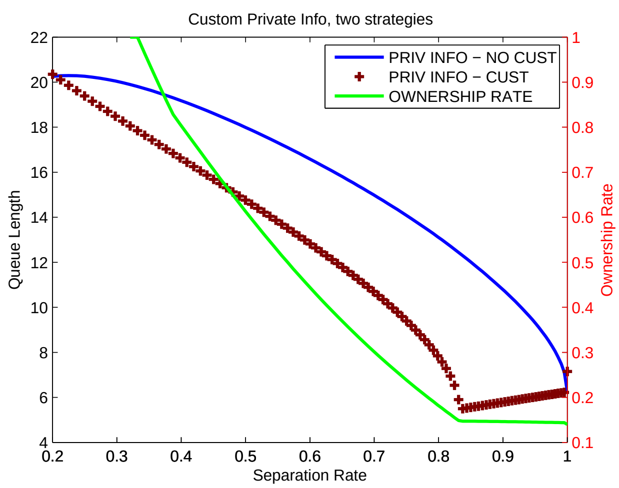


Figure 11: Flow value of search with all choices

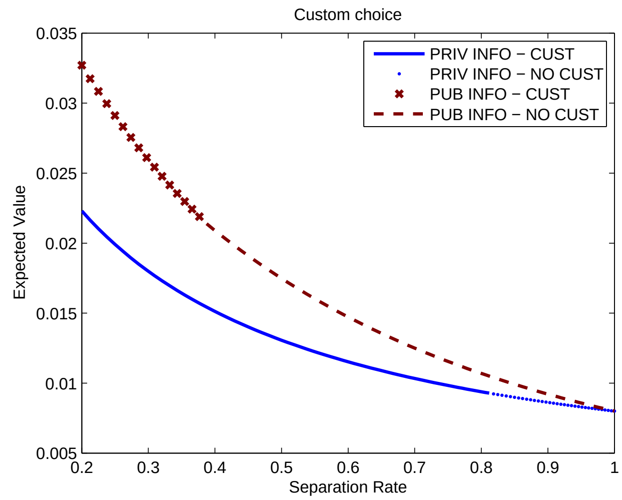


Figure 12: Market tightness (queue length) with all choices

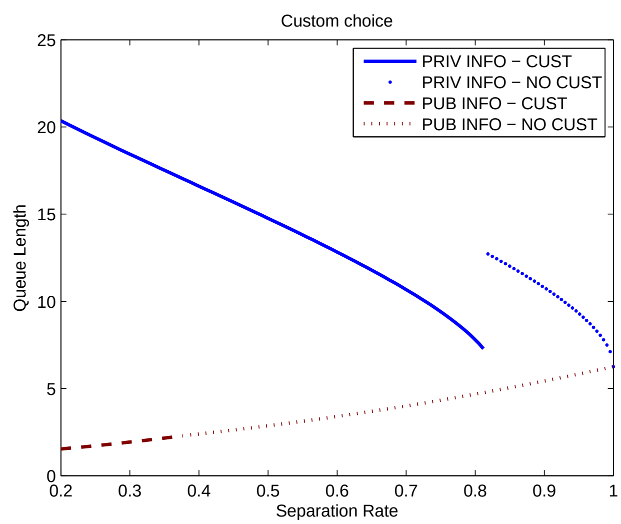


Figure 13: Rent with all choices