The Rent-to-Price is Right (After Controlling for Unobserved Quality) - Preliminary *

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Abstract

We use a large repeated cross-section of properties to estimate a selection model of the supply of owner-occupied and rental housing. We find that physical characteristics and unobserved quality and not location are important for selection. We interpret this as strong evidence in favor of contracting frictions in the rental market relating to maintenance and modification of physical housing characteristics. Accounting for selection is important for estimates of rent-to-price ratios and can explain some puzzling correlations between rent-to-price ratios and homeownership rates.

1 Introduction

Rent-to-price ratios vary dramatically across the urban landscape as do the market shares of owner-occupied and rental housing. What explains the variation in rent-to-price ra-

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tios? Why are some housing units more likely to be owned by owner-occupiers while others are more likely to be owned by landlords? How do dwelling values and rents vary with the propensity to be selected into owner-occupancy and what can these facts tell us about user costs and contracting frictions in the rental market?

These are crucial questions for understanding how household choices are affected by local geography. They are also crucial because they are intimately tied together with important macroeconomic questions about household savings and insurance against financial risks. In the UK and the US approximately 60% of households tie up a large part of their financial portfolio in a single, risky, illiquid asset; housing. Why is this the case? Why don't financial and rental housing markets provide contracts that enable households to enjoy the consumption flow from a rented three bedroom detached 120 square-meter house in the suburbs while enjoying the dividend flows and potential capital gains of the wider financial market?

In this paper, we use a rich micro data set to show that the physical characteristics of a property (as opposed to location) are by far the most important determinants of its propensity to be owned. At the same time, the prices of physical characteristics in the rental sector are higher than in the owner-occupied sector. Despite this high relative price, properties with high value physical characteristics are not likely to be supplied to renters. This pattern of relative prices and sectoral allocations is consistent with the theory that agency problems in the rental sector increase the cost of upkeep and care[1] for properties relative to the cost in the owner-occupied sector; especially for larger properties and for properties that are more detached. In other words, rental-sector user costs of housing capital increase with property size faster than owner-occupied user costs.

In addition, we find that accounting for unobserved quality is important for understanding these user cost patterns. The selection of properties into owner-occupancy has a strong effect on the relative distribution of observed and unobserved characteristics in the two markets. Accounting for this selection can explain two curious features in the raw data. Firstly, correcting for selection eliminates a puzzling pattern in the rent-to-price ratio. After controlling for selection, predicted rent-to-price ratios do not increase with property value. This in turn implies large corrections to the way rental price indices

[1] Throughout we refer to these costs as maintenance costs. They are the costs required to keep a property at constant quality.

and cost-of-living measures are constructed. Secondly, aggregate measures of maintenance rates rarely show a meaningful difference between rentals and owner-occupied properties. We show that not properly accounting for selection leads to biased measures of the difference in maintenance costs that are large enough to obscure the agency costs. Indeed, under some assumptions about interest rates and capital gains, our estimates suggest (as an upper bound) that rental sector maintenance costs of an average quality small property is more than twice as large as its owner-occupied maintenance costs while rental sector maintenance costs of an average quality large property would be seven times larger than its owner-occupied maintenance costs.

We exploit the tremendous variation in dwelling characteristics, values, rents and ownership rates within a single but large housing market in England between 2008-2012 to develop a simple model of the "supply" of housing to the rental and owner-occupied housing markets. Property owners who are endowed with a property, take prices and rents as given and decide whether to situate their property in the owner-occupied sector or the rental sector. We then analyze the implications of our findings in the context of the simplest possible dynamic housing model to show that:

1. Observable physical characteristics of a property are important determinants of the probability of being in the owner-occupied sector. Housing units with high value physical attributes (large or more detached dwellings) are more likely to be owner-occupied. At the same time, rent-to-price ratios for these "large" properties are higher than for smaller properties. These relationships are stable over time despite large changes in property values during the time period. These facts are consistent with large or detached properties having higher maintenance needs and also higher relative rental maintenance costs due to contracting frictions.

2. Location is unimportant for the likelihood of being owner-occupied once physical characteristics are controlled for. Rent-to-price ratios vary significantly with location but in a unstable manner that may be due in part to time and location dependent expectations of capital gains. If these expectations are common to both landlords and owner-occupiers, this variation in rent-to-price ratios has no implication for selection into owner-occupancy.

3. Housing units with high unobserved quality (and therefore higher rents) are much less likely to be in the rental sector. Attributes of a dwelling that are unobserved

in our data include features like the layout of the dwelling, the architectural style, whether it has South facing windows, whether it has a high quality kitchen or if there's a garden that requires upkeep. Rental dwellings have lower unobserved quality on average. However we find that not all unobservable attributes affect selection. This is consistent with some unobservable attributes being harder to contract upon for landlords and thus having higher maintenance costs in the rental sector. A further implication is that rent-to-price measures based only on observable attributes that do not control for selection are biased.

1.1 Relation to the literature

Owner-occupied housing and rental housing both provide housing services. There is an extensive household tenure-choice literature that studies the relationship between the utility flow from owning versus renting and households' characteristics. For instance, Diaz and Luengo-Prado (2008) and Blow and Nesheim (2009) examine how the flow shadow price of housing for owner-occupiers can differ systematically from the cost of renting a similar housing unit in large part due to differences in the Lagrange multipliers from households' constrained maximization problems. In general, the multipliers are functions of households' current assets, income and other state variables.

In this paper, we study what aspects of housing units explain why some units are more likely to end up in the rental sector while others are more likely to end up in the owner-occupied sector. Glaeser and Shapiro (2003) observe that there is a striking difference in the homeownership rates of single versus multi-family housing units throughout the US, which leads them to note that "homeownership is particularly correlated with housing structure." Here we show that the same is true in England and that this correlation is found consistently across many structural characteristics including dwelling type, dwelling size and unobserved quality.

The technology that provides housing services is the same regardless of housing sector: in both sectors, a physical housing unit provides the services. However, it has long been mooted that the contracts that govern the provision of housing services in the rental and for-sale markets are constrained by tenure-dependent information frictions. A literature going back to Sweeney (1974) and Henderson and Ioannides (1983) has argued that contracting frictions result in higher maintenance costs and less upkeep and investment in the rental sector. Because of monitoring costs, tenants under-invest in maintenance resulting in a higher depreciation rate in the rental sector. In this literature, it is supposed that these differential costs are likely to be correlated with the physical characteristics of the property. As a result, a housing unit with higher rental-specific maintenance costs, or for which rental contracting frictions are greater, is more likely to be found in the owner-occupied sector.

In the corporate finance literature, studies of selection due to various contracting frictions and the effects of selection on the distribution of observed returns are common.[2] In the housing literature, despite long-standing theories of contracting frictions and ownership[3] and the cautionary warning in Glaeser and Gyourko (2007), there are no studies that control for supply side selection in hedonic estimations of rents and values.[4] Heston and Nakamura (2009), using data from federal employees in Alaska, Washington D.C., the Pacific and Caribbean Islands, which includes owner-occupiers' estimate of the rental (flow) value of their house, finds that owner-occupied housing units are 15 percent more valuable than observably equivalent rentals. We are the first to (a) estimate a selection model of hedonic housing prices and rents for a large housing market (in our case, the Greater London housing market), (b) to estimate the importance of unobserved quality in this market, (c) to analyze the implications of these models for sector specific user costs.

If we assume that a single risk-adjusted discount rate prices all housing in the market as in Epple et al. (2013), then we can say more. In this case, if different housing units have different rent-to-price ratios, then these differences must be due either to differing expectations about the future or to differences in the costs of renting out the property. We argue that expectations about the future, given rents and values, should not systematically affect selection into renting. Furthermore, we use repeated cross-sections sam-

[2]Among many others, see Prabhala (2008).

[3]Linneman (1985) notes that the "efficiency" of landlord provided housing services is an important factor determining ownership rates. Casas-Arce and Saiz (2010) examine how different jurisdictions' legal systems and propensity to enforce contracts affect ownership propensities. Hanson (2012) looks at how the mortgage interest tax deduction interacts with home sizes to affect ownership rates in the US. Hilber (2005) examines neighborhood externality risks in the AHS and finds that they are negatively correlated with home-ownership. Coulson and Fisher (2014) study how property size affects a building's management structure. Harding et al. (2000) find that homeowners that are more likely to default on their mortgage may under-maintain their house.

[4]There are, however, a number of studies of selection effects on various aspects of household demand: Goodman (1988); Campbell and Cocco (2007); Rosen (1979); Kan (2000).

pled from periods of both housing price decline and boom in England and find that the estimated relationship between physical attributes, selection and rent-to-price remains very stable. We find that recent movements in the rent-to-price rations of housing are reflected entirely in the value of land, which is consistent with the methods and findings in Davis and Heathcote (2007); Davis and Palumbo (2008); Amior and Halket (2014).

We use a theory on the supply of owner-occupied versus rental housing given relative prices to estimate of the potential size of the moral hazard problem described above. Many theories of household demand for homeownership incorporate higher maintenance costs for rentals and a limited supply of "high value" rentals into their models (e.g. Chambers et al. (2009b,a); Chen (2010)). Often these two elements are the primary reasons why households choose to own in these models. We show that selection due to agency problems can simultaneously explain both the higher maintenance costs and the limited supply of *physically* valuable rentals. Our estimate of the size of the agency problem is large but consistent with the less direct estimates from these models.

There are several studies that attempt to measure whether rentals have higher maintenance costs. Their findings are mixed. Galster (1983) estimates that owner-occupiers occupy better properties and better maintain them. Shilling et al. (1991) estimates a hedonic model of sales values for rental and owner-occupied single-family property in a single parish in Louisiana and finds that rentals depreciate faster. Malpezzi et al. (1987) estimates hedonic models of rents and values from the AHS and finds that rents decline evenly with age whereas values decline at a declining rate. However, Gatzlaff et al. (1998) finds limited evidence of differential maintenance by comparing appreciation rates of rentals and owner-occupied housing units. Our findings on bias and selection imply that comparisons across tenure of observationally similar housing units will not necessarily reveal evidence of contracting problems. Properties with more contracting issues select into owner-occupancy.

This paper is also part of a growing literature that exploits the time and cross-sectional variation in rent-to-price ratios. Several studies (see Verbrugge (2008); Landvoigt et al. (Forthcoming); Epple et al. (2013); Verbrugge and Poole (2010); Heston and Nakamura (2009)) using US data have found that rent-to-price ratios decline with property values. If we estimate rents and values using UK data without accounting for selection, we also find that rent-to-price ratios decline with property values. The more expensive a property is, the lower is its predicted rent-to-price ratio. As ownership rates are (unconditionally) increasing in dwelling values, this could lead one to the curious conclusion that households tend to own homes that have low rent-to-price ratios. This is a bit puzzling from the household's perspective. Here we show that this unconditional correlation between ownership and rent-to-price ratios breaks down once one controls for selection. Households actually tend to own housing units whose physical characteristics imply high rent-to-price ratios.

Sections 2 and 3 introduce the model and data, respectively. Section 4 explains our estimation procedure and section 5 discusses the results.

2 Model

A property has observed characteristics $z \in \mathbf{R}_n$ and unobserved characteristics $\varepsilon \in \mathbf{R_2}$. Observed characteristics include features like the location, type of dwelling (detached, semi-detached, etc.), size (square meters), number of bedrooms, and age of structure. We assume that the value of unobserved characteristics is completely captured by a two dimensional vector that we label "unobserved quality". This vector has dimension of at least two because selection into the owner-occupied sector is not perfectly correlated with values. In addition, *a priori*, it seems likely that some characteristics are more valued in the rental sector while others are more valued in the owner-occupied sector.

If a dwelling unit is in the rental sector, its rent is observed. If it is in the owner-occupied sector, its value is observed. Let log annual rent be given by

$$\ln R(z,\varepsilon) = \alpha z + \lambda_1^r \varepsilon_1 + \lambda_2^r \varepsilon_2. \tag{1}$$

This is a log linear approximation to the true hedonic rent function. The parameters $(\alpha, \lambda_1^r, \lambda_2^r)$ measure the percentage impact of observed and unobserved quality on rental prices. Let the log value in the owner-occupied sector be

$$\ln \pi^o(z,\varepsilon) \quad = \quad \beta z + \lambda_1^o \varepsilon_1 + \lambda_2^o \varepsilon_2. \tag{2}$$

This is a log linear approximation to the hedonic value function. The parameters $(\beta, \lambda_1^o, \lambda_2^o)$ capture the percentage impact of observed and unobserved quality on values in the owner-occupied sector.

Let the log value of a dwelling in the rental sector be

$$\ln \pi^r(z, \varepsilon) = (\beta - \gamma) z + (\lambda_1^o - \lambda_1^s)\,\varepsilon_1 + (\lambda_2^o - \lambda_2^s)\,\varepsilon_2 \tag{3}$$

The parameters $(\gamma, \lambda_1^s, \lambda_2^s)$, when they are positive, capture the reduced form net loss in value of renting out a dwelling relative to selling it in the owner-occupied sector. When they are negative, they capture the net gain from renting the dwelling in the rental sector. We discuss how rental values are related to rents in Section 2.1 below.

Assuming investors maximise profits, a housing unit is observed in the owner-occupied sector if

$$\ln \pi^o(z, \varepsilon) \geq \ln \pi^r(z, \varepsilon). \tag{4}$$

That is, if

$$\gamma z \geq -\lambda_1^s \varepsilon_1 - \lambda_2^s \varepsilon_2 \tag{5}$$

The, values π^o and π^r are conditional on sector. The unconditional value of a property is the value of the property in the market where it is most valuable. That is,

$$P(z, \varepsilon) = \max_{\{own, rent\}} \{\pi^o(z, \varepsilon), \pi^r(z, \varepsilon)\}$$

The parameters of the price and rent functions may vary over time. We leave their dependence on t implicit.

Under the assumption that $\varepsilon \sim N(0, \Sigma)$ and that ε is independent of z, this is a standard Heckman selection model (Heckman, 1979). Define

$$\Lambda = \begin{bmatrix} \lambda_1^r & \lambda_2^r \\ \lambda_1^o & \lambda_2^o \\ -\lambda_1^s & -\lambda_2^s \end{bmatrix}.$$

The parameters (Σ, Λ) are not identified. Instead, we define $\eta = \Lambda\varepsilon$ and seek to estimate the parameters (α, β, γ) and $\Omega = \Lambda \Sigma \Lambda^T$ where Ω is the covariance matrix of η. Note that $\eta \in \mathbf{R_2}$, but since $\varepsilon \in \mathbf{R}_2$ by assumption, Ω is not full rank. η_1 is the error in the rental price equation, η_2 is the error in the owner-occupied price equation, and η_3 is the error in the selection equation.

The model has several important features. First, the value of unobserved characteristics in the owner-occupied sector is not restricted to be perfectly correlated with the value in the rental sector. Second, the impact of unobserved characteristics on selection is not restricted to be perfectly correlated with owner-occupied value nor with rental value. Third, the correlation of η_3 and η_2 may differ from the correlation between η_3 and η_1. We can identify the variance of η_1 and the variance of η_2. We can also identify the correlation of η_1 and η_3. We cannot identify the correlation of η_1 and η_2. However, the fact that Ω is rank 2, implies that it can take on only two possible values. This fact is shown in Appendix A.

2.1 User costs and the rent-to-price ratio

The value of a property in a sector, either $\pi^o(z,\varepsilon)$ or $\pi^r(z,\varepsilon)$, equals the willingness to pay of the marginal buyer in that sector. The willingness to pay of each buyer is determined by his or her utility or rent flow from the property, the cost of maintenance and expectations about future utility and financial value of the property, taking into account taxes, inflation, and uncertainty. We assume this can be characterized by two Poterba-like user cost equations (Poterba, 1992):

$$\pi^o(z,\varepsilon) = \frac{u(z,\varepsilon)}{r^o(z,\varepsilon) + c^o(z,\varepsilon) - g^o(z,\varepsilon)} \tag{6}$$

$$\pi^r(z,\varepsilon) = \frac{R(z,\varepsilon)}{r^r(z,\varepsilon) + c^r(z,\varepsilon) - g^r(z,\varepsilon)} \tag{7}$$

where for each sector i, $r^i(z,\varepsilon)$ is the effective discount rate, $c^i(z,\varepsilon)$ is the cost of management and maintenance (including amortized vacancy costs), and $g^i(z,\varepsilon)$ is expected capital gains. $u(z,\varepsilon)$ is the utility flow for an owner-occupier.

Each element in these equations may vary both across property types and sector. For example, mortgage interest payments are not deductible from taxable income in England for owner-occupiers but are for landlords. This may be reflected in differences between r^o and r^r. Capital gains are not taxed for owner-occupiers but are taxed for landlords. This is subsumed in differences between g^o and g^r. Lettings are exempt from Value Added Taxes in the UK but *net* rental income may be subject to income taxes. Assuming a common income tax rate, this can be subsumed into $c^r(z,\varepsilon)$. Costs of vacancies in the rental sector can also be subsumed in c^r.

In general, for a property of type (z,ε), the user costs in the two sectors will differ. Properties with relatively high rental sector user costs will be selected into the owner-occupied sector. Owners of inframarginal properties will not be indifferent between the two sectors. For inframarginal owners in the owner-occupied sector, $P(z,\varepsilon) = \pi^o(z,\varepsilon) > \pi^r(z,\varepsilon)$ while for inframarginal rental sector owners $P(z,\varepsilon) = \pi^r(z,\varepsilon) > \pi^o(z,\varepsilon)$. Only for owners of those properties at the margin, $P(z,\varepsilon) = \pi^o(z,\varepsilon) = \pi^r(z,\varepsilon)$, do the two user cost equations (6)-(7) collapse to the more familiar single equation user cost formula (such as the one in Poterba 1992). After discussing estimates of (π^o, R, π^r), section 5 discusses the extent to which these estimates are consistent with different assumptions about how (r^i, g^i, c^i) vary across properties and across the two sectors.

3 Data

We use data from the confidential version of waves 2011-2014 of the English Housing Survey (EHS). The EHS used a complex multistage methodology. Each wave comprised two surveys which were then combined to produce two samples. Each sample was constructed using data from surveys from multiple waves.

In each wave, the EHS team conducted a "Household Survey" and a "Physical Survey". For example, to construct the 2011 wave, the EHS team sampled approximately 17,500 households in the financial year 2008/2009 (April 2008 - March 2009). These households were drawn from the list of addresses held by Royal Mail.[5]

Respondents from this selection (approximately 17,000) comprised the Household Interview sample. The EHS team then chose a sub-sample of these dwellings (approximately 8000 in 2008/2009), including vacant ones, and performed a physical inspection. This is called the "Physical Survey." The sub-sample was constructed from the 17,500 by taking a sample of all social housing addresses and a sub-sample of private addresses. Private rental properties were over-sampled. Finally, to construct the final "Housing Stock sample", the EHS team combined data from two physical surveys. For instance, the Housing Stock sample in the 2011 wave is comprised of the physical surveys from 2008/2009 and 2009/2010. Weighting for the final sample is based on this 2

[5] At each sampled address, one dwelling was sampled. At each dwelling, one household was sampled.

year sampling window.

We focus discussion on the 2011 wave of the EHS. While we also analyze the 2012, 2013, and 2014 waves, these later waves have some limitations. In the later waves, property values were top-coded at £1,000,000. Also, due to budget cuts, the later waves used smaller samples and collected information on a smaller range of topics. Despite these limitiations, our results are robust across waves.[6]

Property values recorded in the survey were obtained in one of two ways. For a subset of the owner-occupied properties, owners self-reported what they thought the market value of their home was. For the remainder of owner-occupied properties, a professional surveyor valued the property on-site. Rental sector rents were self-reported by tenants.

Much of our analysis focuses on a sub-sample of dwellings within 140 km of Trafalgar Square in London. We call this region "Greater London." We restrict the analysis to this region because we want to focus on a single economic market.

We present summary statistics for the owner-occupied, private rental and "social housing" sectors. The latter are non-market rate rentals where the government either directly owns the properties or offers subsidies to landlords in the sector. However, when we estimate the model, we restrict the analysis to private sector housing. Determinants of housing supply in the private sector are very different from those in the social housing sector. In the private sector, investors may buy and sell properties freely and prices are determined by the market. In the social sector, supply is largely determined by political forces, not by choices of investors. In addition, prices in this sector are subsidised and highly regulated.

Table 1 displays the overall market shares of owner-occupied housing, private rentals, and publicly assisted housing in England and Greater London. In England in 2008-2010, 67.9% of housing units were owner-occupied units while 14.3% were private rentals and 17.8% were publicly assisted units. In England, publicly assisted housing consists of Local Authority provided housing (LA) and housing provided by registered social landlords (RSL).[7]The Greater London area is roughly similar to the entire country with regards to tenure: there are slightly more private rentals and fewer owner-occupiers in

[6]Because the samples in each wave use data from a two year span, the samples overlap. For instance, the samples in the 2011 and 2012 waves each use the same data collected in 2009/2010.

[7]RSL's are non-profit organizations that provide low-cost housing. They are regulated by the government and highly subsidized.

London. The share of private rentals has increased by three percentage points over the four waves at the expense of owner-occupancy.

Table 1: Market shares: Greater London and England (%)

Region	EHS Wave	Owner-occupied	Private rented	LA or RSL
London	2011	66.6	15.7	17.7
	2012	65.3	17.0	17.8
	2013	63.1	18.7	18.1
	2014	62.4	19.5	18.2
England	2011	67.9	14.3	17.8
	2012	67.0	15.1	17.9
	2013	65.3	16.4	18.3
	2014	65.0	17.1	17.9

Note: Market shares are computed using sampling weights for each wave. London refers to the Greater London sample area. The 2011 wave uses data from April 2008 - March 2010. The 2012 wave uses data from April 2009 - March 2011. The 2013 wave uses data from April 2010 - March 2012. The 2014 wave uses data from April 2011 - March 2013.

Table 2 shows how market shares vary with distance from the center of London. Within 10 km of the center, the owner-occupied share is 37.9% while the private rented and social housing shares are 23.7% and 38.4% respectively. Moving further out, the owner-occupied share increases to 72.9% more than 50 km from the center while the rental and social housing shares decline to 13.4% and 13.7% respectively. We will see that these patterns with respect to distance do not persist after controlling for structural characteristics.

Table 2: Market share by distance: Greater London 2011 wave (%)

Distance	Owner-occupied	Private rented	LA or RSL
Less than 10 km	37.9	23.7	38.4
10 - 20 km	61.6	19.8	18.6
20 - 30 km	69.8	13.5	16.8
30 - 50 km	71.4	13.1	15.5
More than 50 km	72.9	13.4	13.7

Note: Market shares are calculated using data and sampling weights from the 2011 wave of the EHS. The 2011 wave uses data from April 2008 - March 2010.

Tables 3 and 4 show how market shares vary with size and dwelling type. Large properties, semi-detached and detached houses and bungalows are much more likely to be in the owner-occupied sector while small properties, converted flats and dwellings in multi-unit structures are more likely to be in the rental sector. We will see that these patterns hold up even after controlling for location and other property characteristics. However, it cannot be explained by relative prices in the two sectors.

Table 3: Market share by dwelling size: Greater London 2011 wave (%)

Dwelling size	Owner-occupied	Private rented	LA or RSL
Less than 50 sq. m.	33.1	27.4	39.5
50 - 60 sq. m.	47.5	25.4	27.2
60 - 80 sq. m	60.3	17.1	22.6
80 - 100 sq. m.	74.6	12.6	12.8
More than 100 sq. m.	90.1	7.24	2.63

Note: Market shares are calculated using data and sampling weights from the 2011 wave of the EHS. The 2011 wave uses data from April 2008 - March 2010.

Table 4: Market share by dwelling type: Greater London 2011 wave (%)

Dwelling Type	Owner-occupied	Private rented	LA or RSL
Semi detached	73.9	13.0	13.7
Detached	94.4	5.0	0.40
Bungalow	76.8	5.0	18.3
Converted flat	39.3	48.5	15.2
Low rise	32.2	26.7	38.4
High rise	20.7	19.7	48.1

Note: Market shares are calculated using data and sampling weights from the 2011 wave of the EHS. The 2011 wave uses data from April 2008 - March 2010. The semi-detached category includes “End Terrace" and “Mid Terrace".

4 Estimation procedure

We estimate the model parameters from equations (1), (2), and (5) using maximum likelihood. We explore several specifications. In the main specification, we include indicator variables for dwelling type and dwelling age[8], an eighth-order polynomial in dwelling size (square meters), and a set of variables that account for the dwelling's geographic location. For owner-occupied properties, we also include an indicator for whether the property value is self-reported or not.

The confidential version of the EHS reports each dwelling's full postcode. We match each postcode with its geographic coordinates using the Office for National Statistics's Postcode Directory for 2013. Because postcodes can change over time, there are a few unmatched postcodes. In 2014, there is 1 unmatched owner-occupied property out of 5,184 and 2 unmatched private rentals out of 2,683 for all of England. In 2011, there are none. The numbers of unmatched properties for other waves are similar. For these unmatched properties, we imputed coordinates using the mean geographic coordinates of all postcodes sharing the same postcode district (postcodes are grouped geographically and the first three to four characters of a 7-8 character postcode are its postcode

[8]Dwelling types are detailed in Table 3. Dwelling age categories include: 1) pre-1919, 2) 1919 to 1944, 3) 1945 to 1964, 4) 1965 to 1980 or 5) post 1980.

district). For each property, we then convert its geographic coordinates to polar coordinates (r,θ) centered around Trafalgar square. For each property we compute r, the Euclidean distance from Trafalgar Square and θ, the angular distance from due east measured in radians. That is, $\theta = 0$, is east, $\theta = 0.5\pi$ is south, etc.

In our empirical model, we model location effects as a nonparametric function of (r,θ). In the main specification, we include the interaction of an eighth-order polynomial in distance with a 5th order trigonometric expansion in terms of θ. The distance variable captures the impact of distance from London on property values and on selection into the owner-occupied sector. The angular distance variable θ captures variation in outcomes that depends on direction of travel. For example, the rate of decline of prices with distance is higher heading east than west. In a second specification, we drop the arc distance variable in order to measure the average effect of distance. We also explore including indicator variables for the numbers of bedrooms, kitchens, living rooms and bathrooms as well as using levels rather than logs of values and rents. For all cases, the sample is private rental and owner-occupied housing units within Greater London, using the sample weights provided in the EHS.

5 Results

Parameter estimates for the main specification are detailed in Table 5. Most of the parameters are statistically significant and have plausible values. Because the parameters are difficult to interpret we plot predictions for log rent, log value and for the market share of the owner-occupied sector as functions of the explanatory variables. We also plot point-wise confidence bands for these predictions. The graphs are discussed below.

5.1 Location

The decline of property values and rents with distance is dramatic. Figure 1 shows that a property in the owner-occupied sector 10 km away from the center of London is worth only 1/3 of an identical property at the center. For the same change in distance, rent in the rental sector declines to 41% of the rent at the centre. Owner-occupied properties decline in value about 10% per km. Rental properties rents decline by about 9% per km. In both sectors, the hedonic functions flatten out significantly at distances greater than

10 km. In the owner-occupied sector, moving from 10 km to 20 km reduces property values by about 22% and from 20 km to 40 km by about 16%. For rental properties, moving from 10 km to 20 km reduces rents by 14% and from 20 km to 40 km reduces rents by 10%.

Figure 1 also shows the estimated relationship between distance and the owner-occupancy rate. The "unconditional" line plots the estimated relationship between distance and ownership when no other correlates are included. This curve reproduces the numbers in Table 2[9]. The "conditional" line plots the relationship with distance after controlling for dwelling characteristics. The figure plots the owner-occupancy rate for a semi-detached 100 square meter dwelling built after 1960. Unsurprisingly, the unconditional line shows that owner-occupancy is far more prevalent 20 km outside of London than inside the city center. However, the conditional line shows that, once one controls for other housing unit characteristics, distance essentially plays no role in selection into owner-occupancy. Owner-occupancy as a function of distance is essentially flat at around 80% for this property type. It is essentially flat for all property types.

Figures 2 and 3 show similar results if one analyses the relationship with distance conditional on direction θ. The figures show the relationship with distance along the four points of the compass, East, South, West and North. The graphs show that, regardless of direction, the qualitative pattern is the same. Both values and rents fall dramatically, values fall faster than rents, and the functions flatten out after about 20 km and even more after 40 km. The function is flatter in the Eastern direction and is completely flat after 40 km. In contrast, in all other directions, the function is steeper than East and does not completely flatten out after 40 km. In some directions (e.g. East and South), 140 km from Trafalgar Square is a point in the middle of the sea. Thus the confidence intervals in those directions blow up. Also, these results are obtained without controlling for lot size which is not observed. However this likely biases upward (towards zero) the slopes of the hedonic rent and value functions with respect to distance: lot sizes are probably larger further away from the city center where land is cheaper.

In summary, both rents and values fall with distance. Rents relative to values rise with distance but housing units are not more likely to be found in the rental sector. Why

[9]The "unconditional" line differs from the those in Table 2 only because the former is the homeownership rate for houses not in the LA/RSL.

then don't investors in properties far from the centre convert more properties into rental units? We use equations (5) and (7) to frame an answer.

One possible explanation is that maintenance costs relative to rents rise as the value of the location falls. This point is best illustrated by thinking of the value of a property as being composed of the value of land and the value of built structure. In general, structure requires maintenance, while land does not. Assuming that maintenance is a function of the value of structure only, maintenance costs must be increasing in the proportion of the value that is structural. Given that the value of land decreases quickly as distance increases, the proportion of value that is structural increases with distance. A second possible explanation is that vacancy costs in the rental sector are higher further out because the rental markets there are thinner resulting in longer expected vacancy durations. A third possible explanation is that properties close to the city center had higher expected capital gains during the period of our study.

Some limited evidence on these points can be obtained by studying changes in the hedonic functions over time. Figure 4 shows estimated hedonic values and rents with respect to distance for all four waves of the EHS, 2011-2014.[10] In the most recent wave, 2014, the rental function is steeper with respect to distance than the value function, the opposite of the earlier waves. Figure 7 shows time series of two house price indexes for 2009-2012 obtained from the UK Land Registry.[11] These show realized capital gains for properties within 10 km of London and those between 10 km and 100 km of London. Values closer to London have risen much more than values further away, particularly since the end of 2011. This is also reflected in Figure 6. Relative values in London fall in 2009-2010 (which is reflected in the 2012 wave) but then rise again in the 2013 and 2014 waves. The unstable relation between rent-to-price and distance displayed in Figure 4 and the ex-post high relative capital gains in London (to the extent that these capital gains were expected ex-ante), is suggestive that the differential cost explanation

[10]Note that due to disclosure requirements of the Secure Data Service, all values and rents are normalized to be equal across waves at Trafalgar Square. As a result, it is not possible to compare levels of the hedonic price functions across years.

[11]The UK Land Registry records all residential property transactions in England. The data include the location of the property but not many of the other characteristics that are in the EHS. To compute the price indexes, we constructed a sample of all transactions within 100km of Trafalgar Square. We then formed two sub-samples: housing units within 10km of Trafalgar Square and housing units further than 10km away. For each subsample, we regressed log values on a 10th order spline of time at the daily frequency. The plotted lines are the fitted values, normalizing log values to be 0 for each series on January 1, 2010.

is less relevant and that differential capital gains help to explain the low rent-to-price ratios in London in 2008.

5.2 Structure

5.2.1 Dwelling type

Figure 8 shows how values, rents and ownership vary with structure type. Property values for detached houses and bungalows are about 22% higher than for semi-detached houses whereas converted flats and dwelling in low-rise units are about 20-22% cheaper. Rents follow a similar pattern. Rents for detached houses and bungalows are about 24% more expensive. The rent-to-price ratio is approximately constant across the categories of semi-detached, detached and bungalows. For dwellings in multi-unit structures, rents are 33% lower. So, the rent-to-price ratio for multi-unit structures is much lower. These results are stable over waves.[12]

In contrast to location, the conditional relationship between dwelling type and predicted ownership is qualitatively similar to the unconditional relationship. The unconditional relationship is detailed in Table 4. Excluding the social housing sector, 95% of detached, 85% of semi-detached properties and 93.9% of bungalows are in the owner-occupied sector while various types of dwellings in multi-unit structures (converted flats, low rise and high rise) have ownership rates that vary between 44.8% and 54.7%. Physical features are important determinants of selection into the owner-occupied sector. Figure 8 shows that conditional on location and other characteristics, the average predicted ownership rate is between 80% and 90% for semi-detached, detached and bungalows and falls to around 60% for dwellings in multi-unit structures.

The pattern is similar to the stylized fact documented in Glaeser and Shapiro (2003) that in the US, housing units in multi-unit structures are extremely likely to be rented (85.9% in their study) whereas single-unit housing is very likely to be owned (85.5% in their study). Ownership rates do not vary quite as much in England across structure types (this is true even in the full sample).

In England property ownership predominantly takes one of two forms, freehold or leasehold. Freehold ownership is ownership in perpetuity. Leasehold ownership is own-

[12]Results from other waves on dwelling type as well as other unreported results are available upon request.

ership of a long lease (for example 75 years or 99 years).[13] It is clear that property values should depend on the freehold or leasehold status of the property. Unfortunately the EHS only records information on the type of holding for owner-occupied properties. For the Greater London sub-sample, leaseholds comprise only 10 percent of owner-occupied properties. In addition, ownership type is highly correlated with dwelling type. In the EHS sample, fewer than 23% of flats are freeholds while nearly 94% of detached houses are freeholds. Giglio et al. (2015) finds that leasehold flats sell for a a noticeable duration-dependent discount compared to otherwise identical freeholds. However they also find that the type of holding does not affect rents. When an indicator for ownership type is included in the property value equation, the parameter estimate is 0.1198 (with a standard error of 0.0447). Freehold status increases property values nearly 12% relative to leasehold status. The estimates in Figure 8 are robust to including an indicator for leasehold in our estimation of equation 2.

5.2.2 Size

Figure 9 (left panel) shows how rents and values change with respect to the total floor space of the property. Property values increase approximately 7% per 10 square meters. Rents increase approximately 11.6% per 10 square meters. As a result, the rent-to-price ratios increases with respect to size. Figure 10 shows that this pattern remains stable over time. Most of the variation in values and rents over time is captured by changes in the value of location (i.e. land) and not in the valuation of dwelling type or size.

The center panel of figure 9 shows how size affects the probability of being owner-occupied. Again, we compare the results from the selection model to an "unconditional" probit of ownership on size. The effects are dramatic. Unlike location and like dwelling type, size is hugely important for explaining variation in selection even after controlling for other covariates.

The bottom panel in Figure 9 shows how the predicted average unobserved quality for an average housing unit conditional on sector varies with size. In the owner-occupied sector, average unobserved quality does not vary with size. However, this is not true in the rental sector. In the rental sector, bigger dwellings have much lower unobserved quality. The average quality difference between a 50 square meter rental property and a

[13] A third form of ownership, "commonhold", exists but is almost never used due to legal uncertainties.

100 square meter rental property is almost 22%. Large housing units in the rental sector are likely to be of much lower unobserved quality.

5.3 Unobserved quality

The final two columns of Table 5 show the relationship between unobserved quality and selection. Properties with unobserved characteristics that would imply a one percent higher rent are one percent less likely to be in the rental sector. However, characteristics that lead to high unobserved property values do not affect selection. Unobserved "rental quality" is correlated with selection. Unobserved "owner-occupied" quality is not.

These results are subtle. Characteristics that are unobservable to econometricians may also suffer more acutely from third-party verification problems. Enforcing contracts to invest in and/or maintain these characteristics may be particularly costly, if possible at all. Landlords may therefore choose properties with fewer of these characteristics.[14] With this in mind, one way to explain the results is as follows. Suppose $\lambda_1^r, \lambda_2^o, \lambda_1^s > 0$ and $\lambda_1^o, \lambda_2^s = 0$. In this case, one could think of ε_1 as an amenity that affects users' enjoyment of a property but that comes at a high maintenance cost. Such an amenity raises rents, is negatively correlated with selection into the rental sector, and has zero net impact on property values. The high maintenance cost exactly offsets the use value. ε_2 on the other hand could be an amenity that affects both values and rents but does not affect selection, perhaps because there are no maintenance concerns associated with it. In other words, perhaps ε_1 could be a jacuzzi - nice to use but a nightmare to maintain, while ε_2 could be the unimpeded light from South facing windows.

Finally, some models of homeownership and housing demand use a preference specification which includes a preference for owning (a.k.a a "warm glow" from owning).[15] In calibration exercises, such a preference for owning is often required to generate high home-ownership rates. Our results show that an econometrician measuring demand for homeownership using only observable housing characteristics would indeed find a preference for owning. This is because rentals, on average, have lower unobserved quality.

[14] Kanemoto (1990) builds a theory of underinvestment in housing and security of tenure that has a similar mechanism.

[15] For example, see Iacoviello and Pavan (2013); Kiyotaki et al. (2011).

5.4 Implications for user cost of housing

The joint distribution of owner-occupied and rental sector user costs can be computed directly from our parameter estimates. Let $u^o = \frac{u(z,\varepsilon)}{\pi^o(z,\varepsilon)}$ and $u^r = \frac{R(z,\varepsilon)}{\pi^r(z,\varepsilon)}$ and recall that $\eta = \Lambda\varepsilon$. If we assume that the service flows from dwelling (z,ε) are the same regardless of which sector the dwelling is in, then $R(z,\varepsilon) = u(z,\varepsilon)$. Combining this with equations (1) - (3) implies that

$$\ln u^o = (\alpha - \beta)z + \eta_1 - \eta_2 \tag{8}$$

$$\ln u^r = (\alpha - \beta + \gamma)z + \eta_1 - \eta_2 - \eta_3. \tag{9}$$

As a result, the bivariate distribution of user costs is log normal conditional on z. The mean is $\nu = ((\alpha - \beta)z, (\alpha - \beta + \gamma)z)$. Using the estimates from Table 5, the covariance matrix is given by

$$\Psi = \begin{bmatrix} 1.0388 - 2\omega_{12} & 1.9414 - 2\omega_{12} \\ 1.9414 - 2\omega_{12} & 3.8440 - 2\omega_{12} \end{bmatrix}.$$

where $\omega_{12} \in \{0.0536, -0.1477\}$. This last fact follows from the formula derived in Appendix A. We cannot point identify ω_{12} but the possible values are the roots of a quadratic equation. Equations (8) and (9) also imply that the ratio of user costs satisfies:

$$\ln u^r - \ln u^o = \gamma z - \eta_3. \tag{10}$$

5.4.1 Variation with respect to location

The rent-to-price ratio increases with distance in several waves but decreases with distance in 2014. At the same time, location is unimportant for selection. Using equation (10), these facts imply that differential users costs between the two sectors do not vary with distance. This can be seen in the top panel of Figure 13 which shows average log user costs in the two sectors as a function of distance. The two curves are nearly parallel. In other words, while effective interest rates, maintenance costs, and expected capital gains, may vary with distance from London, they do not vary differentially across housing sectors.[16] As discussed in Section 5.1, it is likely that both rental and owner-occupied maintenance costs as a proportion of value rise with distance. Apparently though, in some time periods like those covered in the 2014 wave, this maintenance effect on the rent-to-price ratio is dominated by other effects. That is, during this period either the discount rate in London went up relative to outside London or relative expected capital gains fell in London.

5.4.2 Variation with respect to structure

The more detached and/or the larger a property is the higher is its rent-to-price ratio but the lower is its likelihood of being a rental. Detachedness and size are each positively valued and are each negatively correlated with being in the rental sector. Considering equations (6) and (7), this implies that either $\frac{r^o}{r^r}$ or $\frac{c^o}{c^r}$ decreases or $\frac{g^o}{g^r}$ increases with detachedness or with size. The lower two panels in Figure 13 show the resulting predictions for average log user costs as functions of size and dwelling type in the two sectors. User costs in the owner-occupied sector increase about 35% when moving from a 50 sq. meter property to 110 square meters. For the same change in property size, rental sector user costsfrom 3% to 11% of the value of the property. Similarly owner occupied user costs are 65% higher for detached dwellings vs. dwellings in multi-unit structures. Detached property rental sector user costs are almost 450% higher. There are enormous increases in relative rental sector user costs for bigger properties and for more detached properties.

What explains these enormous increases? Is it likely that $\frac{g^o}{g^r}$ is dramatically different for detached houses than for dwellings in multi-unit structures? Is this ratio likely to be dramatically different for 100 square meter flats versus 50 square meter flats? This ratio may vary slightly with these physical features due to sectoral differences in taxation of capital gains. For instance, capital gains below a certain threshold are tax exempt for owner-occupiers. However, any variation due to differential tax treatments should also be reflected in our findings with respect to location. This is not the case. Location is uncorrelated with ownership after controlling for observable and unobservable structural characteristics. As discussed above, this suggests that $\frac{g^o}{g^r}$ is roughly constant with respect to location.

[16]It seems unlikely that the individual factors vary differentially in such a way to cancel one another out.

In contrast, in the case of costs, it is theoretically plausible that rental costs c^r increase faster than c^o when size increases or when one compares detached houses to dwellings in multi-unit structures. This is the direct or indirect implication of Galster (1983), Henderson and Ioannides (1983) and Coulson and Fisher (2014). Our findings suggest that this differential increase in costs is large. We compute an estimate of an upper bound for this magnitude in Section 5.4.4.

In the case of interest costs, it is also theoretically plausible that interest costs in the rental sector, m^r, increase faster than m^o. For instance, some property owners (either landlords or owner-occupiers) may face tighter borrowing constraints than others. As a result, they may face higher interest rates. It is possible that less constrained owner-occupiers tend to live in physically more valuable housing units (but not locationally more valuable housing units). In this case, the marginal owner-occupier's discount rate would decline with structure value. At the same time, if the marginal landlord's discount rate was independent of property characteristics, then m^o/m^r would decrease relative to physical value. Our study does not provide direct evidence that can shed further light on the extent to which this theoretical possibility is empirically relevant. Further investigation is required to determine whether and to what degree mortgage costs vary across owner-occupiers, across landlords, and across different types of housing units.

5.4.3

5.4.4 Implication for maintenance costs

If furthermore we make the extreme assumption that $r^r - g^r = r^o - g^o$, then equation 10 becomes:

$$\frac{1+\frac{c^r}{r-g}}{1+\frac{c^o}{r-g}} = e^{\gamma z - \eta_3}.$$

In Figure 15, we calibrate $c^o = .017$ (consistent with measures of owner-occupied depreciation in Gatzlaff et al. (1998); Malpezzi et al. (1987); Amior and Halket (2014), among others) and set $r - g = 0.01$. We then plot several measures of c^r. The average c^r, which is what the average cost of maintenance would be if all properties were rented, is higher than c^o and increases faster with z. The counterfactual cost of maintaining owner-occupied properties were they instead rented is still higher. Conditional on the extreme assumptions in this section, this shows that the moral hazard problem for landlords and tenants can be very large. Strikingly, however, the average maintenance costs of those properties that are actually rented are lower than those paid by owners for their properties. This is because the rented properties are of lower unobservable quality. Therefore, estimates of differential maintenance costs that did not control for selection would fail to find higher costs in the rental sector.

5.5 Bias in imputed rents and/or values

Beyond simply biasing estimates of maintenance costs, the estimation results imply that hedonic estimates of rents and values that do not control for selection are also biased. For rents, these biases are statistically and economically significant. Moreover the bias creates striking patterns in the data.

To illustrate the bias, we re-estimate α and β without controlling for selection. We then use these biased estimates to predict rents and values for all housing units in the sample. Figure 11 plots the predicted rent-to-price ratios against the predicted log value from the biased regressions for both rentals and owner-occupied properties. The biased estimates imply that homeownership rates are increasing in the predicted value of a home even though the predicted rent-to-price ratio declines in the value of the home. This is a common finding: Verbrugge (2008); Heston and Nakamura (2009); Verbrugge and Poole (2010); Bracke (2013); Epple et al. (2013) all find that rent-to-price ratios decline with values while Landvoigt et al. (Forthcoming) estimates that housing service flows rise less than one-for-one with property values in the cross-section. [17] The relationships shown in Figure 11 and in these studies are puzzling from a certain angle and are a challenge for models which attempt to explain the distribution of household homeownership choices: why do so many households choose to buy expensive properties when seemingly equivalent rental properties are relatively cheap? Estimates from our selection corrected model provide the answer: The rentals are not equivalent. More expensive properties in the rental sector on average have lower unobserved quality.

Using parameter values from the biased regression results, Figure 12 (left, center and right) plots the predicted values and rents as functions of dwelling type, distance and size respectively. Comparing these figures to their counterparts from section 4 (Fig-

[17] Halket and Pignatti (2014) shows that some of this co-variation can be explained by differences in rental vacancy rates.

ures 8, 2 and 9, respectively), several facts are apparent. There is no bias in the hedonic estimates with respect to location. However, the predicted relationships between rents and physical characteristics - dwelling type and size - are biased. In fact, the relationship between rent-to-price and value predicted by the biased estimates is negative whereas the relationship predicted by the selection corrected model is positive. Using the biased estimates, one would conclude that larger, detached homes (which are more expensive) have lower rent-to-price ratios. The selection correction model results show that the opposite is true. This dichotomy between location and structure was already evident from our findings discussed above. These figures show how large the bias is: it qualitatively reverses patterns. Correcting for the bias eliminates the puzzle raised by Figure 11.

6 Conclusion

Housing units are not randomly selected into a housing sector. Physical attributes including some that are unobservable in our data are important for selection. These findings are consistent with theories of contracting frictions over maintenance and upkeep of the property.

The results also imply that properly accounting for the bias that selection imparts may encourage refinements in the construction of price indices both for housing and for consumer prices. It may also help to better understand some of the relative movements of rents and values over time such as those documented in Campbell et al. (2009).

Finally, models of households' homeownership decisions, such as Landvoigt et al. (Forthcoming); Cocco (2005); Diaz and Luengo-Prado (2008); Henderson and Ioannides (1983), largely have abstracted away from explicit considerations of the multi-characteristic nature of housing units. Our findings here point to a need to examine households' desire to own jointly with their desire to live in certain housing units. Perhaps, households that have a higher demand for larger housing units or detached houses or housing units with high maintenance amenities are more likely to save for a down-payment everything else equal.

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A Identification of Ω

All the elements of Ω are point-identified except ω_{12}. The identified set for ω_{12} consists of two points. To see this consider the following. Since Ω is rank 2, one of its columns can be written as a linear combination of the others. This implies

$$\begin{aligned} \omega_{11} &= \delta_1 \omega_{12} + \delta_2 \omega_{13} \\ \begin{bmatrix} \omega_{21} \\ \omega_{31} \end{bmatrix} &= \begin{bmatrix} \omega_{22} & \omega_{23} \\ \omega_{32} & \omega_{33} \end{bmatrix} \delta \end{aligned}$$

where $\delta = (\delta_1, \delta_2)$ is a vector of weights. Solving the second two equations for δ yields

$$\begin{aligned} \delta_1 &= \frac{\omega_{33}\omega_{12} - \omega_{23}\omega_{13}}{D} \\ \delta_2 &= \frac{-\omega_{23}\omega_{12} + \omega_{22}\omega_{13}}{D} \end{aligned}$$

where $D = \omega_{22}\omega_{33} - \omega_{23}^2$. Substituting this into the first equation yields

$$\omega_{11} = \omega_{12}\left(\frac{\omega_{33}\omega_{12} - \omega_{23}\omega_{13}}{D}\right) + \omega_{13}\left(\frac{-\omega_{23}\omega_{12} + \omega_{22}\omega_{13}}{D}\right)$$

which is a quadratic equation in the unknown ω_{12}. This equation can be written as

$$\frac{\omega_{33}}{D}\omega_{12}^2 - 2\left(\frac{\omega_{23}\omega_{13}}{D}\right)\omega_{12} + \left(\frac{\omega_{22}\omega_{13}^2}{D} - \omega_{11}\right) = 0.$$

This equation has solutions

$$\omega_{12} = \frac{\omega_{23}\omega_{13} \pm \sqrt{\omega_{23}^2\omega_{13}^2 - \omega_{33}\left(\omega_{22}\omega_{13}^2 - D\omega_{11}\right)}}{\omega_{33}}.$$

B Figures and Tables

Figure 1: Rent, Value and Ownership vs. Location

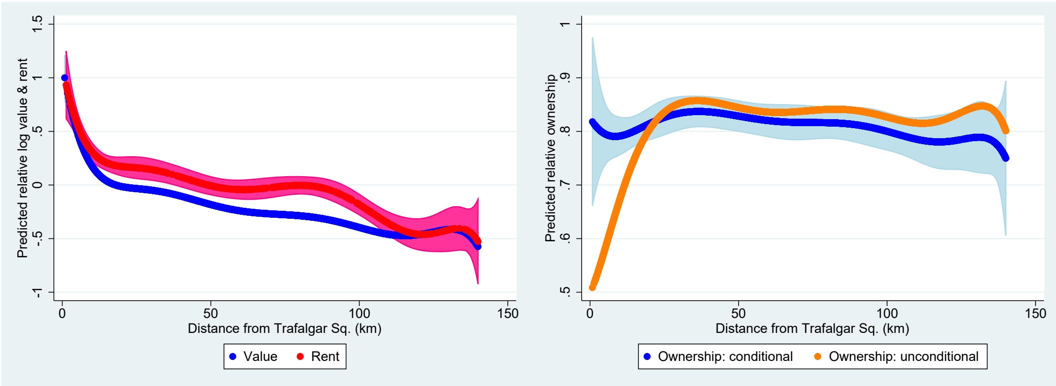


Figure 2: Rent and Value vs. Location : East and South

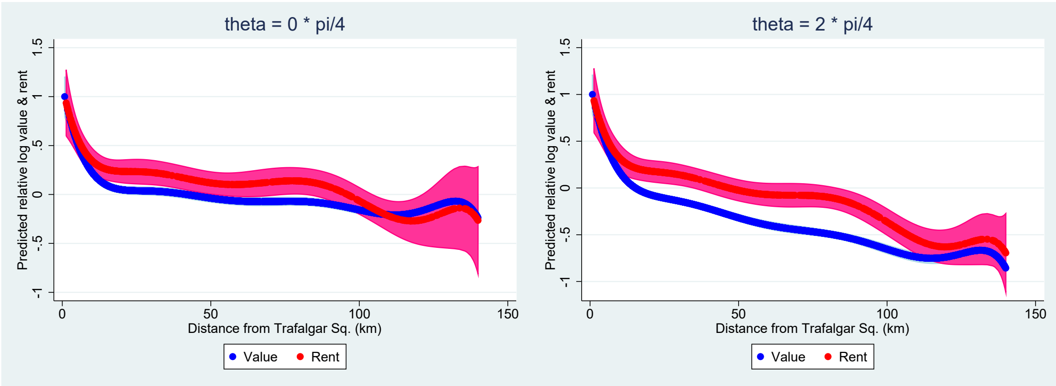


Figure 3: Rent and Value vs. Location: West and North

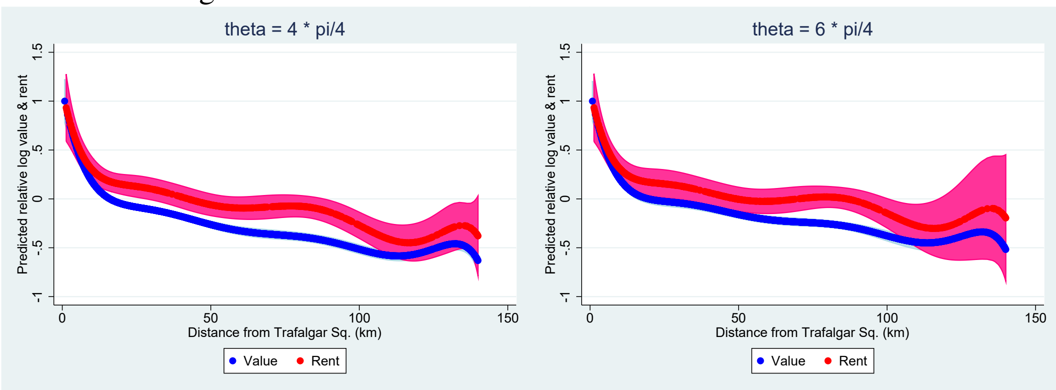


Figure 4: Rent and Value vs. Location: time variation

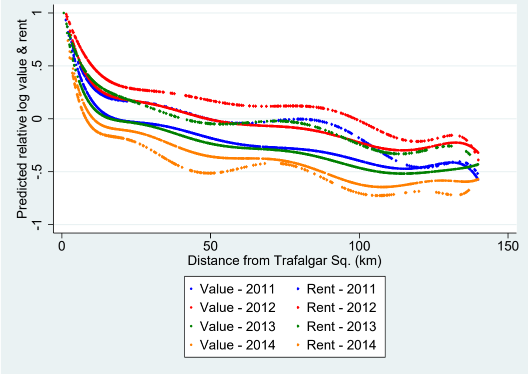


Figure 5: Rent and Value vs. Location: time variation (2)

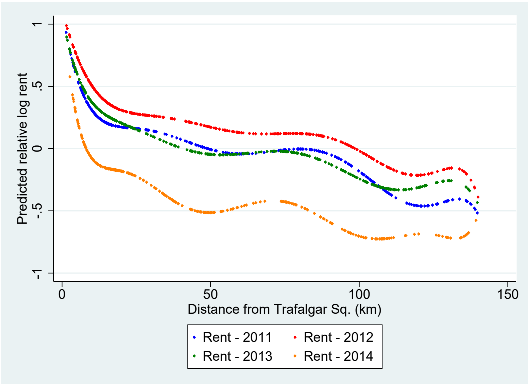


Figure 6: Rent and Value vs. Location: time variation (3)

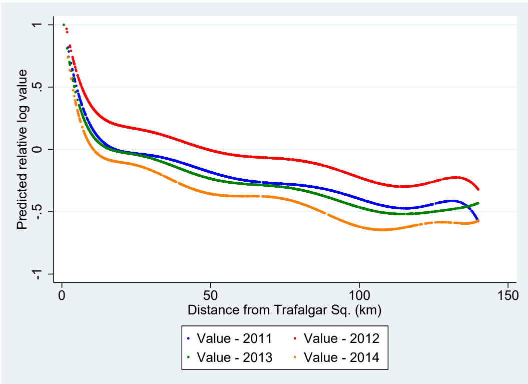


Figure 7: Time Series of Values from Land Registry

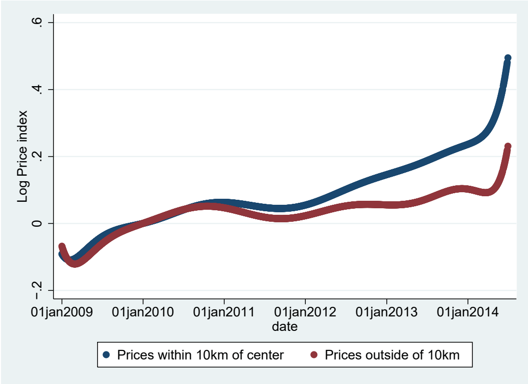


Figure 8: Rent, Value and Ownership vs. Dwelling Type

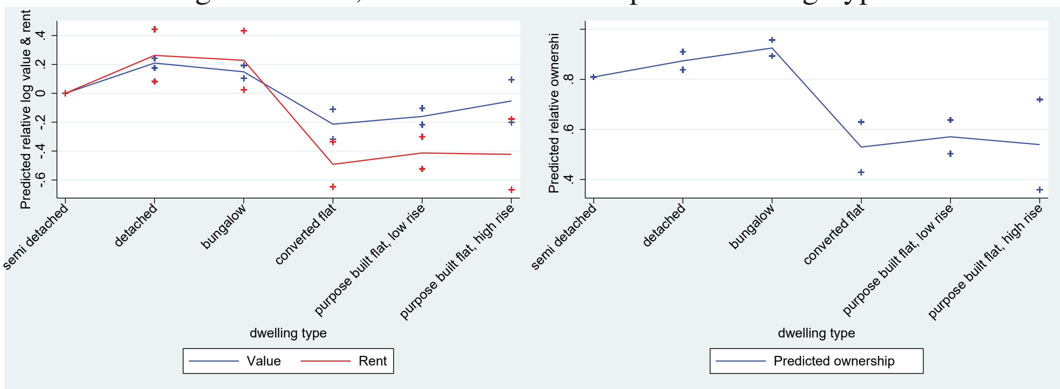


Figure 9: Rent, Value, Ownership and Unobserved Quality vs. Size

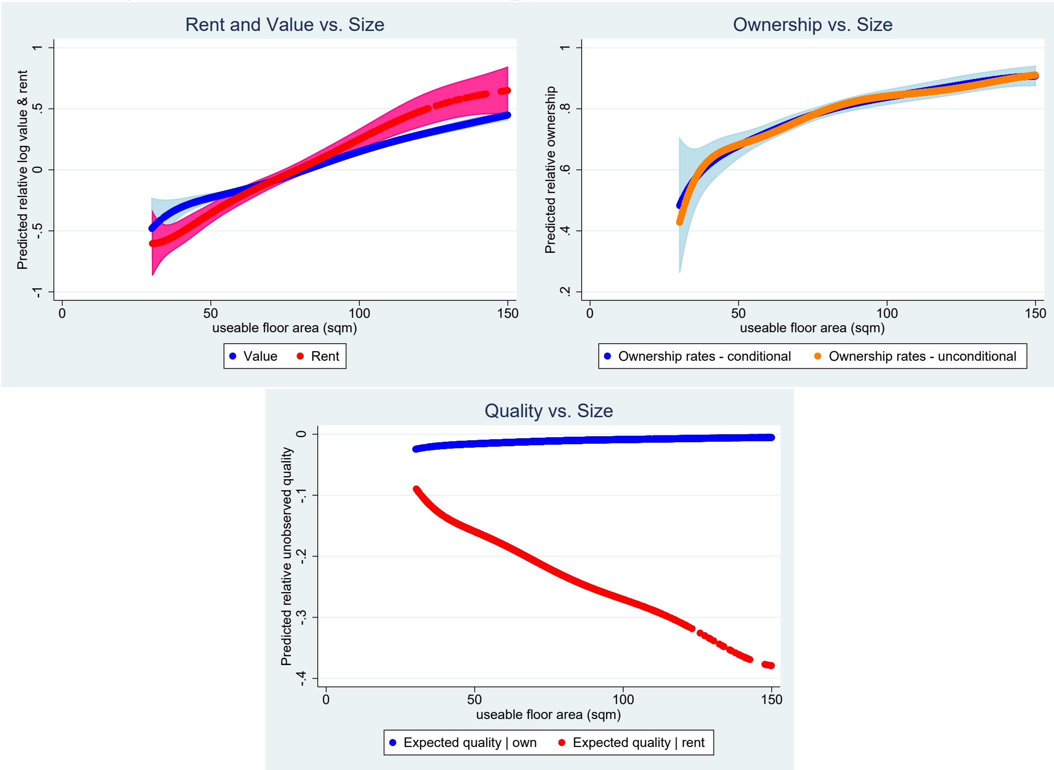


Figure 10: Rent and Value vs. Size: time variation

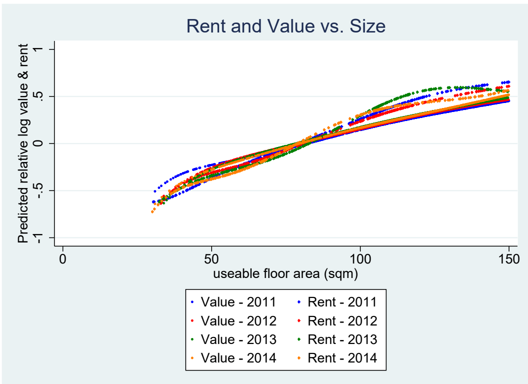


Figure 11: Raw Correlation between Rent-to-Price Ratios and Ownership Without Controlling For Selection

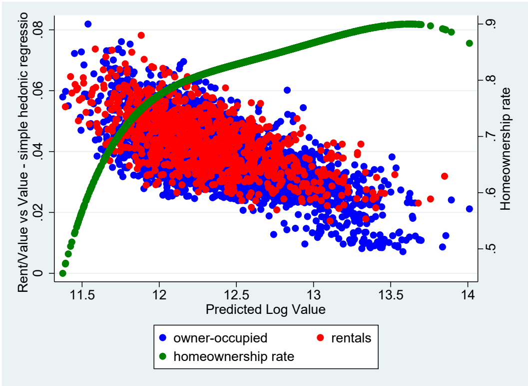


Figure 12: Rents and Values vs. z (ignoring selection bias)

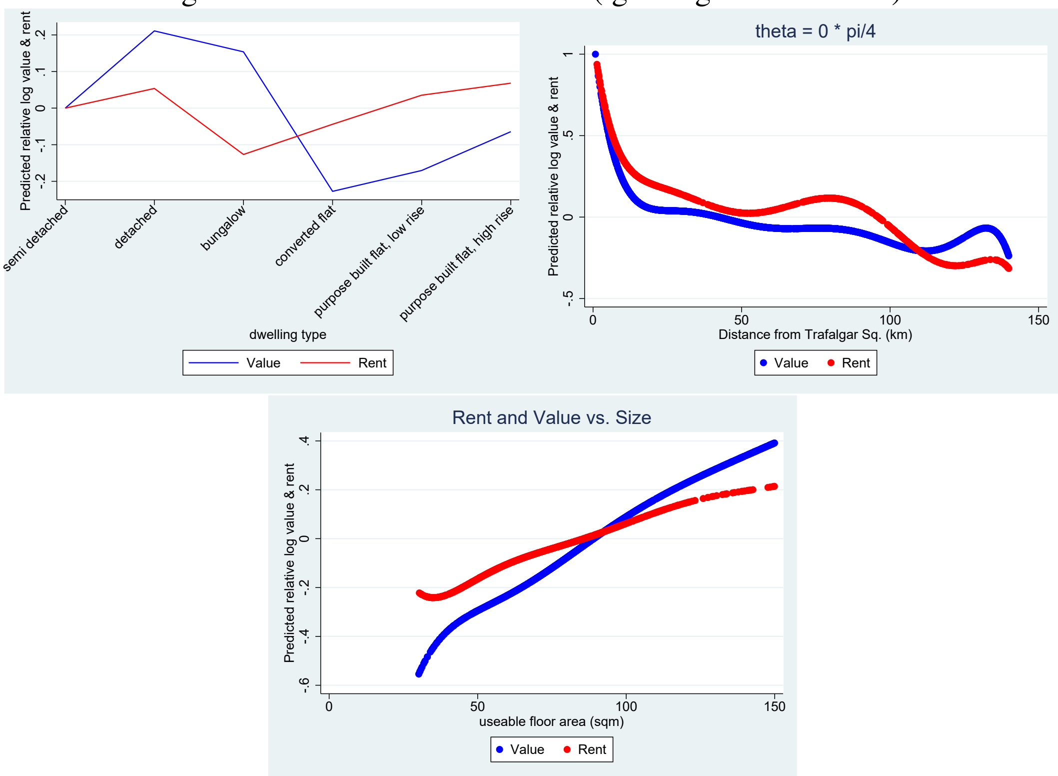
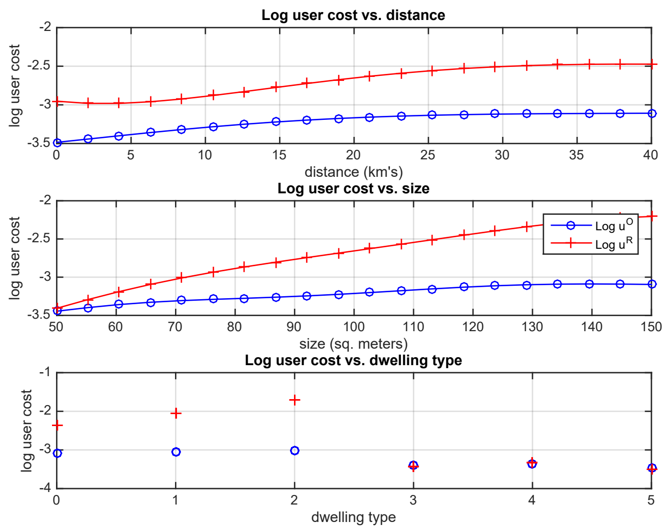
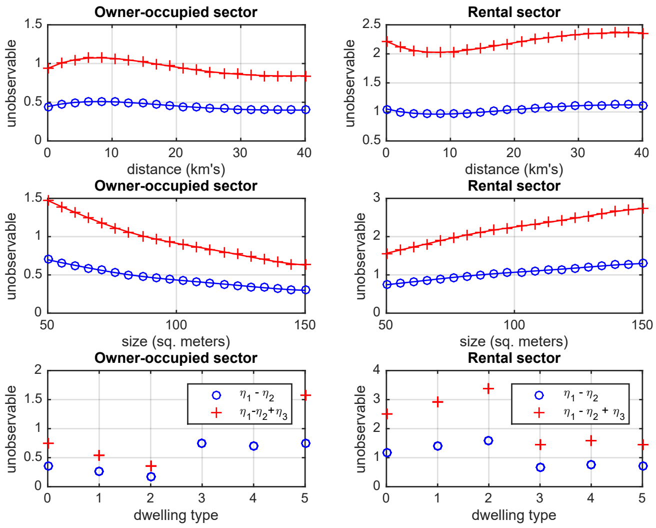


Figure 13: Log User Costs as a function of characteristics z



Note: Dwelling types: 0 = detached, 1 = semi-detached, 2 = bungalow, 3 = converted flat, 4 = purpose built, low rise, 5 = purpose built, high rise

Figure 14: Unobservable Component of Log User Costs as a function of characteristics z



Note: Dwelling types: 0 = detached, 1 = semi-detached, 2 = bungalow, 3 = converted flat, 4 = purpose built, low rise, 5 = purpose built, high rise

Figure 15: Contracting Costs as a function of characteristics z

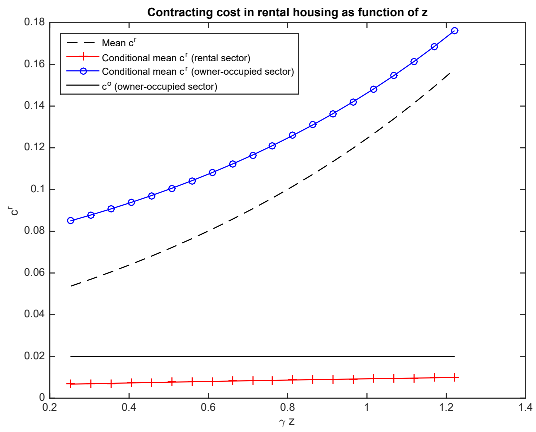


Table 5: Estimation Results - Hedonics

	MLE - Own	MLE - Rent	Probit	Selection-Own	Selection-Rent
Dwell. type					
detached	0.2094	0.2628	0.2681	0.2690	
	(0.0174)	(0.0922)	(0.0882)	(0.0881)	
bungalow	0.1490	0.2286	0.5720	0.5648	
	(0.0225)	(0.1038)	(0.1157)	(0.1155)	
converted	-0.2139	-0.4918	-0.8019	-0.8012	
	(0.053)	(0.0796)	(0.1284)	(0.1285)	
low rise	-0.1603	-0.4130	-0.6955	-0.6975	
	(0.0295)	(0.0567)	(0.0875)	(0.0873)	
high rise	-0.0530	-0.4226	-0.7730	-0.7765	
	(0.0749)	(0.1248)	(0.2315)	(0.2313)	
Dwell age					
1919 - 1944	-0.0175	0.1884	0.2557	0.2583	
	(0.0211)	(0.0602)	(0.0806)	(0.0806)	
1945 - 1964	-0.0909	0.0481	0.2575	0.2617	
	(0.0205)	(0.0679)	(0.0869)	(0.0875)	
1965 - 1980	-0.1068	0.2064	0.3613	0.3643	
	(0.0200)	(0.0685)	(0.0841)	(0.0842)	
Post 1980	-0.0498	0.1694	0.287	0.2908	
	(0.0210)	(0.0654)	(0.0878)	(0.0878)	
selfReport					
1	-0.0878				
	(0.0158)				
$\rho_{23} = corr(\eta_2, \eta_3)$				0.1040	
				(0.0553)	
$\rho_{13} = corr(\eta_1, \eta_3)$					-0.9759
					(0.0048)
Σ_{22}				0.2855	
				(0.0096)	
Σ_{11}					0.7533
					(0.0415)
$\rho\Sigma$				-0.0297	-0.7351
				(0.0156)	(0.0429)

From the 2011 wave of the EHS, using sampling weights. Omitted from the table but included in the estimation are the polynomials in size and the location variables. *Probit* are coefficients from a probit regression of all variables on a dummy for owner-occupancy.