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Published in:
Journal of Urban Economics

DOI:
[10.1016/j.jue.2015.11.007](https://doi.org/10.1016/j.jue.2015.11.007)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2016

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):
van Ommeren, J. N., & van der Vlist, A. J. (2016). Households' willingness to pay for public housing. *Journal of Urban Economics*, 92, 91-105. <https://doi.org/10.1016/j.jue.2015.11.007>

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ARTICLE INFO

Article history:

Received 10 November 2014

Revised 29 October 2015

Available online 11 January 2016

JEL classification:

R21

Keywords:

Nonmarket allocation

Public housing

Marginal willingness to pay

Queueing

ABSTRACT

In the presence of price controls, nonmarket housing allocation mechanisms such as queueing prevent households from revealing their marginal willingness to pay for housing through market prices. We derive the households' marginal willingness to pay using the intuitive idea that the length of the queue for a specific house reflects the households' willingness to pay for housing characteristics. We apply our methodology to public housing in the Amsterdam Metropolitan area and show that, *on average*, the households' marginal willingness to pay for a unit of public housing is close to its marginal costs. This suggests that the welfare loss of public housing through distortions in housing supply is rather limited and is mainly through distortions in housing demand. We provide indirect evidence of the latter by showing that queueing induces inefficient matching of households and housing.

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1. Introduction

For regulated rental housing markets with nonmarket allocation and rent control, standard hedonic pricing methods in the toolkit of the economist cannot be applied because these methods require rents to be freely determined (Rosen, 1974). We will start from the premise that in regulated rental housing markets, households do not reveal their willingness to pay through the price, but through other mechanisms such as queueing and waiting. This paper proposes an intuitive methodology that estimates the marginal willingness to pay for housing characteristics on waiting lists. We apply this methodology to public housing by estimating a hedonic waiting time function which reveals the effects of housing characteristics (including the controlled rent) on the length of the waiting time.² Based on this hedonic waiting time function, we derive the households' marginal willingness to pay for public housing and compare this with the cost of providing public housing.

Waiting lists are central to the allocation of a number of goods (Cheung, 1974). Typical examples are waiting lists for public health care treatment where individuals have to wait for treatment or surgery (e.g., Pizar and Prentice, 2011) or public housing where households have to wait for rental housing (Lindsay and Feigenbaum, 1984).³ Public housing waiting times strongly vary (from months to decades in our data) because of heterogeneity in housing characteristics such as location, size and their value when commercially sold, which we will exploit in our methodology. For households on waiting lists, the price of a public house is equal to its rent plus the cost of receiving the public house later (Propper, 1995; Deacon and Sonstelie, 1985, 1989, 1991).

Allocation mechanisms of public housing that use waiting time strongly differ between countries and even between cities of the same country. We focus on Amsterdam where it is *not* the case that households line up for a specific public house or in a specific neighborhood (as in New York). In Amsterdam Metropolitan Area, which contains several municipalities, a *choice-based* allocation system is used in which eligible households may choose from

[☆] We would like to thank three anonymous referees, the editor Stuart Rosenthal, Geoffrey Turnbull, participants of the 2013 European Economic Association Conference in Gothenburg, the 2013 European Real Estate Society Conference in Vienna, the 2014 Urban Economics workshop in Barcelona and the 2014 European Regional Science Conference in St. Petersburg for suggestions for improvement.

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² Public housing covers 46% of the European Union rental market. For previous analysis of public housing, we refer to Olsen and Barton (1983) and Currie and Yelowitz (2000).

³ The idea to use queueing time to derive the willingness to pay has been used before in the context of a homogeneous good where its demand is independent of the demand for other homogeneous goods on waiting lists (Lindsay and Feigenbaum, 1984; Pizar and Prentice, 2011). For healthcare, this assumption seems accurate (i.e., new kidneys demand is independent of heart surgery demand). In markets with heterogeneous goods such as housing, this assumption is untenable, as the length of the queue for one good type is related to the length of the queue of other good types. Other healthcare studies studying waiting lists apply contingency valuation methods, which have well-known limitations (Propper, 1995; Bishai and Lang, 2000).

a large set of houses that are different in many characteristics including the level of the controlled rent.⁴ Registered households may apply for any public house which becomes vacant in the municipality where they live or work. Conditional on applying, the household with the highest priority status – defined as the household with the longest waiting time – is considered first. Once eligibility is checked, which depends mainly on household income, the household may either accept or reject the offer. Households are permitted to reject unlimited without penalty to maintain the position in the waiting list. When a vacant house is rejected, the household with the next-to-highest priority status is considered until the house is accepted. The rental contract offered to the household is permanent. As a consequence, when household incomes of public housing residents increase above eligibility targets (after a certain period), residents will not be evicted out of their current residence into the private sector.

We are interested in the welfare effects of supplying public housing which is allocated using waiting time and where the rent is controlled. Our paper fits therefore in the literature that assumes that there is no medium of exchange as money (Wheaton, 1990; Svensson, 1994; Anas, 1997; Abdulkadiroglu and Sönmez, 1999; Arnott and Igarashi, 2000; Sönmez and Unver, 2010, 2011). We mainly focus on the distortionary effect of *inefficient public housing supply* (i.e., public housing associations offer houses that are too large or too small, on average, from a welfare perspective) and estimate the *average* of the households' marginal willingness to pay for public housing, where the average is defined for the population of public housing renters. This estimate is useful, because for households with a quasi-linear utility function, which is a somewhat restrictive assumption as discussed later on, and given constant returns to scale in housing production (which is a common assumption, see Epple et al., 2010), public housing supply is optimal when the average of the households' marginal willingness to pay for public housing is equal to its marginal cost. In the current paper, we test for this optimality condition.

We emphasize that our empirical analysis focuses on rent-controlled public housing and not to rent-controlled private housing. A key difference is that rent control of private housing *reduces* private supply below its optimal level in terms of quality (Moon and Stotsky 1993). In contrast, public housing suppliers receive substantial subsidies in order to reduce rents but not housing quality and there is not necessarily a welfare-reducing reduction in the housing suppliers' expenditure on housing or housing maintenance. In contrast to private suppliers, it is imaginable that public housing suppliers oversupply quality, implying that houses are offered that are too luxurious from a welfare perspective. Consequently, in general, it is unknown whether the suppliers' expenditure on public housing supply is insufficient or excessive from an economic welfare perspective.

Our contribution is threefold. First, we propose a methodology to derive the marginal willingness to pay for housing characteristics given nonmarket housing allocation based on waiting time. We are particularly interested in households' willingness to pay for one monetary unit of public housing, i.e. the marginal willingness to pay for the *market value* of a public house when sold in the private property market. The market value is of interest because it is not only a reasonable measure of renters' overall housing consumption but also the preferred measure of societies' capital costs for public housing. The latter is important, because it enables us

to compare the societal benefits of one unit of public housing with the societal costs of provision.

More formally, we model the use of the waiting time as a non-market allocation mechanism where (identical) households (who are eligible for public housing) choose from a given set of heterogeneous public houses with different rents and market values.⁵ Rents are regulated at the national level. It is therefore reasonable to treat the rent as exogenous because it is primarily determined through a regulatory process rather than market forces.⁶ The length of the queue for each type of public house is then endogenously determined, effectively creating a market for public housing, which is cleared by a *distribution* of waiting times. One of the immediate implications is that houses that are more attractive to renters (e.g., houses with a lower rent-to-market value) have a longer queuing time. Based on the market equilibrium distribution of queuing times, households will sort themselves into different types of houses which reveals their willingness to pay for public housing characteristics.

Second, we apply the methodology to public housing in Amsterdam Metropolitan area. Our data are roughly a 10% random sample of all *new rental contracts* obtained from one of the largest public housing associations in this area. We have selected households that received a public house through waiting (rather than through an urgency label, which applies for example for divorced females with small children). We then focus on the subsample of households who do not receive housing subsidies and who use public housing for the first time.⁷ The sample analyzed by us contains 774 observations. Although this sample is not very large, we emphasize that we are the first study to use detailed information on housing allocation matches including the rent paid, as stipulated by the rental contract, as well as the queuing time which allows us to estimate the renters' marginal willingness to pay, MWP, for public housing characteristics.⁸

To be more precise, we estimate the average MWP for a monetary unit of public housing and show that it close to its marginal costs suggesting that the *supply* of public housing is not too far from its optimum. Our results are quite different from studies which report deadweight losses of reductions in *private* housing supply due to rent control, which receives a lot of attention in the literature (e.g., Gyourko and Linneman, 1989; Moon and Stotsky, 1993; Sims, 2007). Our results are in line with Glaeser and Luttmer (2003) that the distortions of housing market regulation are not so much through inappropriate supply but through inefficient matching.

Third, we contribute to the literature which argues that households vary in their willingness to pay for housing. Due to rent con-

⁵ For alternative, but restrictive, approaches using measures of residential mobility, see Bartik et al. (1992) and Van Ommeren and Koopmans (2011). In the latter approach, households are assumed to search for accommodation. We assume that households simultaneously choose the length of the queue and the characteristics of the public house. The latter seems reasonable when the market is thick as is the case for the Netherlands.

⁶ In our econometric estimation procedure, we will provide estimates assuming that the rent is endogenous to deal with unobserved housing characteristics.

⁷ In the Netherlands, housing subsidies are provided by the national government as a supplementary income to *poor* households. We select households that do not receive housing subsidies for a number of reasons. One fundamental reason is that housing subsidies are household specific. Another reason is that housing subsidies are not observed and these have to be approximated with imputed subsidies, and that subsidies will change when the income of the household will change. We focus on households who occupy public housing for the first time, because only for these households' waiting time is well-defined.

⁸ We cite Geyer and Sieg (2013): "Local housing authorities are not willing to disclose detailed micro-level data on wait lists. To our knowledge, there is no empirical research that uses household level, *wait list data* to study rationing in public housing markets. The key challenge is, therefore, to estimate a model that treats the wait list as latent." In the current paper, we estimate the model that treats the waiting list explicitly.

⁴ Choice-based allocation, which implies that registered households actively search in a vacancy list, has been introduced in many other cities including London in 2001, and Toronto in 2014. In London, about one hundred households apply per unit, so the market is thick. The latter also applies in Amsterdam.

trol combined with an inefficient allocation mechanism, substantial welfare losses may occur through inefficient matching of heterogeneous households with heterogeneous public housing (Glaeser and Luttmer, 2003). We will provide empirical evidence of this by showing that allocation based on waiting lists prevents matches of housing to households that do occur in non-regulated markets. For example, given non-regulated housing markets, a well-known result is that high-income households tend to live in larger and more expensive houses. We show that for houses with a long waiting time (more than 10 years) this result does *not* hold. More in general, we show that the most attractive houses (in terms of housing expenditure by society) are allocated to a group of households that do not have the highest willingness to pay for those houses (but likely have low waiting time costs).

The rest of the paper is as follows. Section 2 introduces a methodology to estimate the households' willingness to pay for housing characteristics when households queue for housing. Section 3 discusses welfare issues. Section 4 describes the institutional context and our data. Finally, we present our findings and discussion in Section 5. Section 6 concludes.

2. Estimation methodology

2.1. Willingness to pay for public housing

Let us suppose an economy with a given stock of vacant public housing. Identical households enter the economy through private housing, but prefer to use public housing. We assume public houses differ in their quality levels offered to households, hence they differ in their (indirect) instantaneous utility level denoted by v . Due to excess demand for public housing, there is a positive queue for each public house. The length of the queue of each public house is endogenously determined. We focus on the steady-state. Given these assumptions, it can be shown that, in equilibrium, queuing time and quality (utility level) are positively related (for a formal demonstration see Appendix A). Consequently, economic theory indicates that in equilibrium a positive relationship queuing time τ and quality level v will emerge.⁹

Let us now assume that the utility function v is a function of housing characteristics, X and the rental price r and consequently $v = v(X, r)$. X may include any housing characteristic. We are interested to estimate the willingness to pay for public housing. As explained in the introduction, we will focus on the households' willingness to pay for one additional monetary unit of public housing, captured by the market value of a public house when sold in the private property market. Market value is of interest because it can be considered as a reasonable measure of renters' housing consumption as well as of societies' capital costs for public housing. In the current application, we are interested to know to what extent v depends on this market value and will assume that X refers to the market value.

Given $v = v(X, r)$ and a positive – and therefore monotonic – relationship between queuing time τ and quality level v , it immediately follows from the chain rule that:

$$\frac{\partial v / \partial X}{\partial v / \partial r} = \frac{\partial \log \tau / \partial X}{\partial \log \tau / \partial r}. \quad (1)$$

⁹ It is straightforward to show that this result holds not only for this specific housing model but in general using a revealed-preference argument in the spirit of Samuelson (1947). Assume that the lifetime utility level of a new household who enters the economy depends positively on the quality level of the public house the household is waiting for and, due to a positive discount rate, negatively on the waiting time of the public house. Suppose that a household who enters the economy is indifferent between two choices, C, composed of v_c and τ_c , and D, composed of v_d and τ_d . In case, v_c exceeds v_d , then τ_c must exceed τ_d . Hence, the result follows.

Hence, the ratio of the marginal effect of X on the queuing time and the marginal effect of r on the queuing time equals the ratio of the marginal effect of X on the household utility and the marginal effect of r on the household utility, where the latter ratio defines the (negative of the) household's marginal willingness to pay for X , denoted as MWP_X . Hence, we define $MWP_X = -[\partial v / \partial X] / [\partial v / \partial r]$, or equivalently:

$$MWP_X = -\frac{\partial \log \tau / \partial \log X}{\partial \log \tau / \partial \log r} \frac{r}{X}. \quad (2)$$

Hence, MWP_X can be derived given information on $\partial \log \tau / \partial \log X$, $\partial \log \tau / \partial \log r$. We will estimate $\partial \log \tau / \partial \log X$ and $\partial \log \tau / \partial \log r$ and report MWP_X for mean values of X and r .

In a market, where public authorities set rent levels exactly at their market level, then the marginal effect of log rent on log queuing time must be equal to the marginal effect of log market value on log queuing time. When public authorities set rent levels below their market value, one expects that the elasticity of the willingness to pay for public housing with respect to rent, ϵ_x , defined as (minus) the ratio of the queuing time elasticity with respect to market value and the queuing time elasticity with respect to rent, exceeds one, because households gain more from an increase in market value than they lose from a proportional increase in rent. The elasticity of the willingness to pay for public housing with respect to rent is then defined as:

$$\epsilon_x = -\frac{\partial \log \tau / \partial \log X}{\partial \log \tau / \partial \log r} \frac{r}{X}. \quad (3)$$

Later on, we will test whether this WTP elasticity exceeds one.

2.2. Empirical approach

2.2.1. Estimation methodology

Our estimation methodology aims to identify the willingness to pay for public rental housing as defined by (2) by estimating queuing time models, where queuing time depends on the rent as well as the market value. Similar to recent developments in the hedonic approach literature (e.g., Bajari and Benkard, 2005), we will *not* make any restrictive assumption about housing supply. Because the rent r is controlled, the market is cleared based on queuing time. This implies that queuing time τ for a public house depends on X and r .

For estimation purposes, we will assume that $\log \tau$ is a linear function of $v(X, r)$. Furthermore, $v(X, r)$ is assumed to be linear in $\log X$ and $\log r$. Given these assumptions, $\log \tau$ will be a linear function of $\log X$ and $\log r$. We will focus on this log-linear specification, but we will also consider other functional forms (e.g. translog). We will consider a range of log-linear specifications, but in all specifications, we will control for year and month dummies D in order to capture any time trends in market value and in rent. Hence, we will assume the following log-linear specification:

$$\log \tau = \alpha + \beta \log X + \gamma \log r + \varphi D + \varepsilon, \quad (4)$$

where α , β , γ and φ are coefficients to be estimated and ε is random error. Given β and γ , we know $\partial \log \tau / \partial \log X$ and $\partial \log \tau / \partial \log r$. This allows us to calculate MWP_X using (2) as well as to calculate ϵ_x using (3). Hence,

$$MWP_X = -\frac{\beta}{\gamma} \frac{r}{X}; \quad \epsilon_x = -\frac{\beta}{\gamma}. \quad (5)$$

The estimate of MWP_X can be interpreted as the structural estimate of the utility function and, for example, invariant with the distribution of housing supply, as we have assumed homogeneous households. The standard error of the estimate of MWP_X and ϵ_x can be calculated using the delta method.

We emphasize that (4) will be estimated for households who are *heterogeneous*. Given heterogeneity of households, households

will sort themselves based on their preferences for types of housing as well as differences in marginal utility of income. The estimated coefficients in (4) must then be interpreted as the average of individual-specific coefficients. Unfortunately, Eq. (5) does not provide the average of the marginal willingness to pay (because the average of the ratio of two variables is not equal to the ratio of the averages of those two variables). To deal with this issue, we will assume that the marginal utility of income is the same for all households, implying that γ is constant for all households, whereas β may still differ between households. Given this assumption, which may not be unreasonable because differences in household income are relatively small compared to differences in household income for the whole population, by estimating (4), we get estimates of γ and the average of β . In this case, one may interpret the estimate of MWP_x based on (5) as a reduced form estimate of the average marginal willingness to pay.

2.2.2. Instrumental variable approach (IV)

One may estimate (4) using OLS. However, the OLS estimator of the rent may be biased, because it does not allow for the possibility that the public housing supplier sets the levels of the rent conditional on the observed queueing time. We have then reversed causality and the rent will be endogenous. Given rent control, it is at least theoretically conceivable that housing suppliers reduce the rent levels for public housing buildings at less attractive locations or for buildings with an ugly view. At the same time, households are less willing to wait longer for apartments at less attractive locations or with an ugly view. The consequence is then that the OLS estimates of rent are biased towards zero and the marginal willingness to pay for public housing estimated with OLS might be an overestimate.¹⁰

More fundamentally however OLS assumes away the presence of unobserved variables that are correlated to the rent and which are not captured by the market value, consequently the rent is endogenous.¹¹ This may occur, for example, when households in the public housing sector, who are predominantly poor, differ in their preferences of attractiveness of housing compared to the households in the owner-occupied sector, or are relatively rich, which determine the market value. When public housing households differ in their preferences from house owners (the market value does not capture public housing household preferences, e.g. about social capital, Rosenthal, 2008), then the estimates will be biased. For example, public house households may prefer neighborhoods that are considered less attractive (by homeowners) or may be less concerned about ugly views. One way to address this issue is to include more control variables (e.g., spatial fixed effects). Although this has certainly advantages in terms of getting more consistent estimates, there will be reductions in the efficiency of the estimator resulting in larger standard errors. Therefore, we will discuss estimates with and without additional spatial fixed effects.

To address both endogeneity issues we will apply a standard instrumental variables approach (2SLS) making use of the institutional setting which determines the setting of the rent. We note that the maximum legal rent is determined using a (national) administrative measure of housing characteristics using points where each characteristic of the house has a certain point value. This measure is based mainly on the size of the public house (in square meters), but includes also many details such as whether the kitchen is luxurious.¹² Public housing associations cannot influence

this administrative point measure (which is set by an independent commission) and this measure is set independently of the waiting list length.

We will use the administrative measure as an instrument of rent. This instrument will be shown to be a strong instrument. Because the administrative measure is set independently of the waiting list length, it is a valid instrument to deal with reversed causality. Importantly, a wide range of unobserved characteristics (e.g., neighborhood characteristics, ugly view etc.) which may determine both the rent as well as the queueing time are not included in the administrative measure. Hence, by instrumenting the rent with the administrative measure, we have relaxed the underlying OLS assumption that all unobserved housing characteristics that influence the waiting time and that are related to the rent are fully captured by the market value. Given the exclusion restriction that, conditional on market value, there is no direct effect of housing characteristics included in the administrative measure (house size, luxurious kitchen etc.) on waiting time, the administrative measure is a valid instrument of rent.

The above exclusion restriction can be criticized because it is conceivable that some of the characteristics included in the administrative measure have a direct effect on waiting time. In particular, it is conceivable that house size has a direct effect, because house size is not only the most important determinant of the measure (see Appendix B), but also is an important characteristic of housing in general. To deal with this criticism, in a sensitivity analysis, we will also control for house size. Hence, the exclusion restriction is then that, controlling for market value, the housing characteristics in the measure, except for the size of the house, have no direct effect on waiting time. We believe this is a much less restrictive exclusion assumption.

2.3. Willingness to pay for housing characteristics

We have assumed above that $v = v(X, r)$ and focused on the case where X refers to the market value. Although this is not the focus of the current paper, it is important to point out that we can also estimate the marginal willingness to pay for different types of housing characteristics. Let us suppose now that preferences of households in the public sector depend on house size, J , and on $\hat{X}$ which captures the effect of net market value, i.e. the market value controlling for the effect of house size J and dummies D . Consequently, $v = v(\hat{X}, r, J, D)$.¹³

The variable $\hat{X}$ is not directly observable, but can be estimated because X can be written as a function of J , D , and a residual term $\hat{X}$. Hence, we will follow a two-step approach. First, we will estimate the following standard hedonic price function:

$$\log X = \Delta + \Pi J + \Omega D + \log \hat{X}, \quad (6)$$

where $\log \hat{X}$ defines the residual term, and where Greek letters are coefficients to be estimated. Second, given the residual of this hedonic price function, we will estimate:

$$\log \tau = \alpha + \beta \log \hat{X} + \gamma \log r + \theta J + \varphi D + \varepsilon. \quad (7)$$

The household marginal willingness to pay MWP_J and the elasticity of the willingness to pay for house size ϵ_J is then defined by:

$$MWP_J = -\frac{\theta}{\gamma} \frac{r}{J}; \quad \epsilon_J = -\frac{\theta}{\gamma}. \quad (8)$$

¹⁰ In our data, the rent to maximum rent is on average 0.85, hence this source of endogeneity is likely less of an issue.

¹¹ As pointed out by a referee, the R^2 in the OLS estimates is rather low, making it plausible that some unobserved variables are not captured by market value.

¹² For example, for each square meter, the administrative measure increases by one point. For a luxurious kitchen, this measure increases by two points. Location

characteristics did not determine this administrative measure of housing services during the period of observation.

¹³ It is important to control for $\hat{X}$ (and not for X), otherwise one obtains the marginal willingness to pay for J in addition to the marginal benefit of J captured through its effect on market value (because J will usually also affect the market value).

3. Welfare: optimal supply and (in)efficient matching

In an equilibrium with market allocation based on competitive prices and where housing is efficiently supplied, it is well known that households choose welfare-optimal housing. The market equilibrium is then the optimal equilibrium as described in textbooks (e.g., [Snyder and Nicholson, 2012](#)). In a setting where governments interfere by introducing public housing, this result only holds under specific conditions. We will focus on the (partial) equilibrium where income levels of households are given.

Let us first assume that households are homogeneous and hence the supplied private housing will be homogeneous. Public housing will be offered below the marginal cost of supply. The implied subsidy may create a welfare distortion through a substitution and an income effect. The income effect will be absent when households have a quasi-linear utility function (housing demand does not depend on income); the substitution effect will be absent when public houses are identical in terms of housing characteristics to private houses, and public and private housing are perfect substitutes ([Snyder and Nicholson, 2012](#), chapter 5). Given these conditions, the household's marginal willingness to pay for a unit of public housing is equal to its costs. The subsidy induced by public housing is then not distortionary from a welfare perspective.

In the context of housing demand, a quasi-linear utility function may not be appropriate (housing demand is positively related to household income, as we will make explicit in [Section 5.5](#), and housing expenditure as a share of income is substantial), hence the uncompensated and compensated price elasticities for housing demand may differ substantially). A public housing policy that substantially reduces housing expenditure of poor households may then increase their housing demand. The inefficiency caused by the subsidy will be ignored here. One justification is that in most countries, one of the goals of the public housing policy is to increase housing expenditure of poor households (rather than subsidizing their incomes, which is the standard textbook first-best policy if one aims to help the poor).

Homogeneity of households seems a restrictive assumption, but this can be easily relaxed. Let us suppose now there are M types of homogeneous households that differ in their demand for housing (e.g., some have children others have not). Then the private market will supply M types of housing. Households will optimally choose from M different types of private housing, and will sort themselves into the types of public housing which offer them the highest utility. In the optimal equilibrium, each type of household must be allocated to a public house of the same corresponding type. In this case, for each type of household, the marginal willingness to pay for a unit of housing must be equal to its marginal costs.

In the optimum, the public housing supplier must supply M different types of housing such that for each house the marginal benefits are equal to marginal cost ([Snyder and Nicholson, 2012](#), chapter 12). To empirically examine the optimal supply condition at the household level is not an easy task. We will focus therefore on the aggregate. The optimal supply condition requires that the *total* marginal willingness to pay (the sum of all individuals' marginal willingness to pay for housing) is equal to the *total* marginal supply costs (the sum of the marginal costs for all houses). We will now assume that there are constant returns to scale in production of (private and public) housing, which is a common assumption in the theoretical literature, and in line with the empirical literature ([Epple et al., 2010](#)), which implies that the marginal cost are constant. Given this assumption, the optimal supply condition at the aggregate level implies that the average of the households' marginal willingness to pay for public housing is equal to the marginal cost, where the average is taken over all types of households. We will focus on this condition empirically.

Given optimal public housing supply and heterogeneous households, there may still be substantial welfare losses when a non-market allocation mechanism is used, because each household of a certain type is usually not efficiently matched to the corresponding type of public housing (i.e., matches that would occur if the marginal rent were equal to the marginal cost). Consequently, even given optimal supply and the use of waiting lists, the market equilibrium will *not* be efficient due to inefficient matching ([Glaeser and Luttmer, 2003](#)). We will also discuss a simple method which indicates inefficient matching in our data.

4. Data and descriptives

4.1. Institutional context

In the Netherlands, about 80% of the rental market (about 40% of the whole stock) is public housing, which is supplied by local housing associations.¹⁴ Housing associations are not-for-profit organizations which aim to provide homes for those in housing need, to maintain and manage property properly, to keep rents at affordable levels, and to invest in communities and neighborhoods. Public housing is offered at rents below market rents ([Conijn, 2011](#)) implying that (implicit) subsidies to Dutch public housing providers are substantial: in the 1990s, public housing associations have received the stock of housing for free from the national government.

The rent is set by the public housing supplier following rules on maximum rents as set by the Department of Housing. Maximum rents are regulated at the national level using a very detailed quality measure of structural property characteristics (e.g., it includes the length of the kitchen sink), see [Appendix B, Table B1](#). The rules stipulate that the public housing association applies a formula which determines the quality of the rental unit, and therefore the maximum rent. The formula, which is publicly available, is the same for the whole country during our period of observation and does not differ between neighborhoods.¹⁵ Housing associations frequently set the rent somewhat below the maximum rent usually on the grounds that the household is poor (in our data, the average discount is about 14%, on average). The maximum rent is annually adjusted and maximally around €650 in the period under investigation.

Households have the right to apply for public housing providing their annual income does not exceed a threshold. In the Amsterdam Metropolitan area, during the period of observation, the maximum income level restriction was frequently not enforced by public housing authorities and many households with incomes up to €40,000 got access.¹⁶ For those who live outside the city, additional restrictions apply (e.g. they have to work in the city). For some forms of public housing, other eligibility criteria apply (e.g. age, student status). Eligible households may choose from a large set of houses that are different in many characteristics including the level of the controlled rent.

¹⁴ Also in Austria, Denmark and England is public housing the dominant rental market form ([Scanlon and Whitehead, 2007](#)). In Hong Kong, nearly half of the inhabitants occupy public housing. The provision of public housing is one of the key components of China's Twelfth Five-year Plan.

¹⁵ Renters can calculate the quality of their property using the website www.huurcommissie.nl. For 2010, the monthly maximum rent per quality credit is €4.43 (up to 80 credits) and €4.85 (above 80 credits). For a housing unit of 100 credits, the maximum rent is €451.40 per month. When households disagree about the maximum rent level, they may request an independent rent-arbitrage commission ("Huurcommissie.nl") for a rent reduction within 6 months after signing the rental contract.

¹⁶ The maximum annual household income in our sample is €61,000.

Public housing is the dominant form of supply in this area: about 77% of rental supply refers to public housing owned by a non-profit organization (Amsterdam Statistics, 2012). In Amsterdam, poor households, which are overrepresented relative to other cities, who do not have access to public housing typically choose private renting rather than opting for owning a house.

Queuing starts after registering which is only possible for those who live (or work) in the metropolitan area and who are at least 18 years old. Many parents who live in Amsterdam register their children when they become 18 years old (and still live at home). Registration for public housing is therefore akin to acquiring an option that these young adults may or may not exercise (when registering, for example, they do not know their future income and whether they want to live in Amsterdam in the future). Pre-emptive registering is a sensible strategy, because the monetary costs of staying in the queue are essentially zero (€15 per year).

When a public housing unit becomes vacant, it is offered to the household with the longest queuing time on the list (if rejected, the house is offered to the next household).¹⁷ Upon signing the rental contract, the household is checked for eligibility (based on its current household income). Within the Amsterdam Metropolitan area we distinguish between three cities (including surrounding villages): Amsterdam, Almere and Haarlem. The latter two cities are located approximately 20 km from Amsterdam.¹⁸

Households queuing for public housing need to register in each city separately. Cities differ in their eligibility criteria. To queue in Amsterdam, households must either work or live in Amsterdam or Almere. For Almere, there are no restrictions during the period investigated. It is therefore reasonable to argue that the public housing markets for Amsterdam and Almere are fully integrated in terms of housing and employment opportunities. For Haarlem, households must either work or live in this city. Because of its vicinity to Amsterdam, a good highway connection, specially designed bus lanes and trains, many inhabitants of Haarlem commute to Amsterdam, its public housing market can be considered to be fully-integrated into the rest of the Amsterdam Metropolitan area in terms of employment opportunities.

4.2. The data

Our data are roughly a 10% random sample of all new rental contracts obtained from one of the largest public housing association of Amsterdam Metropolitan area for 2008–2010. It includes detailed information on all new matches between public houses and households during this period. For each house, we have information about the rent level, the maximum rent that the supplier may ask, and the property-tax appraisal value that is used for tax purposes. The latter value is based on three similar private housing properties recently sold in the same neighbourhood (chosen by the local authority) which may be affected by the extent of rent control in the neighbourhood (Fallis and Smith, 1984; Hubert, 1993). We will refer to the latter value as the *market value*, i.e. the value of the property when sold in the private market.

Our measure of market value is an appropriate measure of housing consumption as well as capital costs for society for pub-

lic housing except when its presence strongly reduces the market value of nearby properties. Häckner and Nyberg (2000) show that the size of this reduction is extremely limited. Furthermore, in our data, we have information about structural *housing characteristics* such as type (e.g., multi-family building), size and, whether an elevator or a garden is available. We have information on the *household* in terms of size and annual income at the time of signing the rental contract.

We will analyze the (completed) queuing time for households who start to use public housing for the first time (including those who have just left their parents' house and formed a new household) as for this group queueing time is observed.¹⁹ We exclude student units and housing for the elderly, which are allocated based on different rules than just waiting time. We also exclude observations for households with an urgency label (for health or safety reasons associated with abuse and for urban renewal projects).

Given these selections, we have 1993 rental contracts for the period 2008–2010. For the analyses presented, we exclude those observations for which we do not have full information on queuing time, rent or market value.²⁰ To avoid outliers, for the queuing time, the market value of the rental unit, and the rent-to-market-value ratio, we exclude the lower and upper 0.5% of the distribution and, the upper 1% of the income distribution (including these outliers provides almost identical results). Further, we exclude a couple of observations with reported rents above €650, which exceeds the maximum rent that suppliers are allowed to ask. This sample, which will call the *full sample*, leaves us with 1763 observations (43% Almere; 29% Haarlem; 28% Amsterdam). There is a large variation in queuing time ranging from 2 months to 45 years. Based on administrative criteria, our data cover 13 districts (3 for Almere, 3 for Haarlem and 7 for Amsterdam), 130 neighbourhoods and 873 postcode areas (digit six).²¹

Finally, in order to apply our estimation strategy, we will make another data selection. In many European countries, including UK and the Netherlands, poor households, including a substantial share of households that live in public housing, receive a housing subsidy from governments as a supplementary income, see Koning and Ridder (1997). In the Netherlands, the level of the subsidy is household-specific, because it does not only depend on the level of the rent but also on household income (Rijksoverheid, 2010). Consequently, the level of the subsidy cannot be included in the analysis as an exogenous housing characteristic, but excluding this information generates substantial measurement error in the housing expenditure of the household. Another, but less fundamental, issue is that these housing subsidies are not observed in our data, although they can be approximated with imputed subsidies (as we know household income).²² To avoid these issues, when applying our estimation strategy, we will mainly focus on a subsample of households that are *not* eligible for housing subsidies, because their household income exceeds a certain threshold.

4.3. Descriptive statistics

The main descriptive statistics are given in Table 1. The mean queuing time is 6.0 years, with a standard deviation of 3.1, slightly

¹⁷ Eligible households receive a list of vacant units and may apply electronically. On average, about hundred households apply, consequently the market is thick.

¹⁸ Housing supply is strongly affected by post-WW II reconstruction policy. Housing shortage in the 1950s led the national government to control almost all rents, introduce a system of housing allocation based on waiting lists, and initiate strictly planned, large-scale construction of subsidized housing. The 1960s shows a shift in planning policy to limit urban sprawl. In the 1980s, Almere, a new *growth city* was established on land gained from the sea (Faludi and Van der Valk, 1994). Many Almere inhabitants commute to Amsterdam. Haarlem is a more traditional European city that limits urban sprawl but at the same time contains new growth areas (Van der Vlist and Rietveld, 2007).

¹⁹ For other households, i.e. those who have lived before in public housing, we do not have a meaningful measure of queueing time.

²⁰ For some observations, we do not have information on the rent or market value at the date of signing but only for the next year. We include these observations. Excluding these observations does not alter the results.

²¹ Postcode areas relate to one side of one street and include on average 12 houses.

²² Furthermore, there is the complication that the subsidy level usually falls over time when the household income increases and therefore the marginal effect of subsidy is less than the marginal effect of a reduction in rent.

Table 1
Descriptive statistics.

	All households		Subsidy-eligible households		Subsidy-noneligible households	
	Mean	St. dev	Mean	St. dev	Mean	St. dev
Queuing time (years)	6.03	3.08	5.95	3.16	6.12	2.97
Market value (€)	154,084	42,109	150,563	42,968	158,593	40,565
Rent (€)	425	101	398	93	460	100
Rent-to-market-value (%)	3.45	0.87	3.33	0.86	3.61	0.85
Housing characteristics						
Apartment	0.80		0.84		0.74	
Building age (years)	38.2	30.6	41.7	31.4	33.8	28.8
Size (m ²)	56.4	15.9	52.9	14.7	61.0	16.1
Rooms	2.93	0.97	2.76	0.91	3.15	1.00
Household characteristics						
Age head (years)	34.3	11.4	35.3	12.0	33.1	10.4
Number of members	1.86	1.13	1.91	1.15	1.80	1.09
Children	0.55		0.61		0.48	
Annual income (€)	22,752	10,821	15,360	5,946	32,198	7,906
Number of observations	1763		989		774	

more than the median which is 5.1 years (4.4 years in Almere, 4.9 years in Haarlem and 8.7 years in Amsterdam).²³ The average monthly rent (net of service fees) is €425. The average market value of the property is about €154,000.²⁴ The average rent-to-market-value ratio is equal to 0.035. The coefficient of variation of this ratio is 0.27, which seems sufficiently low to estimate separate effects for rents and market value. The distributions of the four variables of main interest are given in Fig. 1.²⁵ In Appendix B, Fig. B2, the distribution of the ratio of rent to maximum rent (that is rental unit specific) is provided. Except for a small number of observations, this ratio is always smaller than, or equal to, one.²⁶ The mean (median) is 0.86 (0.85), so the average rental discount is 14%. The rent is exactly equal to the maximum rent for only 5.3% of the observations.

About 80% of public housing in Amsterdam are apartments. On average, a public house has 56 m² (equivalent to about three small rooms) and is built in the beginning of the 1970s (about 38 years ago). Households which occupy these houses have, on average, an annual income of about €23,000, of which 0.55 have children. The average age of the head of the household is about 34 years. About 6% of the households lived previously in one of the two other cities just before moving into public housing indicating that the three cities have one integrated housing market.

We are particularly interested in the effects of the rent and market value on queuing time. Because rent and market value are strongly correlated, it is informative to examine the bivariate relationship between queuing time and the rent-to-market-value ratio. In line with theoretical considerations, Fig. 2 shows a strong negative relationship. Differences in queuing time shown are economically important. For example, when the rent-to-market-value ratio is 0.025, the average queuing time is about 8 years. When

this ratio is about 0.050, average queuing time is slightly more than 4 years. These descriptive statistics suggest that by waiting for another 4 years, a household may save about half the rent (by €200). The lifetime savings are then in the order of €72,000 over a lifetime (assuming a discount rate of 4% and, unrealistically, that the household will never move). Alternatively, and more realistically, the households may not choose a public house with a lower rent, but enjoy a more attractive public house, for example at a more attractive location (with an increased market value of about €80,000).

Table 1 shows also descriptive statistics distinguishing between households that are eligible for housing subsidies and households that are not eligible for these subsidies (because their incomes are too high). Despite the substantial income differences between these two latter groups, the mean market values of the houses occupied by both income groups are almost identical, which is suggestive evidence of inefficient matching and will be discussed later.²⁷

5. Empirical results

5.1. Willingness to pay for public housing

We show here the results for the hedonic queuing time function (4). We regress log of queuing time on log rent as well as log market value. Table 2 presents results for the main IV as well as an OLS specification. In all specifications, robust standard errors are reported. For the IV, the instrument is strong, with a *F*-test of above one hundred (the first-stage results are reported in Appendix C).²⁸ For the IV specification (1), the rent elasticity of queuing time is -0.86 and the market value elasticity of queuing time is 0.99. Hence, this indicates that queuing time is an effective mechanism to allocate different types of public housing. The size of the effect of market value is economically important. For example, when the market value of a property increases by 10%, queuing time increases by about 6–7 months.

Applying (5), for mean values of market value *X* and rent *r*, we find that the households' monthly marginal willingness to pay for the market value (in euros) is equal to €0.00392 (=1.35 × 460/158,593), hence the annual households' willingness

²³ The mean queuing time is comparable to the queuing time in some areas of London.

²⁴ The mean market value is about 70% of mean owner-occupier house price (CBS, 2011), showing that public housing units are in general of lower quality. We have estimated a standard hedonic model of log market value on housing characteristics on property size (in square meters), number of rooms, dwelling type, building period, while controlling for time and neighbourhood fixed-effects. The results of this hedonic model are very similar to those obtained by studies using house ownership data, indicating that the market value data used here can be interpreted as house prices. These results can be received upon request.

²⁵ In Appendix B, Fig. B1, the distribution of our instrumental variable, the quality measure of the public housing unit, is provided.

²⁶ These observations apply to observations with a very low maximum rent such that the rent difference in absolute value might have been too small for renters to make an effort to ask for a rent reduction. An alternative explanation for these observations may be measurement error.

²⁷ The main prediction by Landvoigt et al. (2014), although derived in a different context, seems to hold in our data: the poorest households occupy more expensive housing than in the absence of social housing, whereas the richest households occupy less expensive housing than they otherwise would.

²⁸ The effect of log instrument on log rent is somewhat smaller than one and equal to 0.83.

Fig. 1. Queueing time, rent, market-value and rent-to-market-value ratio.

Fig. 2. Queueing time (in years) and rent-to-market-value ratio.

Table 2
Queuing time.

	(1) IV	(2) OLS
Log market value, β	0.99 (0.09)	0.93 (0.10)
Log rent, γ	−0.86 (0.11)	−0.69 (0.09)
Constant	−5.10 (0.94)	−5.35 (0.99)
R^2		0.17
Number of observations	774	774
WTP elasticity, ϵ_x	1.15 (0.13)	1.35 (0.17)
MWP (annual)	0.040 (0.01)	0.047 (0.01)

Note: dependent variable is log queuing time. Estimates control for year and month dummies. Robust standard errors are reported.

to pay for an investment of one euro in public housing is about €0.047. Hence, households are willing to pay each year €0.047 when the market value of their public house is increased by one Euro.

The value of 0.047 is close to the long-term capitalization rate in the private rental market (the ratio of the net operating income produced by an asset and its capital costs). For example, in the Netherlands, the rent-to-market value ranges between 0.047 and 0.052 (DTZ, 2011). This is one of our main, and maybe surprising, results. It strongly suggests that in the Amsterdam area, the supply of rent-controlled housing using a system of (subsidized) public housing is close to what would be supplied in a private market without rent control. In other words, this suggests that the types of housing currently supplied by public housing sector in the Amsterdam area are not structurally different from what would be supplied in a situation with a market allocation mechanism.

It is interesting to compare this result with the standard textbook result of rent control in a market with private supply. According to the textbook, private suppliers will reduce housing supply creating a welfare loss, although this welfare loss is limited (for an illuminating discussion, see Glaeser and Luttmer, 2003). In the case of Amsterdam it seems that this welfare loss has been fully eliminated by the local public authorities.

The results furthermore indicate that ϵ_x , the elasticity of the willingness to pay is equal to 1.35, hence larger than one (see Table 2). The elasticity ϵ_x is (just) statistically different from 1 at the 5 percentage significance level. In other words, the average MWP most likely exceeds the average rent-to-market-value ratio. This result is consistent with the observation that renters receive a substantial rent discount.

Another way of capturing the consequences of this rent discount is by focusing on the sum of β and γ , which captures how much longer a household is willing to wait given a 1% increase in the market value of a property combined with a 1% increase in the rent. It turns out that this sum is 0.24, implying that the household is willing to wait 0.24% longer.

5.2. Sensitivity analyses

To examine the robustness of our results, we have done an extensive sensitivity analysis to address potential weaknesses of the above analysis. We find that the OLS estimates are very close to the IV estimates, see specification (2). Recall that the instrumental variable approach only deals with unobserved housing characteristics (including neighborhoods characteristics, ugly views from the house) that are *not* included in the administrative measure. Hence, these estimates indicate that endogeneity issues due to the

presence of unobserved variables that are captured by the instrumental variable approach (such as beautiful views from the house) are minor. To examine this issue further, we have applied again our instrumental variable approach to specification (1) but now we also control for size of the house, which is the main determinant of the administrative rent measure (see Appendix B). Again we find essentially the same result indicating that our IV approach not only deals with unobserved housing characteristics that are not included in the administrative rent measure but also that it is not sensitive to the assumption that size of the house has no direct effect on the waiting time. This makes it more likely that other, but less important, housing characteristics included in the administrative measure have a direct effect on the waiting time.²⁹

As discussed above, we have re-estimated the IV specification (1) when controlling for additional spatial fixed effects. First, we have controlled for 13 different districts. We find essentially the same marginal willingness to pay for public housing, 0.038, although it is imprecisely estimated as the standard error is equal to 0.037. This result also holds when we in addition to these controls include building size and age (the MWP is 0.036 with a standard error of 0.035).

We have also estimated the model with OLS while controlling for 13 district dummies. This increases the standard error of the MWP somewhat, however the marginal willingness to pay for public housing is still reasonably precise estimated. The MWP is equal to 0.054 with a standard error of 0.024. We have also estimated the model with OLS while controlling for 130 neighborhood dummies. The marginal willingness to pay for public housing is then 0.045 with a standard error of 0.019. Hence, our OLS estimates remain very robust with respect to spatial fixed effects.

Another issue is that the double log specification may be too restrictive. To address this issue, we have estimated a translog model, which includes the square of the log market value, the square of the log rent as well as the interaction of the log market value and the log rent. We estimate this model with OLS. It appears that the mean MWP is essentially the same. Consequently, it appears that for other specifications (including those not discussed here), the annual MWP for market value is approximately the same as point estimates discussed above.

Further, one may wonder to what extent parameters vary between cities within the Amsterdam area. In particular, one may wonder to what extent the effect of rent is the same within submarkets, because the variation of the estimated ratio of β and γ is mainly through variation in γ , i.e. in the effect of rent. We have estimated separate models for the three cities, but the point estimates are difficult to interpret due to extreme large standard errors. Consequently, we have estimated a model that does not restrict the effect of rent to be identical in the three submarkets with OLS (see Table 3). We observe now that the mean MWP is somewhat higher (and with larger standard errors) but similar across local housing markets (we find the same result when we do not restrict the effect of market value to be identical in the three submarkets).³⁰

²⁹ Fig. 1 suggests that our specification may be sensitive to outliers. In particular, one might worry that there are a relative large number of observations with very long or very short queuing times. One may also argue that extremely long queuing times (e.g., more than 15 years) may not have been optimally chosen by households (because it is difficult to predict the future many years ahead). Hence, we have estimated a Tobit model, where observations with a queuing time of more than 10 years are right-censored. We then find that the mean MWP is essentially the same. In addition we have estimated a Tobit model, where observations with a queuing time of less than 2 years are left-censored. We then find that the mean MWP is essentially identical.

³⁰ As discussed in detail in the previous version of this paper, one may include households that receive housing subsidies in the estimation procedure and where one includes the subsidy level. The results of such an approach however are difficult

Table 3
Queueing time, differences between cities (OLS).

	(2) OLS	
Log market value, β	0.59	(0.11)
Log rent Almere, γ_{Almere}	−0.32	(0.10)
Log rent Amsterdam, $\gamma_{\text{Amsterdam}}$	−0.25	(0.10)
Log rent Haarlem, γ_{Haarlem}	−0.30	(0.10)
Constant	−3.52	(1.06)
R^2	0.20	
Number of observations	774	
WTP elasticity Almere, ϵ_x	1.81	(0.40)
MWP Almere (annual)	0.072	(0.02)
WTP elasticity Amsterdam, ϵ_x	2.31	(0.72)
MWP Amsterdam (annual)	0.060	(0.02)
WTP elasticity Haarlem, ϵ_x	1.97	(0.49)
MWP Haarlem (annual)	0.063	(0.02)

Note: See Table 2.

Table 4
Queueing time and willingness to pay for size and number of rooms (OLS).

	(1) Size (sq. m.)		(2) Number of rooms	
Log size, θ	0.22	(0.03)	0.20	(0.02)
Log rent, γ	−0.35	(0.04)	−0.39	(0.04)
Residual market value, $\log \hat{X}$	0.34	(0.04)	0.31	(0.04)
Constant	3.55	(0.18)	4.53	(0.24)
R^2	0.25		0.25	
Number of observations	774		774	
WTP elasticity, ϵ_x	0.63	(0.06)	0.53	(0.08)
MWP size (annual)	62.13	(6.09)	927	(84.9)

Note: Estimates control for apartment dummy, log of building age, year, month and district fixed effects.

5.3. Willingness to pay for house size

We have argued above that our procedure can also be used to estimate the households' marginal willingness for a specific housing characteristic. We will focus on estimating the marginal willingness to pay for the size of the house. Following the two-step approach explained above, in the first step, we have estimated (6), by regressing log market value on log house size (in square meters) including 13 district dummies, as well as year and month dummies (these results can be received upon request).

We are mainly interested in the estimates of the second step, based on (7), which are shown in the first column of Table 4. The reported standard errors are adjusted to take into account that we apply a two-step procedure. Note that in this analysis, the residual market value captures unobserved factors that are not explicitly controlled for (e.g., a quiet road). We find that the marginal effects of log rent are similar in magnitude as those of Table 3. The size of the effect of residual log market value is 0.34. The effect of log size is highly significant, with a point estimate of 0.22. The implied annual marginal willingness to pay for one square meter is 62 (with a standard error of 6). These results seem plausible.³¹ The implied renters' willingness to pay for size has an elasticity of about 0.63. The point estimate is in line with Dutch house price regressions

for house owners which have values of around 0.7 (Van Ommeren et al., 2011).³²

In the Netherlands, it is common to measure house size by means of square meters. In other countries, it is more common to measure house size by means of number of rooms. For this reason, we have repeated the analysis by including the number of rooms (rather than square meters) as a measure of size. Again the results seem to make sense. The implied annual marginal willingness to pay for one additional room is €927 (with a standard error of €85).

5.4. Inefficient matching

One fundamental question we have not addressed is to what extent households are efficiently matched to different types of housing. Or phrased differently, is it possible that the allocation mechanism induces inefficiency in matching. The most desirable houses in our sample are then not allocated to households with the highest marginal willingness to pay for these houses but rather to households for whom the waiting costs of obtaining public housing later are low. We emphasize that it is reasonable to believe that households *strongly* differ in their costs of waiting for a public house. For example, for a household which expects to stay maximally 3 years in Amsterdam, the costs of waiting for more than 3 years are infinite, whereas for households who expect to stay in Amsterdam for the rest of their life, it is beneficial to wait many years if the gains of receiving a specific public house are large enough (e.g., a large apartment at one of the most expensive locations at the 'Herengracht' canal).

To examine this, we assume that the market value of the public rental property fully captures housing consumption of public housing residents. In addition, we assume that when queueing times are small, e.g. a couple of months, the inefficiency of matching is small, whereas given long queueing times, let us say 10 years, the allocation outcome is far from the efficient market allocation.³³

The idea of our method is then to compare the effects of household characteristics on housing consumption for two different groups of matches. One group with short and another group with long queueing times. For short queueing times, one expects that the effects are closer to those matches of an unregulated market.³⁴ For the group of matches with a long queueing time, which is dominated by households with low waiting time costs, the effects of household characteristics on housing consumption must be very different from matches in an unregulated market, because one expects that households with low queueing time cost are likely to occupy the most attractive social housing units in our sample.

To explore this idea, we first provide a scatterplot of log market value by log income for two equally-sized groups in Fig. 3.³⁵ One group refers to houses with a short queueing time of less than 3.92 years (the lower quartile) and another group refers to houses with a long queueing time of more than 7.7 years (the upper quartile). For the first group, the average queueing time is 2.63 years, whereas for the second group, the average queueing time is 10.2 years. Clearly, these are very distinctive groups of houses.

³² The size elasticity of house price in our data is about 0.55.

³³ Note that in non-regulated house ownership markets, there is no queueing time, but usually the process of buying a property and obtaining a mortgage takes a couple of months; in addition, after signing the contract, it usually takes a couple of months before the new owner can move in. The impact of queueing for less than 6 months in social housing is therefore likely negligible from an economic point of view.

³⁴ Households choose their queueing time, hence some of the observed differences between the household characteristics effects of these groups are due to differences in (unobserved) household characteristics and are therefore pure selection effects.

³⁵ The result shown here is based on the full sample of households including those that are eligible for subsidies. The analysis based on the sample of households that are not eligible are very similar.

to interpret, because the subsidy level depends on household income level (in addition to the rent level) and is therefore not a given housing characteristics. Estimates that include households that receive housing subsidies (and where we interpret the housing subsidy as a house characteristic) provide very similar results. These results can be received upon request.

³¹ To interpret this estimate, note that this estimate is of the same magnitude as the average annual rent per square metre of €76.

Fig. 3. Log market value by log income.

Table 5
Market value for public houses with short and long queuing time.

	(1) OLS Short time		(2) OLS Long time	
Log income	0.13	(0.02)	0.01	(0.02)
Presence of children	0.10	(0.02)	0.01	(0.03)
Age/10	−0.03	(0.01)	−0.01	(0.01)
Almere	−0.38	(0.03)	−0.15	(0.04)
Haarlem	−0.31	(0.04)	0.08	(0.03)
Constant	10.70	(0.17)	12.06	(0.18)
R^2	0.34		0.07	
Number of observations	437		438	

Note: Dependent variable is log market value. (1) Includes houses with queuing time of less than 3.92 years (lower quartile) and (2) includes houses with queuing time exceeding 7.7 years (upper quartile).

Fig. 3 indicates that for the group with short queuing times, higher income households are more likely to be matched to rental properties with a high market value. A positive effect of income is in line with one of the main stylized facts for the relationship between household income and housing consumption. However, for the group with long queuing times, there is no effect of household income on market value. We interpret this as suggestive evidence of inefficient matching.

To explore this idea more thoroughly, we have regressed log market value on household demand indicators that are usually included in housing consumption studies (log household income, presence of children, age of the head of the household and two city dummies). For both queuing time groups, the results are presented in Table 5. They show that for every household variable, the effect on market value is much more pronounced than for the short queuing time group. Moreover, for the short queuing time group, the direction of the effect is in line with the effects usually found in demand studies of unregulated markets. For example, the income elasticity of market value is positive (0.13, with a standard error of 0.02) for the short queuing time group, whereas for the long queuing time group this elasticity is essentially zero (0.01, with a standard error of 0.02). Similarly, for the short queuing time group, households with children increase their housing

consumption by about 10%, whereas there is no difference in housing consumption for households with or without children for the long queuing time group. Notably, the R^2 of the latter regression is only 0.07 for houses with a long queuing time, but 0.34 for houses with a short queuing time.³⁶

In other words, for houses with a long queuing time, it appears that households are matched randomly to public housing, at least as captured by household demand characteristics such as household income and number of children. Interestingly, the assumption of random matching was made by Glaeser and Luttmer (2003) within a theoretical framework to support their argument that misallocation is a key issue of rent control. Random matching may be argued to be an extreme assumption and not in line with the idea that households have to queue. Nevertheless, our results indicate that, even within a queueing system, this assumption seems to hold for households with long queuing times, who are matched to houses seemingly randomly.

6. Conclusion

One of the most important tools for economists is the hedonic pricing method. This method is widely used in housing markets to estimate willingness to pay. One of the more restrictive assumptions of this approach is that the price of the good is freely determined in the market. For the public housing market, rent control combined with nonmarket allocation invalidates this assumption. Consequently, the rent level is not revealing about the household's willingness to pay for public housing. This is a relevant issue because in many cities, rent control is substantial, and queueing time for rental housing is considerable. We focus on the public housing sector in the Amsterdam Metropolitan area, where houses are supplied by non-profit housing associations that use queueing time to allocate houses using a choice-based allocation system.

We introduce a novel methodology to estimate the renters' marginal willingness to pay for public housing when public houses

³⁶ Note that our results of inefficiency refer to misallocation at the moment of a new match. Misallocation is expected to be more common for households that remain for a long time in public housing.

are allocated to eligible households using waiting lists. For the Amsterdam Metropolitan area, we demonstrate that queuing time is highly responsive to the rent and the market value of the public house. When the market value of a public house increases by 10%, queuing time increases by about 6–7 months. The households' marginal willingness to pay for public housing is estimated to be about five percent of market value. This estimate is close to the long-term capitalization rate in the private rental market, which is the cost of society to provide public housing. This is one of our main, and maybe surprising, results. It strongly suggests that in the Amsterdam area, housing supply given rent control and nonmarket allocation is close what a private market without rent control would supply. In other words, this suggests that the types of housing currently supplied by the public housing sector in the Amsterdam area are not structurally different from what would be supplied in a situation with a market allocation. Hence, we find that although the households' average marginal willingness to pay for public housing exceeds the marginal rent, public housing supply is not (extremely) distorted.

It is important to contrast this result with rent control in a market with private supply. Given rent control, private suppliers will reduce quality of their housing supply which creates a welfare loss. In the case of Amsterdam public housing, it seems that this type of welfare loss has been reduced or even eliminated by providing subsidies to public housing associations.

Our study also provides evidence of inefficient matching of households and housing. We demonstrate that matches between households and public houses with very long queuing times are (close to) random, in the sense that houses with very long queuing times are allocated to a group of households for which holds that housing consumption hardly depends on household characteristics, such as income and number of children. Hence, these matches are likely extremely inefficient, which supports the idea that the deadweight loss of public housing is mainly due to inefficient matching of houses to households and less so due to inefficient supply, in line with Glaeser and Luttmer (2003).

Appendix A. Steady-state queueing model for public housing

A.1. Household behavior

Let us suppose a steady-state economy, where each (infinitely small) period a given number of identical households N_0 enter and leave the housing market (for a dynamic allocation problem with overlapping generations, see Kurino, 2014). Households leave the housing market after a fixed (and finite) period T . Households are risk neutral, have perfect information and discount the future at rate ρ . Houses differ in the utility level offered to households (e.g., because of differences in rent level). For each house, the households' utility is defined.

Households that enter the housing market have free access to houses supplied in an unregulated competitive private market that offer an instantaneous utility v_0 (per period). The quality of housing is denoted by h , and provided at a cost $c(h)$. The marginal benefit of private housing, $v'(h)$, is equal to its marginal cost, $c'(h)$.

Households have to queue to obtain public housing, households with a queuing time denoted by τ . The instantaneous utility derived from a public house is denoted by v . There is a continuous distribution of v . To avoid trivial outcomes, we assume that $v > v_0$, so public housing is strictly preferred to private housing. The supply of public houses, and therefore the distribution of v , is given. The number of public houses is denoted as N_1 . The public housing market is not sufficiently large to accommodate all households. Consequently, $N_1 < N_0$, where $N_0 - N_1$ captures the excess demand for public housing. N_v denotes the number of houses that offer instantaneous utility v . Therefore, $N_1 = \int_v N_v dv$.

Households who enter the housing market choose a house type v and a corresponding queuing time, hence we write $v = v(\tau)$. The households' lifetime utility V of a household that enters the housing market can then be written as:

$$V = \int_0^\tau v_0 e^{-\rho t} dt + \int_\tau^T v(\tau) e^{-\rho t} dt, \quad (A1)$$

where excess demand for public houses implies $\tau > 0$. Interpretation of (A1) is straightforward. For a period of length τ , the household will enjoy utility v_0 . After τ , the household enjoys utility $v(\tau)$ for a period of length $T - \tau$. Eq. (A1) can be rewritten as:

$$\rho V = v_0[1 - e^{-\rho\tau}] + v(\tau)[e^{-\rho\tau} - e^{-\rho T}], \quad (A2)$$

where the discounted lifetime utility ρV is the weighted average of v_0 and $v(\tau)$, with weights equal to $1 - e^{-\rho\tau}$ and $e^{-\rho\tau} - e^{-\rho T}$ respectively.

Maximization of lifetime utility V with respect to τ implies the following condition:

$$\partial\tau/\partial v = \frac{1}{\rho[v(\tau) - v_0]} \frac{e^{-\rho\tau} - e^{-\rho T}}{e^{-\rho\tau}} > 0. \quad (A3)$$

This (non-homogeneous) differential equation has a straightforward and intuitive implication: houses that offer a higher utility will have longer queues (more precisely, the equation implies that the marginal increase in τ with respect to v equals the inverse of the (discounted) difference between the utilities of the public house and current house, captured by $v(\tau) - v_0$). The queuing time will be an increasing function of utility v . The differential condition also implies that the length of the queue for each particular type of house is determined by the distribution of houses supplied. Because the distribution of housing is continuous, and the relationship between τ and $v(\tau)$ is monotonic, there is a (unique) continuous distribution of queuing times in equilibrium.

The above model can easily be extended to more realistic settings. For example, the above model does not allow for residential moving within the public-housing sector. Allowing for residential moving within the sector, the general result of a positive relationship between the utility of a house and the length of the queue for that house remains (results can be received upon request).

A.2. Equilibrium

The number of households that are in the queue and will obtain after queuing for $\tau(v)$ time a house that offers utility v is denoted as n_v . Hence, in steady state, the number of households who obtain a house that offer v at a certain moment in time is equal to $n_v/\tau(v)$. Similarly, the number of households that leave a house of utility v at a certain moment in time is $N_v/[T - \tau(v)]$. The steady-state conditions imply that the number of households that leave a queue of length $\tau(v)$ must be equal to the number of households that occupy a house of utility v and that leave the public housing market. In steady state:

$$n_v = \frac{N_v \tau(v)}{T - \tau(v)}. \quad (A4)$$

Eq. (A4) determines a positive relationship between the number of households who queue for a house v and the queuing time, as $\partial n_v / \partial \tau(v) = TN_v / [T - \tau(v)]^2 > 0$. We have now three equations that determine the equilibrium. Eq. (A3) determines the queuing time τ as a function of utility v . Eq. (A4) determines the number of households that are in the queue who will move after $\tau(v)$ time to a house of utility v . Finally, $\int_v n_v = N_0 - N_1$ guarantees that the total number of households in the queue is equal to excess demand for public houses.

Table B1

Calculation scheme: quality measure.

Characteristic	Unit	Quality per unit
Property type		
Apartment	Yes	5
Townhouse	Yes	12
Single family home	Yes	17
Monument	Yes	50
Living area		
Living area	m ²	×1
Kitchen	m ²	×1
Bedroom(s)	m ²	×1
Bathroom	m ²	×1
Other area		
Garage	m ²	×0.75
Washing room	m ²	×0.75
Attic	m ²	×0.75
Energy efficiency		
Bedroom(s) heated		×2.50
Other area heated		×1
Energy label:		
A		40
B		28
C		15
D		11
E		5
F		1
G		0
Kitchen		
Size of sink	m	×1
Microwave		×1.50
Refrigerator		×0.75
Other appliances		×0.50
Bathroom		
Toilet		×3
Sink		×1
Baths		×7
Disabled/service		
Facilities	Yes	+35%
Patio/garden > 3 m ²	Yes	8

Note: See www.huurcommissie.nl. **Fig. B1.** Quality measure.

Fig. B2. Rent-to-maximum rent.

Table C1
IV first stage results.

	OLS	
Log market value	0.20	(0.02)
Log quality measure	0.83	(0.03)
Constant	−0.29	(0.24)
R^2	0.71	
Number of observations	774	

Note: Dependent variable is log rent. Estimates control for year and month dummies.

Appendix B. Quality measure public housing

The quality of public housing is determined on a quality measure Q which depends on the characteristics of the rental unit. The table below shows how the quality measure is determined (Fig. B1 and B2).

Appendix C. Instrumental variables first stage results

See Table C1.

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