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Published in:
Regional Science and Urban Economics

DOI:
[10.1016/j.regsciurbeco.2021.103719](https://doi.org/10.1016/j.regsciurbeco.2021.103719)

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:
2021

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

Citation for published version (APA):

van Duijn, M., & Rouwendal, J. (2021). Sorting based on urban heritage and income: Evidence from the Amsterdam metropolitan area. *Regional Science and Urban Economics*, 90, [103719].
<https://doi.org/10.1016/j.regsciurbeco.2021.103719>

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Sorting based on urban heritage and income: Evidence from the Amsterdam metropolitan area

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ARTICLE INFO

JEL classifications:

R2

J1

Z1

Keywords:

Location choice

Urban heritage

Income

Sorting

Heterogeneous household preferences

Counterfactual simulation

ABSTRACT

We study the relationship between cultural heritage and city structure in a residential sorting model. Contrary to previous research, we find that all income groups attach a large value to the proximity of urban heritage while there are important differences associated with other household characteristics. In line with previous research, we find that all households attach value to the share of high-income households in neighborhoods. Our approach covers both elements and we use the estimated version to investigate the overall impact of cultural heritage on within-city structure. We simulate the housing market equilibrium in a counterfactual situation without spatial differences in the presence of cultural heritage. The results suggest that without highly valued inner city amenities, households' location choice in European cities, such as Amsterdam, would be much more similar to US cities.

1. Introduction

Urban amenities play an important role in the current revival of interest in urban living. While the strength of traditional forces behind the concentration of economic activities that were mainly related to employment has weakened, the importance of consumer amenities has grown (Glaeser et al., 2001). Brueckner et al. (1999) suggest that such amenities is an important driver of the location of high and low-income households in urban areas. In their theory, the demand for these amenities is highly income elastic. The rich will therefore tend to locate in the city center when it is amenity-rich, while they will otherwise prefer the suburbs where land is much cheaper. This paper provides an empirical investigation of this issue.

The relative location of high and low-income households is an important issue in urban economics (see, for instance, Wheaton, 1977). The monocentric model, which is the workhorse of this literature,

suggests that the rich should live in the city center because commuting time is more valuable for them. Since many cities (in the US as well as elsewhere) do not confirm this prediction, other factors must be important. One possibility is the durability of housing which tends to make older housing, which is often overrepresented in the central city, less suitable for high-income households.¹ However, old houses are not necessarily inferior – the canal houses in Amsterdam are a clear example.² In fact older housing is an important part of the cultural heritage, which is an important amenity. Under appropriate conditions, old housing or, more general, the amenities associated with ancient residential areas may in fact contribute to the concentration of high-income households in city centers as we will show in this paper for the Amsterdam metropolitan area.

It is well known that the attractiveness of neighborhoods for specific groups of households is substantially influenced by the presence of particular household groups.³ One finding that is especially relevant for

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¹ See Bond and Coulson (1989) for an example of this 'filtering' literature, and Chen and Rosenthal (2008) and Brueckner and Rosenthal (2009) for recent contributions.

² Lazrak et al. (2014) find in a hedonic analysis on Dutch data that the prices of houses listed as monuments 15–20% higher than those of otherwise comparable houses.

³ The classical references for these sorting effects are Schelling (1971; 1978).

the present paper is that all households prefer to live with high-income households, as was documented for instance by Bayer et al. (2007) for the San Francisco Bay Area. The presence of high income households may attract other amenities like better shops, restaurants and theatres, or may be associated in more investments in neighborhood quality.⁴ Through this route, the exogenous amenities may have a further impact on the attractiveness of neighborhoods that reinforces its primary effect. In this paper we consider both the direct and indirect effect of central urban amenities on residential sorting by income.

We investigate these issues by developing a residential sorting model of the ‘horizontal,’ logit-based type (see Kuminoff et al., 2013). This family of sorting models is closely related to the Berry, Levinsohn, and Pakes (BLP) (1995) model and was first applied to study residential sorting by Bayer and his co-authors.⁵ To relax the restriction that unobserved neighborhood characteristics are valued identically by all households, we follow Timmins (2007) and estimate separate logit models for different income groups. This implies that we relax the standard – but restrictive – assumption that all households value the unobserved neighborhood characteristics in the same way. To address the endogeneity of the housing price and the share of high-income households, we consider a large number of potentially useful instruments that have been suggested in the BLP literature, as well as the instrument for the price suggested by Bayer et al. (2004; 2007) and the instrument for demographic composition suggested in Bayer and Timmins (2007). To select the most appropriate instrument we use the method proposed by Belloni et al. (2012). We find that the ‘Bayer’ instruments perform substantially better than all the other instruments suggested by the literature and provide a discussion of the additional exogenous information – relative to the BLP instruments – they exploit.

We estimate our model for Amsterdam, the largest Dutch city, that is well known for its 17th century canal belt. The metropolitan area extends over a much larger area where neighborhoods are often less expensive and closer to open space. In contrast to the literature, we find that households in all income groups attach a large value to urban heritage in their residential neighborhood, which we measure as the part of it included in a conservation area. The values we find are substantially larger than those reported in Van Duijn and Rouwendal (2013) who consider sorting at the higher geographical level of municipalities. Our results confirm that all households prefer to live in neighborhoods with a high share of high incomes. We use the estimated model to simulate the counterfactual situation in which there are no spatial differences in the presence of cultural heritage. In this alternative equilibrium the location pattern of the high-income households differs substantially from what is currently observed. High income households will concentrate more in suburban neighborhoods, the location pattern of many U.S. metropolitan areas. This suggests that preservation and maintenance of cultural heritage is important to keep old inner cities vibrant centers of activity.

The paper makes a number of significant contributions. First we provide an empirical version of the amenity based theory of intra-city household location choice of Brueckner et al. (1999), focusing on cultural heritage as an important and plausibly exogenous amenity. Second we show how the direct impact of central urban amenities interacts with household preferences for the demographic composition of residential neighborhoods. Although our model estimates deviate from Brueckner and Rosenthal, (2009) idea that central city amenities are mainly preferred by higher-income households, our estimated model is – nevertheless – consistent with their conjecture that the difference between residential sorting patterns in US and European cities is caused by differences in central urban amenities. Finally, we provide a careful analysis of the selection of instruments among the large set of

possibilities proposed for the endogenous variables in BLP models using the method proposed by Belloni et al. (2012).

The existing economic literature on heritage has mainly focused on the impact of designation of monuments and conservation areas on house prices. Examples are Coulson and Leichenko (2001) and Coulson and Lahr (2005).⁶ Recent papers include Van Duijn and Rouwendal (2013)⁷ who study the importance of ancient inner cities for the attractiveness of the larger urban areas surrounding them,⁸ Been et al. (2016) who look at the position of preservation areas in the urban environment in which they are embedded, Ahlfeldt et al. (2017) who propose a model for the designation of preservation areas and Koster and Rouwendal (2017) who consider the impact of restoration subsidies for neighborhoods.⁹

The paper is structured as follows. Section 2 discusses the methodology concerning the residential sorting model, its issues, and the introduction of spatial elements in the model. Section 3 describes the data and discusses some descriptive statistics of household and neighborhood characteristics, which is followed by the estimation results in Section 4. In Section 5 we discuss the implications of the estimation results and Section 6 concludes.

2. The location choice model

2.1. The first stage

Our methodology follows Berry et al. (1995) (BLP) who addressed a number of important issues in discrete choice models of market demand. Their inclusion of an unobserved characteristic of the choice alternatives in the model clarified an endogeneity issue associated with the price variable that had long plagued the estimation of logit models of market demand. BLP showed that, under appropriate assumptions, the unobserved characteristic would be absorbed in an alternative-specific constant representing the average utility attached to each choice alternative in the logit model. These alternative-specific constants represent the average utility attached to each alternative by the household population considered and could be analyzed further in a second estimation step using methods for linear equations.¹⁰

We start by assuming that each consumer i ($i = 1 \dots I$) has preferences over n neighborhoods ($n = 1 \dots N$). These preferences refer to neighborhood characteristics that are not all observed by the researcher. Two observed characteristics that are of special importance are the neighborhood housing price, p_j , and the share of high-income households in the neighborhood population, σ_j . Prices are assumed to equilibrate the local (neighborhood) housing markets. The group of high-income households is special because it evokes a ‘social interaction’ effect in that the choices of these actors affect the choice behavior of the others in a direct way. We denote the other observed characteristics of neighborhood j , that are considered as exogenous, as a vector x_j and unobserved

⁶ See Navrud and Ready (2002), and Noonan (2003) for surveys of the early literature.

⁷ Van Duijn and Rouwendal (2013) analyze the effect of urban heritage on location choice using a *between-city* residential sorting model. In the present paper we present a *within-city* analysis which offers the possibility to investigate the validity of Brueckner et al. (1999)’s theory at the appropriate level.

⁸ There are a number of important differences with the present paper. They apply the model to all municipalities in the Netherlands, whereas we focus on the Amsterdam metropolitan area and use much smaller spatial units. They use survey data whereas the present paper uses administrative data. They do not consider the role of demographic composition, which is arguably less important at the municipal level, whereas this is a main focus of this paper. Moreover, they maintain the assumption that unobserved neighborhood characteristics have the same value for all households.

⁹ Other recent studies include Falck et al. (2018) and Sheppard (2015).

¹⁰ See Berry (1994) and BLP for further discussion. In these papers the price of the choice alternatives does not occur in the first (logit) stage of the estimation procedure.

⁴ This is related to Tiebout (1956) sorting, see Epple et al. (1984), Epple and Platt (1998), and Epple and Sieg (1999) for seminal contributions.

⁵ See Bayer et al. (2004), Bayer and Timmins (2005; 2007), and Bayer and McMillan (2012).

characteristics as a scalar ξ_j . Moreover, we allow for idiosyncratic differences in preferences over alternatives ε_j^i .

Each consumer belongs to a group g ($g = 1 \dots G$) and members of a given group have similar preferences. More specifically, we assume that the coefficients in the utility function referring to the price, the share of high-income households and the unobserved neighborhood characteristics are identical for all members of a given group, while we allow the coefficients for the other neighborhood characteristics to be individual-specific. We thus specify the utility function for household i as:

$$u_j^i = \left[\alpha^{g(i)} \ln p_j + \beta^{g(i)} \sigma_j + \bar{\gamma}^{g(i)} x_j + \xi_j^{g(i)} \right] + \left\{ (\gamma^i - \bar{\gamma}^{g(i)}) x_j + \varepsilon_j^i \right\} \quad (1)$$

In this equation total utility is decomposed into a part that is common for all members of group $g(i)$ to which household i belongs – within the square brackets – and a household-specific deviation from that term – within the curly brackets. The first part includes the price, the share of high-income households, the average valuation of all other characteristics within group $g(i)$ and the unobserved characteristic. The second part includes the individual deviation in the value attached to characteristics x and the idiosyncratic preference.¹¹

We assume that the idiosyncratic preferences are i.i.d. extreme value type I distributed. Utility maximizing behavior then implies that choice probabilities are given by the conditional logit model (McFadden, 1973). When estimating the logit model, we treat the expression in square brackets as an alternative-specific constant, $\delta_j^{g(i)}$. Moreover, the deviation from the average in the valuation of neighborhood characteristics is assumed to be a group-specific linear function of a vector of demeaned household characteristics z^i :

$$\gamma^i - \bar{\gamma}^{g(i)} = z^i \Theta^{g(i)} \quad (2)$$

In this equation Θ is a matrix of coefficients. This specification implies that we allow for individual variation in the value attached to the exogenous area characteristics that is potentially related to all observed household characteristics. We do not allow for within-group variation in sensitivity to the endogenous variables, the housing price and the share of high-income households, and in the unobserved characteristic. With respect to the price and the share of high-income households the reason is that these variables are endogenous and that we can only deal with this issue in the second estimation stage.¹² Imposing these assumptions, we rewrite (1) as:

$$u_j^i = \delta_j^{g(i)} + z^i \Theta^{g(i)} x_j + \varepsilon_j^{g(i)} \quad (3)$$

This is the specification we use in estimating the logit model. This results in estimates of the alternative specific constants $\delta_j^{g(i)}$ and parameters $\Theta^{g(i)}$ of the cross-terms of the demeaned household characteristics and neighborhood characteristics.

When there is only one group ($G = 1$), our specification of the utility function is the conventional one in which δ_j equals the average utility attached to alternative j in the population and ϕ_j^i is the deviation of the deterministic part of the utility from the average. By using $G > 1$ we allow for heterogeneity in the evaluation of endogenous and unobserved characteristics across the groups. This allows us to estimate different

coefficients for the housing price and the share of the special group without evoking the concerns about endogeneity that are associated with introducing these variables in the first stage of the estimation procedure.

We thus estimate G logit models. Because we include a full set of alternative-specific constants for each of these models, the sum of the estimated probabilities $\pi_j^i, i \in g$ – that alternative j will be chosen by consumers in the group – divided by the total number of consumers in the group, B^g , equals the observed share of households in that group choosing alternative j , which we denote as s_j^g :

$$\frac{\sum_{i \in g} \pi_j^i}{B^g} = s_j^g \quad (4)$$

which implies that BLP's contraction mapping technique can be used. It follows also that, for the total population the sum of the estimated probabilities that alternative j will be chosen divided by the total population equals the observed share of the total population that chooses j , s_j :

$$\frac{\sum_i \pi_j^i}{B} = \frac{\sum_g B^g s_j^g}{B} = s_j \quad (5)$$

This can be interpreted as the equilibrium condition for the neighborhood housing market to clear. It is satisfied automatically by the estimated model. Moreover, Equation (5) will be used when computing an instrument for the price in the second stage.

We still need to define the share of high-income households per neighborhood. For concreteness we let $g = 1$ denote the group of high-income households. The shares σ_j are determined as follows:

$$\sigma_j = \frac{\sum_{i \in g(i)=1} \pi_j^i}{B s_j} \quad (6)$$

Note that the denominator in this equation equals the total number of houses (or households) in j .¹³

Finally, it is useful to observe that the subdivision of the population in groups requires the presence of enough observations of actors belonging to each of the groups to be able to estimate the model. At the very least, there should be one observation of each group choosing each neighborhood, but in practice one would like to have more. This is not always an innocuous requirement. For instance, low- and high-income households may be strongly overrepresented in some parts of urban areas and strongly underrepresented in others. Extreme sorting would therefore invalidate the procedure just outlined. However, apart from this requirement, no additional assumptions are necessary to enable this method to work.

2.2. The second stage and BLP instruments

The second stage consists of G linear regressions:

$$\delta_j^g = \alpha^g \ln p_j + \beta^g \sigma_j + \bar{\gamma}^g x_j + \xi_j^g, \quad g = 1 \dots G \quad (7)$$

where δ_j^g denotes the alternative specific constant for neighborhood j that has been estimated in the logit model referring to group g . The unobserved characteristics as evaluated by the various groups are the error terms in these equations. Since they may be correlated with the price and the share of high-income households, these variables have to be instrumented.

Instruments have been difficult to find. The literature has relied on the use of nonlinear functions of the exogenous characteristics of the choice alternatives, following the lead of BLP. These authors argued that the characteristics of other alternatives are excluded (by economic

¹¹ Note that we assume, in line with the literature, that all households in a given group g value the unobserved characteristics identically.

¹² Opinions on the importance of this issue differ. Some researchers allow for individual variation in the parameters α and β even though the variables are endogenous. This issue is more substantial for the price than for the share of higher educated (which is uncorrelated with ξ in the first stage if our model is correctly specified). We estimated both specifications – which produced similar results – and only present the estimation results where we do not interact household characteristics with the endogenous variables. Note that we still allow for arbitrary differences in all coefficients across the groups g .

¹³ Also note that our definition differs from that in Bayer and Timmins (2007) who use the average probability that alternative j will be chosen in the total population.

theory) from the utility of a given alternative and can therefore be used to construct instruments of the price. The econometric context of this issue is the fact that conditional moment restrictions imply the possibility to use arbitrary functions of exogenous variables as instruments. Chamberlain (1987) proposed the choice of instruments that minimize the asymptotic variance and BLP argue that their choices may be interpreted as an approximation to such optimal instruments. Approximations are useful, because exact derivation of the optimal instruments is often hard in practice.

The literature contains a number of different suggestions for functions of characteristics that can be considered as useful approximation to the optimal instruments. For instance, Bayer et al. (2007) noted, in the context of residential sorting, that the utility of living in a particular neighborhood can be affected by amenities in contiguous neighborhoods, which invalidates the exclusion restriction for using such amenities as instruments. They therefore exclude characteristics of choice alternatives that are close (within 3 km), and propose the use of characteristics that are nearby, but not too close as instruments (sometimes referred to as doughnut instruments).¹⁴ The literature in industrial organization following BLP contains several other suggestions for instruments. For instance, Dubé et al. (2011) use powers and cross products of the exogenous characteristics. Reynaert and Verboven (2014) attempt to construct optimal instruments using approximations of their characterization in Chamberlain (1987). The residential (Tiebout) sorting literature provides other suggestions. For instance, Epple and Sieg (1999) argue that the ranking of house prices per neighborhood is correlated with the ranking of an index of the local amenities. Indeed, the list of potential instruments one could construct from the exogenous characteristics of alternatives is infinitely large and in the absence of methods to compute the optimal ones, it remains arbitrary which ones to choose.

Belloni et al. (2012) have recently introduced a methodology for approaching optimal instruments through selection from a large number of potential candidates. Their basic assumption is that the model is approximately sparse, which means that the conditional expectation of the endogenous variable can be well approximated by a small number of candidate instruments. They show that variable selection by a particular variant of the lasso (= least absolute shrinkage and selection operator) is very useful for estimating the first stage of an IV regression. Belloni et al. (2012) furthermore show that the method allows for heteroscedasticity and present a procedure to deal with weak instruments. This method is potentially very useful as it offers the possibility to select the best of a potentially large number of instruments and hence provides an alternative way approaching the optimal instruments. Below, we use this method to select instruments from the large set of candidates that have been proposed in the literature.

2.3. Alternative instruments

2.3.1. The housing price

In this subsection we pay attention to other instruments for the housing price and the share of a high-income households that have been proposed in the literature, but that use additional exogenous information. These instruments were developed in various papers with Bayer as a common co-author (see e.g. Bayer et al., 2004; Bayer et al., 2007; Bayer and Timmins, 2007). Hence we refer to them as Bayer's instruments although other authors were involved in the various papers as well.

In the previous section we already mentioned Bayer et al. (2007)'s 'doughnut' version of the BLP instruments for the price associated with the choice alternatives. They use them for preliminary computations of the model and then switch to "a more powerful instrument by calculating the predicted vector of market clearing prices for a version of the model that sets

the vector of unobserved characteristics ξ to zero" (Bayer et al., 2007, p. 621). To understand how this instrument works, it is important to note that the heterogeneity of the population plays an essential role in its functioning. To see this, we consider the case of a single group ($G = 1$), which is the setting in which Bayer et al. (2007) work. Moreover, for the moment we also ignore the 'social interaction' effect associated with the presence of high-income households. Without heterogeneity the average utility of an alternative would be its actual utility for all actors and in the first stage we would only estimate the alternative-specific constants. Using Equation (7), while suppressing the superscript g , we can write the housing price of alternative j as:

$$\ln p_j = (\delta_j - \gamma x_j - \xi_j) / \alpha \quad (8)$$

The counterfactual price when the vector of unobserved characteristics ξ equals 0 is:

$$\ln p_j^{\text{cf}} (= \ln p_j + \xi_j / \alpha) = (\delta_j - \gamma x_j) / \alpha \quad (9)$$

which would be useless as an instrument, because no exogenous information is added.

What happens if the population is heterogeneous? In Appendix B we derive an equation that is analogous to Equation (8)¹⁵

$$\ln p_j = \left(\overline{EU^i} + \overline{\ln \pi_j^i} - \bar{\gamma} x_j - \xi_j \right) / \alpha \quad (10)$$

The first term in braces is the average of the expected maximum utility of all households in the population. It does not depend on j and hence cannot explain variation in the prices. The last two terms also do not provide new information. However, the second term, which is the average of the logged probabilities that alternative j is chosen does so. To investigate it, observe that since demand for housing has to be equal to supply of housing, we must have $\bar{\pi}_j^i = s_j$, that is, the average of the individual probabilities that j will be chosen in the population must be equal to the share of the housing stock present in j . We can therefore rewrite $\overline{\ln \pi_j^i} = \frac{1}{B} \sum_i \ln \pi_{sj}^i + \ln s_j$. The first term on the right-hand side is (apart from the sign) an entropy measure of inequality (see, for instance, Shorrocks, 1980, p. 622 or Theil, 1967, p. 126–7).

We conclude that the term $\overline{\ln \pi_j^i}$ in (10) uses two types of information that is not employed in BLP instruments: the housing stock in each of the neighborhoods and the distribution of the demographic characteristics in the population. That local housing supply has an impact on demand is obvious; the surprising thing is rather that this is so implicit in logit models of residential sorting. The way equilibrium prices depend on the heterogeneity of the characteristics of the actors, according to (10) is less trivial. The heterogeneity in the choice probabilities indicates variation in the quality of the match between household characteristics and neighborhood characteristics. If opinions about the attractiveness of neighborhoods, relative to others, differ widely among households this has an impact on the equilibrium price. With a different demographic composition of the household population, equilibrium prices would also be different.

The quality of the match between household characteristics and neighborhood characteristics is estimated in the first stage, by the logit model, and the results of that model are now used for inference in the second stage. However, a complicating issue is that the first stage estimation results also include the unobserved neighborhood characteristics ξ_j . The suggestion of Bayer et al. (2004) and Bayer et al. (2007) is therefore to strip these terms from the model and compute the prices that

¹⁴ This refers only to their first 'crude' instrument which they use as a first approximation. Their more refined instrument is discussed in the next subsection.

¹⁵ To verify the analogy, note that with homogeneous actors we have: $\pi_j = \exp(\delta_j) / \sum_k \exp(\delta_k)$, which implies that $\delta_j = \ln \pi_j + \ln \sum_k \exp(\delta_k)$ and note that $\ln \sum_k \exp(\delta_k)$, the 'logsum' gives the expected utility EU of the actors.

will equilibrate demand and supply in that situation.¹⁶ These counterfactual prices are the Bayer instrument for the price:

$$\ln p_j^{cf} = \left(\overline{EU_j^{cf}} + \ln \pi_j^{cf} - \bar{\gamma} x_j \right) / \alpha \quad (11)$$

Note that the right-hand side of this equation includes the average of the logged counterfactual choice probabilities, in which the unobserved neighborhood characteristics are absent.¹⁷

Since the unobserved neighborhood characteristics – that need to be known to remove them from the model – can only be estimated in the second stage, Bayer's instrument has unconventional characteristics. It depends on the estimated parameters of the model, which appear in the expressions for maximum expected utility and in the logged choice probabilities. Since the instrument is needed to estimate these parameters, an iterative procedure must be used.¹⁸ Starting values of the price instrument are used to get first-round estimates of the parameters in Equation (7) and the unobserved neighborhood characteristics. The latter are used to compute the counterfactual prices that act as the price instrument in the second round. And so on until convergence is reached.

2.3.2. The share of high-income households

We also need an instrument for the share of high-income households, σ_j , that causes the social interaction effect. We closely follow Bayer and Timmins (2007) who propose to construct it by using the model with all ξ_j s set equal to zero. We set the prices equal to the values of their instrument when doing these computations.¹⁹ That is, we compute the instrument values as the shares of the high income group implied by the counterfactual situation in which there are no unobserved characteristics, prices are set equal to their instrument values and the social interaction effect is also set equal to zero. That is, the instrument for the share σ_j is the share of high-income households associated with the counterfactual situation to which our price instrument refers. We thus define the instrument for the share of high-income households as:

$$\sigma_j^{cf} = \frac{\sum_{g(i)=1} \pi_j^{i,cf}}{B_{s_j}} \quad (12)$$

where $\pi_j^{i,cf}$ denotes the counterfactual choice probabilities that result from the estimated model stripped of the unobserved neighborhood characteristics and with the instrument values substituted for the prices. This instrument thus uses the same information as Bayer's price instrument, but in a different way. What we do is analogous to using a nonlinear function of one or more exogenous characteristics to find new candidate instruments.

The procedure for computing the two instruments can be refined as follows. Instead of leaving the share of high-income households out when computing the price instrument, one can compute both instruments simultaneously. Starting values again provide first-round estimates of all parameters in (7), now including β , and the unobserved neighborhood characteristics. These are used to compute the computation choice probabilities needed to compute the second-round values of the instruments for the price and the share of high-income household. And so

on, until convergence is reached.

2.4. Spillover effects of area characteristics

Since our neighborhoods are relatively small, it is probable that their attractiveness is determined in part by amenities in other neighborhoods in the vicinity. For instance, having the ancient Amsterdam city center within walking distance may still be experienced as an attractive property of a neighborhood, even though it does not belong itself to that center. We therefore allow for the possibility that some neighborhood characteristics are indicators of amenities in different, but close-by, neighborhoods. More specifically, if amenity k in neighborhood j affects the wellbeing of the inhabitants of surrounding neighborhoods, we define characteristic k' of a such a neighborhood j' as a distance-weighted average of amenity k in other neighborhoods:

$$x_{j,k'} = \sum_{j \in C_j} e^{-\phi_{j',j} d_{j',j}} x_{j,k} \quad (13)$$

where C_j is the set of neighborhoods in the proximity of j' . This 'potential' formulation was also employed by Van Duijn and Rouwendal (2013) who used the much larger municipalities as their spatial unit of analysis. Clearly, $x_{j,k'}$ in Equation (13) can be interpreted as a spatial lag of $x_{j,k}$ with exponential weights.^{20,21}

3. Data and descriptive statistics

3.1. Amsterdam and its surrounding municipalities

The study area focuses on Amsterdam and its surrounding municipalities. The set of residential areas we consider approximate the labor market of the Amsterdam metropolitan area. These residential areas serve as a relevant set of choice alternatives for households in the sorting model. For Amsterdam, which is the most populated municipality in our study area, the spatial unit is the neighborhood.²² Amsterdam consists of 97 neighborhoods. For the other municipalities in our study area we sometimes merge neighborhoods in order to get spatial units with enough observations. In our study area, on average, around 1800 households reside in each neighborhood.²³ Comparing this to the average of the Netherlands, it is clear that our study area focuses on the higher populated (urban) areas. We drop neighborhoods with none or only a few houses. These are mainly agricultural²⁴ and industrial areas, such as Centrale Markt, Westelijk Havengebied and Bedrijventerrein Sloterdijk. This leaves us with 85 neighborhoods. Figure A1 in Appendix A shows a map of the resulting areas.

Estimating the model with administratively determined areas as the choice alternatives implies that the size of a neighborhood – the number of households living there – has a mechanical relationship with the estimated coefficient for its attractiveness for the average household. This could be a concern if neighborhood size is significantly correlated with amenities. Although the differences in geographical size of the areas

¹⁶ See Bernasco et al. (2017) for the use of a similar instrument for criminal activity conditional upon neighborhood choice.

¹⁷ The demographic characteristics of the population enter Equation (11) in a nonlinear way via the choice probabilities. Since the nonlinearity of discrete choice models is known to be a source of identification in itself (Brock and Durlauf, 2001) this may contribute further to the usefulness of Bayer's instrument.

¹⁸ It may also be noted that, since the instrument is a function of estimated parameters, it should in principle be considered as a random variable. However, as far as we are aware methods to adjust the standard errors of the estimated parameters for this characteristic do not exist.

¹⁹ Bayer and Timmins (2007) did not consider endogenous prices.

²⁰ We only use the spatial lag for exogenous neighborhood characteristics.

²¹ The distance decay coefficient, ϕ , is arbitrarily set at 0.2. The function is therefore exponentially decreasing and weights are going towards zero when distance increases (weight < 0.1 if distance is 5 km). The cutoff point is set at 5 km. We tested other – non-extreme – values for distance decay which resulted in negligible changes.

²² In Dutch: *buurt*. This is an administrative unit which does not only refer to residential areas.

²³ The average number for the Netherlands is 630 households per neighborhood.

²⁴ Tight spatial planning in the Netherlands has resulted in the preservation of agricultural areas close to large cities. The 'Green Heart' of the Randstad is the primary example, but also to the north of Amsterdam the polder landscape is protected.

we use are substantial, the differences in the size of the housing stock are much smaller because the largest areas are less densely populated. With respect to cultural heritage, the key variable in this paper, the central city neighborhoods in which it is abundantly present are relatively small, although densely populated, suggesting that a possible bias would result in underestimating its value.

Fig. 1 shows the share of the high-income households per neighborhood in the study area.²⁵ The left panel refers to all households and it suggests that the rich are underrepresented in the city center. Although this may give the impression that Amsterdam is more similar to American cities than one would have expected, the background is entirely different. Housing policy in the Netherlands has for a long time emphasized the construction of social housing, especially in the large cities. Even in the center of Amsterdam, the share of social housing in the total stock is large, and since this sector is only accessible to low-income households, this has a substantial impact on the share of high-income households in our study area.²⁶ It is therefore also of interest to look at the share of high-income households in the owner-occupied sector only. This is shown in panel b) of Fig. 1. The picture is clearly different, and the share of high-income homeowners in some of the central area neighborhoods is higher than the surrounding neighborhoods.

As will be clear from this discussion, the owner-occupied and rental sectors of the Dutch housing market differ much. While the market mechanism determines allocation in the former, rent control and the associated excess demand and queuing are dominant in the latter.²⁷ Since allocation of housing in the rental sector deviates from the market

mechanism, we cannot regard the observed choices in this segment of the market as revealing the household's preferences in the same way as this occurs in a market setting. We have therefore estimated separate sets of coefficients for the owner-occupied and rental sectors and will only report estimation results of the former below.²⁸

3.2. Conservation areas

As indicator of urban heritage we use conservation areas. In the Netherlands, conservation areas²⁹ are designated by the National Agency for Cultural Heritage,³⁰ based on expert judgment. Apart from the city center several other parts of the Amsterdam metropolitan area have been given this status.³¹ A large part of the Amsterdam conservation area includes the world-famous canal belt and it has been listed as World Heritage by UNESCO in 2010. The area has many urban amenities such as shops, restaurants, theatres, and has a cosmopolitan atmosphere which is regarded by many as very attractive. It is also a very popular residential area with high house prices. The ancient canal houses are still highly appreciated for residential purposes and only affordable by the rich.

The boundaries of our neighborhoods do not always coincide with those of the conservation areas. We use the size of the area inside the boundaries of a neighborhood that belongs to a conservation area as an indicator of the amount of urban heritage in that neighborhood. For instance, the conservation area of Amsterdam is large, 679 ha (6.79 km²) or about 3% of the total area,³² and it contains the canals, many gabled houses and numerous other monuments. There are ten neighborhoods

Fig. 1. Distribution of high-income households and high income homeowners in the Amsterdam area. Note: The figures are based on households within the highest income quartile (top 25%).

Source: CBS (2008), own calculations.

²⁵ Defined as the top 25% high-income households.

²⁶ The social rental sector in Amsterdam covers approximately 50% of the housing stock – compared to the average of 35% in the Netherlands. Rents in the social sector are controlled according to a national system that links maximum possible rents to the number of quality points. The system ignores the typically large differences in house prices that are associated with urban location. As a consequence, houses with similar structural characteristics have similar rents everywhere in the Netherlands, which implies that social housing is especially cheap in the large urban areas like Amsterdam. This result in long waiting times for rental housing in urban areas. Only low-income households qualify for this segment of the market. Moreover, mortgage qualification constraints limit access to the owner-occupied segment for these households. This results in severe limitation in the interaction between the rental and owner-occupied segments.

²⁷ The allocation system for public housing is based on choice-based lettings. The private rental sector in the Netherlands is negligibly small.

²⁸ Since we use completely separate sets of coefficients for rental and owner-occupied alternatives, this is equivalent to estimating the model only for owner-occupying households (see McPherson et al., 2001). The same procedure was used in Van Duijn and Rouwendal (2013).

²⁹ In Dutch: *Beschermde stadsgesichten*.

³⁰ In Dutch: *Rijksdienst voor het Cultureel Erfgoed*. It is part of the Ministry of Education, Culture and Science.

³¹ The US equivalents of these conservation areas are the historic areas listed on the National Register of Historic Places under the authority of the National Park Service. The UK equivalents of listed buildings – determined at the national level – and conservation areas – designated by lower tier authorities – are listed by the Secretary of State for Culture, Media and Sport and based on the Planning Act 1990.

³² The average size of conservation areas in the Netherlands is around 75 ha (0.75 km²).

that cover a part of it. The one with the largest part of the Amsterdam conservation area is *Nieuwmarkt en Lastage* (1.03 km²).

3.3. Household data and other neighborhood characteristics

Administrative data on households was provided by Statistics Netherlands (CBS). The information refers to 2008 and contains approximately 600,000 households spread over the study area. We select households with at least one employed member and divide this population into three groups of equal size on the basis of income: high, middle and low income.³³ For computational reasons, we take a random sample of these remaining 329,701 households based on the number of observations per choice alternative. For each choice alternative which contains 100 or more of each income group we take a random sample. This leaves us with a dataset in which we observe a minimum of 30 households from each income group per choice alternative. In total this sample contains 86,663 households, which is 26% of the population of households in which at least one member is employed.³⁴

Table 1 shows an overview of the household and neighborhood characteristics. Household characteristics include income,³⁵ housing tenure, composition – whether the individuals within the household are a couple and whether the household has children under the age of 18 – age of head of the household and neighborhood of residence. An important limitation of the CBS data is that they do not contain information about education levels. This is well known to be an important variable as it appears that especially young higher educated people appreciate urban heritage and the associated urban amenities. Although income and education are in general strongly correlated, this is less true for the younger households. Neighborhood characteristics include, apart from the conservation area, the price of a standard house, the share of high-income households in the population of the neighborhood, distance to the nearest concentration of 100,000 jobs, distance to the nearest intercity train station, total size of nature and water of each alternative, and the average age of the housing stock. The price of a standard house is a hedonic price index based on transaction data from the Dutch Association of Real Estate Agents (NVM). We construct the index on the basis of a straightforward log-linear hedonic price regression that includes many housing characteristics and neighborhood dummies. This index reflects the price level of an owner-occupied house controlling for housing quality.³⁶ It thus enables one to compare house prices between neighborhoods with different housing stocks. The average of house prices in Amsterdam is around €230,000 and we have chosen this value to scale our price index to the price of what we refer to as a standard house.

Although our data are rich in several important respects, they are also necessarily incomplete. There are many more urban amenities than we capture in our model. The focus here is on the role of cultural heritage, which is arguable the main consumer amenity of Amsterdam. We assume that other omitted exogenous amenities are not substantially correlated with it. We do not include plausibly endogenous consumer amenities like

³³ We only have reliable information on gross primary household income for households with at least one employed or self-employed member.

³⁴ This means that we have a choice-based sample. We use weighted maximum likelihood to deal with this characteristic (see Manski and Lerman, 1977). To be more specific, when we take a sample of the whole population in a specific neighborhood, we need to attach weights to each of the randomly selected observations. This makes sure that the equilibrium condition, Equation (5), can still be satisfied and that the sample is representative of the whole population. We used this sampling technique multiple times to make sure that our results are robust.

³⁵ Statistics Netherlands provides information on gross primary household income.

³⁶ The price of a standard house should be interpreted as the unit price of the commodity housing in the indirect utility function of the household. The household chooses the number of units, conditional on the choice for a neighborhood, and the housing price prevailing there.

Table 1

Descriptive statistics household and choice alternative characteristics.

Variables	Data source	Mean	SD	Min.	Max.
Household characteristics (N = 329,701)					
Gross primary household income (in €)	CBS (2008)	66,454	57,889	–	–
Couples	CBS (2008)	0.53	0.50		
Household with children (<18)	CBS (2008)	0.32	0.47		
Age of head of the household	CBS (2008)	42	11	–	–
Choice alternative characteristics (J = 85)					
Conservation areas (km ²)	RCE (2012)	0.0991	0.2428	0	1.029
Percentage high-income households (%)	CBS (2008)	32.56	12.35	–	–
Price of standard house (in €)	NVM (2009)	231,042	56,273	144,981	372,550
Distance to the nearest concentration of 100,000 jobs (km)	PBL (2005)	5.93	3.06	0.82	14.78
Distance to the nearest IC train station (km)	PBL (2005)	3.39	2.68	0.60	13.02
Nature (km ²)	CBS (2008)	0.94	1.36	0	7.63
Water (km ²)	CBS (2008)	0.68	1.02	0	4.65
Age of the housing stock	BAG (2010)	62	32	5	175

Note: Some values are hidden (–) because of confidentiality. See Figure A1 of Appendix A for a complete picture of the 85 choice alternatives. Distance to the nearest concentration of 100,000 jobs (km) is a proxy of potential labour market opportunities – created using GIS techniques – which may be an important driver for location choice (as we do not observe individual's job location in our data).

school quality, shops, cafés and restaurants. As explained above, they are probably an important channel through which the ‘social interaction’ effect associated with the share of high income households realizes, but we make no attempt to model this mechanism in the present paper.

4. Estimation results

This section reports and discusses the results of the two estimation steps of the sorting model for neighborhoods in the Amsterdam area.

4.1. First step estimation results

Table 2 reports the estimated coefficients, the matrix $\Theta^{g(i)}$ of Equation (3), for the three income groups. Since the household characteristics are demeaned, these coefficients can be interpreted as referring to deviations from the mean utility of the group. The table shows a relatively large number of significant coefficients, indicating that there is non-negligible heterogeneity in tastes within the three income groups. For instance, results show that high income couples have a lower preference to live within conservation areas than the average high-income household. Older high-income households seem to have a higher preference to live within conservation areas than the average high-income household. For high-income households with children the effect is negative but not significantly different from zero. Note that the significant effect of couples on conservation areas disappears for the middle and low-income households. This implies that especially high income singles have a positive preference to live within conservation areas that is significantly higher than that of the average high-income household.

Table 2

First step results for homeowners: Deviations from mean indirect utility.

Neighborhood characteristics	Household characteristics					
	High-income households					
	Couple		With children (<18)		Age (in years)	
Conservation areas (km2)	-0.404***	0.090	-0.145	0.091	0.057***	0.004
Conservation areas in surrounding neighborhoods	-0.117***	0.033	-0.060**	0.026	-0.010***	0.001
Distance to the nearest concentration of 100,000 jobs (km)	0.007	0.013	0.075***	0.010	0.005***	4.95E-04
Distance to the nearest intercity station (km)	0.092***	0.017	-0.033***	0.012	-0.002***	0.001
Nature (km2)	-0.023	0.022	0.066***	0.016	0.005***	0.001
Nature in surrounding neighborhoods	-0.062***	0.017	-0.032**	0.014	-0.001*	0.001
Water (km2)	0.125***	0.032	-0.015	0.022	0.004***	0.001
Water in surrounding neighborhoods	0.035*	0.021	-0.001	0.016	0.003***	0.001
Age of the neighborhood (in years)	-0.002**	0.001	0.001	0.001	1.43E-04***	4.16E-05
Log-likelihood	-133,928					
	Middle income households					
	Couple		With children (<18)		Age (in years)	
Conservation areas (km2)	-0.049	0.118	-0.167	0.142	0.055***	0.005
Conservation areas in surrounding neighborhoods	-0.140***	0.035	-0.146***	0.037	8.15E-05	0.001
Distance to the nearest concentration of 100,000 jobs (km)	-0.007	0.013	0.023*	0.014	0.003***	0.001
Distance to the nearest intercity station (km)	0.089***	0.016	0.030*	0.016	0.001	0.001
Nature (km2)	0.000	0.023	0.024	0.024	0.006***	0.001
Nature in surrounding neighborhoods	-0.064***	0.019	-0.040*	0.021	0.003***	0.001
Water (km2)	0.096***	0.031	0.000	0.031	0.004***	0.001
Water in surrounding neighborhoods	0.027	0.020	0.068***	0.021	-0.003***	0.001
Age of the neighborhood (in years)	0.002	0.001	-0.003**	0.001	-1.78E-05	5.04E-05
Log-likelihood	-137,213					
	Low-income households					
	Couple		With children (<18)		Age (in years)	
Conservation areas (km2)	-0.069	0.145	-0.271	0.169	0.050***	0.005
Conservation areas in surrounding neighborhoods	-0.134***	0.046	-0.019	0.050	3.37E-04	0.002
Distance to the nearest concentration of 100,000 jobs (km)	0.007	0.018	0.025	0.019	0.001*	0.001
Distance to the nearest intercity station (km)	-0.006	0.022	0.030	0.023	0.003***	0.001
Nature (km2)	-0.019	0.029	0.025	0.032	0.004***	0.001
Nature in surrounding neighborhoods	-0.077***	0.026	0.006	0.029	0.003***	0.001
Water (km2)	0.069*	0.041	0.059	0.044	0.006***	0.002
Water in surrounding neighborhoods	-0.006	0.028	0.004	0.031	-0.003**	0.001
Age of the neighborhood (in years)	0.002	0.002	-0.005***	0.002	1.68E-04***	6.02E-05
Log-likelihood	-135,997					

Note: Parameter estimates are used to calculate the deviations from the mean indirect utility with all variables normalized to have mean zero. Significance at 90%, 95% and 99% level are, respectively, indicated as *, **, and ***. The first step results for renters can be found in [Table D1](#) of [Appendix D](#). The regression results based on other specifications can be obtained from the author.

4.2. Second step estimation results

The second step of the residential sorting model consists of three 2SLS estimations based on Equation (7). The dependent variable is the vector of mean indirect utilities for each income group δ_j^g . There are two endogenous variables: the logged price and the share of high-income households. We used the procedure suggested in [Belloni et al. \(2012\)](#) to find the best among the following sets of instruments:

- The squares and cross products of the exogenous characteristics
- The cubes and third-order cross products of the exogenous characteristics
- BLP-like instruments, including the 'doughnut' versions
- Rankings of the characteristics
- Bayer's instruments as discussed in 2.3

These instruments and the results of LASSO are further discussed in [Appendix C](#).³⁷ We initially limited the set of instruments first to these groups to see how the various suggestions for candidate instruments that have been made in the literature work out for our data. We also provide results for the complete set of candidate instruments. Since we have two endogenous variables, the price and the share of high-income

households, we carried out two instrument selection procedures. In general this resulted in the choice of different instruments. In the second stage we used the union of the sets of the selected instruments for the two variables as instruments.

[Table 3](#) reports the results of the second stage for the three groups of households. We test for weak instruments by using a Wald F statistic based on the Kleibergen-Paap rk statistic ([Kleibergen and Paap, 2006](#)). The results tell a clear story: despite selection of the best instruments from the various groups as suggested by [Belloni et al. \(2012\)](#), with the single exception of Bayer's instruments the selected instruments are weak. Only in the case of BLP-like instruments and Bayer's instruments the estimated coefficients for the price and the share of high-income households are significant. If we select from the complete set of candidate instruments, only the two Bayer instruments are chosen (see column 6). If we use the set of all instruments except the two Bayer instruments, we still have weak instruments. Therefore, we only discuss the results of Column (5).

The coefficients of conservation areas are positive and significant for all income groups. Somewhat unexpected is that the coefficients are not significantly different for the three income groups. In line with, for instance, [Brueckner et al. \(1999\)](#) we expected that the average high-income household would have a stronger preference to live close to conservation areas than the average medium or low-income household. Results from the first estimation step discussed in Section 4.1 suggest that household characteristics, such as marital status and age, are also important in determining the preference of conservation areas.

³⁷ We used the STATA code provided on Christian Hansen's research page for applying LASSO.

We observe similar results for the spatial lag of conservation areas. The positive and significant coefficients show that conservation areas have a positive external effect on the attractiveness of locations just outside the neighborhoods in which they are located. This result is in line with Ahlfeldt et al. (2017) and Been et al. (2017). It shows that spatially lagged exogenous variables are important to include in location choice models. Households do not only enjoy the characteristics from their own neighborhood but also those from surrounding neighborhoods.

The results in Column (6) of Table 3 show that for all income groups, households appreciate living close to high-income households. The coefficient is significantly higher for high-income households than for low-income households. This result confirms that of Bayer et al. (2007) with respect to income. Somewhat surprisingly, we find quite similar coefficients for the house price for all income groups.³⁸

Only few of the other neighborhood characteristics that we include in our location choice model are also important for the location choice of households. The coefficients for the distance to the nearest concentration of 100,000 jobs and for the distance to the nearest intercity train station show a negative but insignificant effect. This is not too surprising as the Amsterdam metropolitan area can be regarded as a single labor market with good accessibility to public transport. For nature we find the expected positive signs of the estimated coefficients, but they are not significant. For water, we find inconclusive results for the main effect but a negative and highly significant effect for its spatial lag. Both amenities are relatively abundantly present in the suburban areas constructed in the postwar period that are less appreciated and we therefore suspect that these variables pick up the presence of the associated negative amenities.³⁹ The age of the housing stock should be expected to absorb this effect to some extent. The coefficients have a positive sign, indicating that older neighborhoods are in general more attractive. This is in contrast to most US city centers where low-income households seem to occupy old homes (Rosenthal, 2008).

5. Implications

In this section, we consider the implications of our estimation results reported in Section 4. The sorting model allows us to calculate the marginal willingness-to-pay (MWTP) of each type of household that we included in the analysis. These figures give a clear overview of the impact of different neighborhood characteristics on the location choice of heterogeneous households with respect to the housing price. Furthermore, the sorting model also allows us to do a counterfactual analysis. The equilibrium property, where housing demand has to match the housing supply, enables us to show how local house prices react when we change neighborhood or household characteristics.⁴⁰ We report changes in the price of a standard house for several areas within the Amsterdam metropolitan area if there were no differences in the availability of conservation areas among all neighborhoods in the Amsterdam area.⁴¹

5.1. Marginal willingness-to-pay

The estimation results reported in Section 4 enable us to calculate the

³⁸ Note that in our model households can decrease the number of housing services consumed in response to high house prices. There are indeed many small housing units in ancient Amsterdam areas where gentrification is important.

³⁹ In their hedonic price analysis Rouwendal and Weijsschede-van der Straaten (2008) also found that the green areas in the suburban quarters of Amsterdam do have no impact on house prices.

⁴⁰ Note that our model does only explain relative house prices. We therefore assume that the average house price remains unchanged in counterfactual simulations.

⁴¹ Similar interpretations are the change in prices if there would be no conservation areas in the Amsterdam area or if all households would not value conservation areas.

MWTP of heterogeneous households for neighborhood characteristics (see Appendix E for technical details). This allows us to compare the MWTP between the income groups and neighborhoods. Column 1 of Table 4 reports the average MWTP of the three income groups. For the high income group the figures represent the MWTP of the average high-income household. Columns 2 through 4 report the deviations from the average of each income group for couples, households with children and age.

The mean MWTP – in terms of higher prices for a standard house⁴² – for an additional percentage point of high-income households in their neighborhood is largest for high-income households (€2666 for a percentage point increase). As we discussed above, we did not allow for differences in the MWTP within the three income groups to prevent endogeneity issues. The differences between the groups that we find are small. Low-income households are still willing to pay around €1700 to live in a neighborhood with a 1% higher share of high-income households.

The MWTP of an average high-income household for living inside conservation areas is large and significant (€31,183 for an additional km² in conservation area). This implies that the average high-income household, that has to pay €31,181 extra for a house in an area with an extra square kilometer of conservation area in their neighborhood, still reaches the same utility as when living in an otherwise equal neighborhood without this amenity.⁴³ The figures for the other income groups are somewhat lower but of the same order of magnitude. The figures are much higher than those reported in Van Duijn and Rouwendal (2013) who used much larger spatial units. Their results refer to living in the municipality Amsterdam instead of another municipality, whereas the results reported here allow us to differentiate between various neighborhoods within the Amsterdam metropolitan area. The results thus show that there is substantial heterogeneity within the municipal boundaries, as seems plausible.

Living not inside but close to conservation areas also contributes significantly to well-being. The mean MWTP is highest for high-income households (€9637). This number can be interpreted as the value attached to an extra square kilometer of conservation area in surrounding neighborhoods – where the distance between adjacent neighborhoods is 1 km (the average distance between the cores of neighborhoods in the Amsterdam area is somewhat lower than 1 km) – that the average household is willing to pay in terms of the price for a standard house.

The interpretation of the mean MWTP figures of the other neighborhood characteristics is similar. Deviations from the mean of each group are shown in Columns 2 through 4 of Table 4. Their interpretation can be clarified as follows: If a household belongs to the high income group, and is a couple with children under 18 while the age of the head of the household is equal to the average in this group, their MWTP for an additional square kilometer of conservation area is €3963 (= -1986 + -1977) lower than the average high-income household. This MWTP is around 10% lower than that of the average high-income household.

These results show that there is large heterogeneity between different types of households. On average, high income couples seem to prefer areas outside the historic center and further from the intercity station where the housing stock is younger compared to the average high-income household. Middle income couples seem only to prefer to live further from the intercity station and in areas with water compared to the average middle income household. Low income couples seem to not to differ that much from the average low-income households. High-income

⁴² Note that there is no presumption that a household actually lives in a standard house. It is the higher price per unit of housing quality – where the standard house represents that chosen unit – that the household is willing to pay.

⁴³ Note that the ceteris paribus condition involved refers also to the random part of the utility function.

Table 3.1

Second step results (1 of 3): Mean indirect utility for each income group.

	High-income households						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Squares and cross products	Cubes and third order cross products	BLP-like instruments	Rank instruments	Bayer's instruments	All candidate instruments	All except Bayer's instruments
Ln(Price of a standard house)	0.622 (2.736)	−63.29 (150.6)	−5.903** (2.815)	4.557 (4.752)	−10.02*** (2.018)	−10.02*** (2.018)	−3.684 (3.712)
Share high-income households (%)	0.0631 (0.0607)	0.303 (2.798)	0.145*** (0.0462)	0.121 (0.0893)	0.116*** (0.0186)	0.116*** (0.0186)	0.116*** (0.0449)
Conservation areas (km2)	−0.603 (0.538)	11.96 (37.22)	0.0576 (0.508)	−2.159 (1.766)	1.352** (0.533)	1.352** (0.533)	−0.157 (0.542)
Conservation areas in surrounding neighborhoods	−0.0701 (0.208)	5.060 (12.02)	0.415* (0.249)	−0.435 (0.494)	0.775*** (0.212)	0.775*** (0.212)	0.250 (0.306)
Distance to the nearest concentration of 100,000 jobs (km)	−0.0624 (0.0543)	−0.224 (0.603)	−0.087 (0.0608)	−0.0626 (0.113)	−0.0911 (0.0556)	−0.0911 (0.0556)	−0.0785 (0.0548)
Distance to the nearest IC train station (km)	0.00774 (0.136)	−0.373 (5.182)	−0.137 (0.126)	−0.102 (0.239)	−0.079 (0.0791)	−0.079 (0.0791)	−0.0862 (0.117)
Nature (km2)	0.0391 (0.112)	0.724 (4.694)	0.0104 (0.176)	−0.127 (0.294)	0.131 (0.179)	0.131 (0.179)	0.0218 (0.140)
Nature in surrounding neighborhoods	−0.131 (0.120)	1.782 (8.049)	−0.0976 (0.119)	−0.452 (0.392)	0.152* (0.0922)	0.152* (0.0922)	−0.106 (0.105)
Water (km2)	−0.0704 (0.181)	0.742 (8.609)	−0.172 (0.18)	−0.353 (0.414)	0.0241 (0.167)	0.0241 (0.167)	−0.135 (0.159)
Water in surrounding neighborhoods	0.0735 (0.105)	−2.112 (7.585)	−0.0121 (0.0956)	0.381 (0.339)	−0.260*** (0.094)	−0.260*** (0.094)	0.0147 (0.0972)
Age of the neighborhood (in years)	−0.00860* (0.0052)	0.130 (0.385)	−9.62E-05 (0.00685)	−0.0242 (0.0188)	0.0132* (0.00759)	0.0132* (0.00759)	−0.0029 (0.00708)
Constant	−8.649 (32.25)	749.8 (1783)	68.29** (33.06)	−55.96 (56.61)	117.5*** (23.9)	117.5*** (23.9)	42.13 (43.83)
Observations	85	85	85	85	85	85	85
Weak F-test	0.556	0.022	2.48	0.297	23.929	23.929	2.095

Note: Dependent variable is δ_j^k which represents the alternative specific constants estimated in the first step of the sorting model. Standard errors are in parentheses. Significance at 90%, 95% and 99% level are, respectively, indicated as *, **, and ***.

Table 3.2

Second step results (2 of 3): Mean indirect utility for each income group.

	Middle income households						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Squares and cross products	Cubes and third order cross products	BLP-like instruments	Rank instruments	Bayer's instruments	All candidate instruments	All except Bayer's instruments
Ln(Price of a standard house)	−0.459 (2.620)	−54.53 (125.3)	−6.698** (2.640)	4.044 (4.188)	−10.76*** (1.906)	−10.76*** (1.906)	−2.443 (1.838)
Share high-income households (%)	0.0259 (0.0585)	0.250 (2.309)	0.109** (0.0433)	0.065 (0.0797)	0.0856*** (0.0175)	0.0856*** (0.0175)	0.0427* (0.0245)
Conservation areas (km2)	−0.578 (0.520)	9.816 (31.16)	−0.0044 (0.498)	−2.071 (1.513)	1.219** (0.524)	1.219** (0.524)	−0.289 (0.36)
Conservation areas in surrounding neighborhoods	−0.0512 (0.194)	4.274 (10.03)	0.409* (0.228)	−0.451 (0.429)	0.761*** (0.202)	0.761*** (0.202)	0.102 (0.174)
Distance to the nearest concentration of 100,000 jobs (km)	−0.0732 (0.050)	−0.213 (0.498)	−0.0975* (0.058)	−0.0697 (0.0996)	−0.102* (0.0545)	−0.102* (0.0545)	−0.0795* (0.0453)
Distance to the nearest IC train station (km)	0.028 (0.128)	−0.335 (4.276)	−0.121 (0.116)	−0.0487 (0.211)	−0.0724 (0.0757)	−0.0724 (0.0757)	−0.00114 (0.069)
Nature (km2)	0.0486 (0.103)	0.59 (3.911)	0.0119 (0.165)	−0.0959 (0.255)	0.123 (0.172)	0.123 (0.172)	0.0537 (0.0924)
Nature in surrounding neighborhoods	−0.123 (0.116)	1.433 (6.716)	−0.106 (0.111)	−0.416 (0.339)	0.126 (0.0908)	0.126 (0.0908)	−0.090 (0.0801)
Water (km2)	−0.0649 (0.167)	0.552 (7.136)	−0.180 (0.161)	−0.302 (0.365)	−0.00194 (0.157)	−0.00194 (0.157)	−0.0698 (0.132)
Water in surrounding neighborhoods	0.0398 (0.103)	−1.757 (6.338)	−0.0293 (0.0936)	0.328 (0.294)	−0.262*** (0.0894)	−0.262*** (0.0894)	−0.00569 (0.0693)
Age of the neighborhood (in years)	−0.00677 (0.00476)	0.108 (0.323)	8.40E-04 (0.00673)	−0.022 (0.016)	0.0135* (0.00762)	0.0135* (0.00762)	−0.00339 (0.00398)
Constant	6.661 (30.90)	648.1 (1484)	80.18*** (31.03)	−47.25 (49.93)	128.8*** (22.55)	128.8*** (22.55)	30.13 (21.80)
Observations	85	85	85	85	85	85	85
Weak F-test	0.556	0.022	2.48	0.297	23.929	23.929	2.457

Note: Dependent variable is δ_j^k which represents the alternative specific constants estimated in the first step of the sorting model. Standard errors are in parentheses. Significance at 90%, 95% and 99% level are, respectively, indicated as *, **, and ***.

Table 3.3

Second step results (3 of 3): Mean indirect utility for each income group.

	Low-income households						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Squares and cross products	Cubes and third order cross products	BLP-like instruments	Rank instruments	Bayer's instruments	All candidate instruments	All except Bayer's instruments
Ln(Price of a standard house)	0.174 (2.588)	−56.55 (128.4)	−6.135** (2.608)	3.489 (3.93)	−10.19*** (1.924)	−10.19*** (1.924)	−2.114 (1.863)
Share high-income households (%)	0.0089 (0.0559)	0.279 (2.335)	0.0921** (0.0407)	0.0599 (0.0774)	0.0752*** (0.0179)	0.0752*** (0.0179)	0.0302 (0.0241)
Conservation areas (km2)	−0.389 (0.499)	0.14 (32.08)	0.206 (0.504)	−1.729 (1.459)	1.350** (0.545)	1.350** (0.545)	−0.0778 (0.374)
Conservation areas in surrounding neighborhoods	−0.0997 (0.200)	4.414 (10.28)	0.366 (0.223)	−0.409 (0.400)	0.713*** (0.199)	0.713*** (0.199)	0.0752 (0.179)
Distance to the nearest concentration of 100,000 jobs (km)	−0.0487 (0.0494)	−0.201 (0.507)	−0.0731 (0.0573)	−0.0492 (0.0968)	−0.0788 (0.0556)	−0.0788 (0.0556)	−0.0563 (0.046)
Distance to the nearest IC train station (km)	−0.00341 (0.127)	−0.449 (4.325)	−0.151 (0.115)	−0.101 (0.205)	−0.116 (0.0803)	−0.116 (0.0803)	−0.0407 (0.0684)
Nature (km2)	0.0667 (0.102)	0.574 (4.004)	0.032 (0.163)	−0.0778 (0.244)	0.13 (0.172)	0.13 (0.172)	0.0692 (0.0951)
Nature in surrounding neighborhoods	−0.133 (0.119)	1.40 (6.88)	−0.113 (0.11)	−0.412 (0.323)	0.099 (0.092)	0.099 (0.092)	−0.101 (0.0809)
Water (km2)	−0.032 (0.164)	0.502 (7.25)	−0.143 (0.159)	−0.278 (0.358)	0.0112 (0.159)	0.0112 (0.159)	−0.044 (0.133)
Water in surrounding neighborhoods	0.0464 (0.102)	−1.755 (6.504)	−0.0267 (0.0911)	0.312 (0.279)	−0.242*** (0.0884)	−0.242*** (0.0884)	−0.00122 (0.0688)
Age of the neighborhood (in years)	−0.00402 (0.00446)	0.113 (0.332)	0.00381 (0.00663)	−0.0174 (0.0154)	0.0157** (0.00765)	0.0157** (0.00765)	−3.22E-04 (0.00413)
Constant	−0.601 (30.47)	672 (1521)	73.75** (30.64)	−40.48 (46.82)	122.1*** (22.76)	122.1*** (22.76)	26.44 (22.03)
Observations	85	85	85	85	85	85	85
Weak F-test	0.556	0.022	2.48	0.297	23.929	23.929	2.457

Note: Dependent variable is δ_j^i which represents the alternative specific constants estimated in the first step of the sorting model. Standard errors are in parentheses. Significance at 90%, 95% and 99% level are, respectively, indicated as *, **, and ***.

households with young children prefer to live in neighborhoods outside conservation areas with more green, further away from the labor market but close to an intercity station compared to the average high-income household. Middle and low-income households with young children prefer younger neighborhoods compared to the average household of that group. The age component seems to play a large role as well. Note that we did not include retired households in the sample so the positive deviations from the mean for living in conservation areas is not surprising. Depending on the income group, households where the head of the household is 10 years older than the average, their MWTP for living in conservation areas increases with around €11,000 to €13,000 in terms of house prices (which is around a 35% increase from the mean MWTP). The same positive, but slightly smaller, numbers are found for the presence of nature and water. This suggests that older households who are still working have a higher preference to reside in areas within conservation areas with preferably a lot of green and water compared to younger households.

Some of the effects we find are not monotone in income. Low-income households are sometimes more similar to high income households than medium income households. This may be related to our lack of information about education that was noted earlier and the attractiveness of Amsterdam for highly educated young people, who often do not (yet) have a high income. More general it may have to do with the attractiveness that a cosmopolitan city like Amsterdam has on specific groups of people who like the special atmosphere of the city although living there does not enable them to reach a particularly high income.

5.2. Impact of urban heritage on house prices and demographic composition

The sorting model suggests that house prices react to changes in amenities. The equilibrium property of the sorting model allows us to estimate the changes in house prices when the number of neighborhood

amenities change. We have carried out a counterfactual simulation in which we compute the price of a standard house that would prevail if there were no differences in the availability of conservation areas in each neighborhood in the Amsterdam area.⁴⁴ Evidently, the spatial spillovers of conservation areas will also disappear but all other neighborhood characteristics remain unchanged.

We use the following procedure. First, we compute the new price equilibrium in the situation without urban heritage while keeping the shares of high-income households constant in the demand equations.⁴⁵ At this price equilibrium the predicted share of high-income households will differ from what they were originally. The second step is to adjust these shares and re-compute the price equilibrium. This procedure is continued until the shares of high-income households do no longer change. In each step the house prices are scaled so as to keep the average housing price equal to its value in the situation where urban heritage was present.⁴⁶

Since our model includes positive spillover effects, there is a possibility that multiple equilibria exist. Bayer et al., (2005) provide an analysis of this situation and a case study that suggests that the presence of more than one equilibrium is more unlikely if there are many choice alternatives and if actors are more heterogeneous. They suggest to check for the presence of multiple equilibria by using a series of 'extreme' starting values in which – in our case – all high-income households are concentrated in a single choice alternative. Although it was impossible to

⁴⁴ We set conservation areas at zero in all neighborhoods. Results will not change if we set the variable at any other value, e.g. the average over all neighborhoods. The important thing is that there are no differences in this amenity between the neighborhoods.

⁴⁵ The price equilibrium computed in this way is unique (see, for instance, Rouwendal, 1990).

⁴⁶ The procedure used by Bayer and McMillan (2012) is identical.

Table 4
Marginal willingness-to-pay results.

High-income households	Average household	Deviations from the mean		
		Couple	Household has children (<18)	Age (+10 years)
High-income households (+%)	2666 ***			
Conservation area (+km2)	31183 ***	−1986 ***	−1977 ***	13068 ***
Conservation area in surrounding neighborhoods	9637 ***	−310 ***	−440 **	−1231 ***
Distance to the nearest concentration of 100,000 jobs (+km)	−2101	34	1024 ***	1041 ***
Distance to the nearest intercity station (+km)	−1822	453 ***	−453 ***	−515 ***
Nature (+km2)	3029	−114	901 ***	1101 ***
Nature in surrounding neighborhoods	1890 *	−165 ***	−236 **	−152 *
Water (+km2)	555	614 ***	−205	941 ***
Water in surrounding neighborhoods	−3233 ***	93 *	−5	324 ***
Age of the neighborhood (+year)	304 **	−12 **	13	33 ***
Middle income households				
High-income households (%)	1837 ***			
Conservation area (km2)	26168 ***	−534	−2511	11843 ***
Conservation area in surrounding neighborhoods	8810 ***	−821 ***	−1182 ***	9
Distance to the nearest concentration of 100,000 jobs (+km)	−2195 *	−73	344 *	543 ***
Distance to the nearest intercity station (km)	−1555	964 ***	453 *	194
Nature (km2)	2633	−3	367	1358 ***
Nature in surrounding neighborhoods	1455	−377 ***	−324 *	397 ***
Water (km2)	−42	1047 ***	−3	836 ***
Water in surrounding neighborhoods	−3032 ***	159	552 ***	−324 ***
Age of the neighborhood (+year)	289 **	21	−44 **	−4
Low-income households				
High-income households (%)	1705 ***			
Conservation area (km2)	30618 ***	−1064	−4596	11244 ***
Conservation area in surrounding neighborhoods	8718 ***	−1115 ***	−173	41
Distance to the nearest concentration of 100,000 jobs (+km)	−1788	110	432	272 *
Distance to the nearest intercity station (km)	−2630	−87	506	704 ***
Nature (km2)	2958	−296	422	875 ***
Nature in surrounding neighborhoods	1211	−641 ***	58	364 ***
Water (km2)	254	1066 *	998	1413 ***
Water in surrounding neighborhoods	−2959 ***	−53	38	−336 **
Age of the neighborhood (+year)	356 **	33	−83 ***	38 ***

Note: The values are in euros. Significance at 90%, 95% and 99% level are, respectively, indicated as *, **, and ***. The significance levels of Column 2 to 4

(deviations from the mean) are based on the first step estimation procedure of the residential sorting model.

take this advice literally because the housing stock in any single area we consider is insufficiently large to include all high-income households, we tried starting situations in which all these households were located in a few areas in which they occupied the whole housing stock. The model always converged to the same equilibrium.

Fig. 2 reports the results of the simulation where we set the conservation areas at zero in all neighborhoods. For a better overview of the effects we aggregate the choice alternatives to the district⁴⁷ level for Amsterdam and to the municipal level for the other neighborhoods. (see Appendix F for the underlying numbers). The upper panel of Fig. 2 refers to actual (left) and counterfactual (right) house prices. As expected, the central areas of Amsterdam become much cheaper, while the housing price in suburban districts of Amsterdam and the surrounding municipalities increases. The standard house prices in the rich Amsterdam districts, which are within or close to the conservation area, decrease the most. Note that the district *Amsterdam Stadsdeel Zuid* is outside of the conservation area but, because of the large spatial spillover effects of the conservation area, house prices in this neighborhood will also decrease. The gap between the price of a standard house in Amsterdam and elsewhere decreases. However, the prices in the city center will still be higher than in most other areas in Amsterdam due to the attractive central location close to the Central station and the accessibility to the job market.

The lower panel of Fig. 2 refers to actual (left) and counterfactual (right) shares of high income households. For many districts and municipalities this share hardly changes. However, we find strong increases in the share of high-income households in suburban municipalities where the initial share of high-income households was already high, such as Abcoude and Landsmeer, and almost no changes in Diemen and Amstelveen, which are closer to the city of Amsterdam. This suggests that when urban heritage in the city center disappears, high-income households are likely to move to ‘posh’ suburban municipalities. Our simulations thus confirm the impression that urban heritage contributes significantly to keep the rich households – especially those rich workers who are single, older and without young children as can be concluded from the MWTP figures – in the center of the metropolitan area. As noted above, Brueckner et al. (1999) have argued that high-income households will only locate in city centers if they have a strong amenity advantage over suburban municipalities. This is consistent with our simulation results, even though we did not find support for their assumption that higher income households have a much larger willingness to pay for living close to urban amenities than others.

6. Conclusion

In this empirical paper, we use a logit-based sorting model to investigate the impact of urban heritage on demographic composition and house prices in a metropolitan region. Our analysis uses the sorting framework developed by BLP and Bayer et al. (2007) in which the price of a standard house is explained by the housing supply and demand equilibrium. To mitigate concerns about the restrictive assumption that unobserved characteristics are valued identical by all actors, we split the population into three groups, based on income, and estimate different logit models for each of these groups. This means that we allow for differences in the sensitivity for the housing price, the share of high-income households and unobserved neighborhood characteristics between these groups.

To clarify the choice of instruments from the large set of suggestions made in the literature, we use Belloni et al. (2012)'s selection procedure

⁴⁷ In Dutch: *Wijk of stadsdeel*. This is an administrative unit which is between the neighborhood and municipal level.

Fig. 2. The impact of cultural heritage on house prices and shares of high income households per neighborhood. Note: The Figure compares the actual situation with the one predicted by the model in case cultural heritage were equally distributed among all neighbourhoods in the area. House prices are standardized to make comparison between areas possible.

for optimal instruments. We find that all standard instruments – nonlinear functions of the neighborhood characteristics that do not use any additional exogenous information – perform poorly. In contrast, the instruments suggested by Bayer and his co-authors in several papers perform very well. We show that these instruments use additional information that combines information about household characteristics – crossed with the neighborhood characteristics – and the nonlinearity of the model.

Our estimates show that all income groups attach a large value to the proximity of urban heritage and that differences in proximity to heritage within the municipality are important. The value attached to urban heritage does not differ much with income, but it varies significantly with other household characteristics. We also find that all income groups prefer to live in neighborhoods with a higher share of high-income households. To investigate the overall impact of cultural heritage on household location choice, we use the estimated model to simulate the housing market equilibrium in the counterfactual situation in which cultural heritage is evenly spread over space. Although we found weak evidence for Brueckner and Rosenthal, (2009) suggestion that especially high-income households are attracted to the urban amenities, our simulations show that spreading urban heritage evenly over space would lead to a substantially more suburbanized location pattern of the high-income households in our study region. Put differently, even though urban cultural heritage is highly valued by all households – not just the higher income groups – European cities would be more similar to US cities if this amenity were absent.

Our study is limited by several assumptions that one could relax in future research. First, we use a scalar indicator of house prices per neighborhood and assume housing quality can be chosen by the households, whereas in reality the housing stock is rigid and the relative price of luxury to modest housing differs over space, see Rouwendal and van Duijn (2021). Second, we estimated separate model for three different income groups, thereby relaxing a restrictive assumption in the BLP literature. Further disaggregation could be possible without sacrificing the quality of the estimates. Third, although the presence of old buildings and street patterns is a remnant of the past, the state of maintenance of cultural heritage including the measures taken to protect its appearance in the surrounding area can be affected by policy, see Koster and Rouwendal (2017). The results of this paper suggest that such measures can be important for keeping old inner cities vibrant centers of activity.

Declaration of competing interest

There is no conflict of interest involved in the submission of this manuscript.

Acknowledgement

The authors thank Kurt Schmidheiny, Stephan Heblich and the other participants of the Workshop on Cultural Heritage and Urban Revival, Nick Kuminoff, Lars Nesheim, two anonymous referees and the editor David Krisztian Nagy for useful comments on previous drafts. The

authors thank Statistics Netherlands, NVM, RCE and PBL for providing us with excellent data. The authors gratefully acknowledge Platform 31, VU

University and the University of Groningen for their financial support.

APPENDIX A. OVERVIEW OF THE CHOICE ALTERNATIVES

Fig. A.1. Amsterdam and surrounding municipalities. Note: The thick red lines show the boundaries of the municipalities within our study area. The thin black lines show the boundaries of the administrative neighborhoods within each municipality. The thick black lines show the boundaries of the combinations of neighborhoods that have been used as choice alternatives within our modelling framework.

APPENDIX B. DERIVATIONS FOR BAYER'S INSTRUMENTS

The derivation presented here are related to the discussion in Section 2.3 of [Weijsschede-Van der Straaten et al. \(2017\)](#). To see how Bayer's instrument for the price works with a heterogeneous population, we start from (1) and write the individual choice probabilities as:

$$\pi_j^i = \frac{e^{\delta_j + \phi_j^i}}{\sum_k e^{\delta_k + \phi_k^i}} \quad (\text{B.1})$$

Taking logs on both sides and rearranging gives:

$$\delta_j + \phi_j^i = \ln \pi_j^i + \ln \sum_k e^{\delta_k + \phi_k^i} \quad (\text{B.2})$$

The second term on the right-hand side is the expected maximum utility of consumer i , which we will denote as EU^i . Taking averages over the population, we find:

$$\delta_j = \overline{\ln \pi_j^i} + \overline{EU^i} \quad (\text{B.3})$$

where we have used the fact that the ϕ_j^i s are on average equal to zero and have used a bar to indicate averages. Ignoring for the moment the 'social interaction' effect, we specify average utility as:

$$\delta_j = \alpha \ln p_j + \bar{\gamma} x_j + \xi_j \quad (\text{B.4})$$

Substitution in (B.3) and rearrangement gives:

$$\ln p_j = \left(\overline{EU^i} + \overline{\ln \pi_j^i} - \bar{\gamma} x_j - \xi_j \right) / \alpha \quad (\text{B.5})$$

In the estimated model (B.5) holds. It is important to note that $\overline{EU^i}$ and $\overline{\ln \pi_j^i}$ are both functions of the utilities and therefore of the (logged) prices and the unobserved characteristics. However, changes in $\overline{EU^i}$ imply an equal shift of all logged prices which leaves all choice probabilities unchanged, while changes in $\overline{\ln \pi_j^i}$ are j -specific and can have an impact on price differences.

We note that, because of the alternative-specific constants, it must be true that the average choice probability of j equals the share of the housing stock in j :

$$\overline{\pi_j^i} = s_j \quad (\text{B.6})$$

This equality is disturbed if all ξ_s are set equal to zero. The counterfactual prices that are Bayer's price instrument are computed by adjusting the price until the market equilibrium condition (B.6) is again satisfied. We write the counterfactual prices as p_j^{cf} and write them similar to (B.5) as:

$$\ln p_j^{cf} = \left(\overline{EU^i}^{cf} + \overline{\ln \pi_j^i}^{cf} - \bar{\gamma} x_j \right) / \alpha \quad (\text{B.7})$$

Note that in (B.7) the unobserved characteristic does not occur because it has been set equal to 0, and that $\overline{EU^i}^{cf}$ and $\overline{\ln \pi_j^i}^{cf}$ have been given a superfix cf because their values will change when the unobserved characteristics are set equal to zero and prices are adjusted so as to re-establish a market equilibrium.

APPENDIX C. THE CANDIDATE INSTRUMENTS AND THEIR SELECTION

In this appendix we provide further information about the sets of candidate instruments and the outcomes of Belloni et al.'s (2012) selection procedure. Full results of first stage regressions are available from the authors upon request.

Squares and cross products

The set consists of the 9 squared exogenous variables and their 36 cross products. Selected instruments for the log price were the squares of variables 1 and 2, and the cross product of variables 2 and 9 and that of variables 6 and 9. For the share of high-income households, only one candidate was selected: the cross product of variables 4 and 5.

Cubes and third order cross products

The set consists of the 9 cubed exogenous variables and their 84 third order cross products. For the price one candidate is selected: the cube of variable 2. For the share of high-income households also only one candidate is selected: the cross product of exogenous variables 3, 4 and 6.

BLP-like instruments

The set consist of the 9 sums of the characteristics of neighborhoods at a distance of less than 5 km, less than 10 km and less than 15 km (27 candidate instruments), the 9 sums of the characteristics of neighborhoods at a distance of more than 5, 10 and 15 km (again 27 candidate instruments), and the 9 sums of the characteristics of the neighborhoods at a distance between 5 and 10, 10 and 15 and 5 and 15 instruments (27 'doughnut' instruments). Selected instruments for the price are the sum of characteristic 2 over neighborhoods at a distance of less than 5 km, the sum of characteristic 2 over neighborhoods at a distance of more than 5 km, and the sum of characteristic 1 over neighborhoods at a distance of more than 15 km. Selected instruments for the share of high-income households are the sum of characteristic 7 over neighborhoods at a distance of less than 10 km and the sum of characteristic 7 over neighborhoods at a distance between 5 and 10 km.

Rank instruments

The instruments are the rankings of the neighborhoods based on each of the 9 characteristics. For the logged price the rank of characteristics 1, 2 and 9 were chosen, for the share of high-income households those of characteristics 5 and 7.

Distance to an ideal neighborhood and number of close competitors

The ideal neighborhood is defined as one in which all characteristics have the most preferred value that exists in the set of neighborhoods. Distance measures were based on normalized values of the characteristics. Candidate instruments were: (i) the Euclidean distance to the ideal, (ii) Manhattan distance, (iii) the maximum of the difference to the ideal value for the 9 characteristics. The close competitors were defined as the number of neighborhoods at a Euclidean distance in characteristics space of at most 1, 2 or 3. In total this gives us 6 instruments based on normalized characteristics. For the log price the Manhattan distance was selected, for the share of high-income households the maximum of the differences and the number of neighborhoods at a Euclidean distance of less than 3.

Bayer's instruments

The computation of these instruments has been discussed in the main text. The price instrument was selected for the log price, the other instrument for the share of high-income households. In contrast to all sets of candidate instruments discussed above the first stages are very strong.

Other issues

When we consider all instruments jointly only Bayer's price instrument is selected for the log price and Bayer's share instrument for the share of high-income households.

When we remove the two Bayer instruments from the set of candidates, the selected instruments for the price are the cross product of characteristics 2 and 9, the cross product of characteristics 1, 4 and 9, and the Manhattan distance to the ideal neighborhood. The selected instruments for the share of high-income households are the cross product of characteristics 1, 4 and 6, the cross product of characteristics 1, 5 and 8, and the sum of characteristic 7 for neighborhoods at a distance between 5 and 10 km.

APPENDIX D. REGRESSION RESULTS CONTINUED

Table D.1
First step results for renters: Deviations from mean indirect utility

Neighborhood characteristics	Household characteristics					
	High-income households		With children (<18)		Age (in years)	
	Couple					
Conservation areas (km2)	-0.230*	0.128	-0.141	0.143	0.022***	0.006
Conservation areas in surrounding neighborhoods	-0.168***	0.049	-0.199***	0.046	-0.009***	0.002
Distance to the nearest concentration of 100,000 jobs (km)	-0.019	0.019	0.052***	0.018	0.005***	0.001
Distance to the nearest intercity station (km)	0.008	0.027	-0.046*	0.025	0.000	0.001
Nature (km2)	-0.074**	0.037	-0.007	0.034	0.002	0.001
Nature in surrounding neighborhoods	-0.043*	0.024	-0.098***	0.024	-0.004***	0.001
Water (km2)	0.231***	0.051	-0.123***	0.044	-0.007***	0.002
Water in surrounding neighborhoods	0.044	0.030	0.109***	0.027	0.009***	0.001
Age of the neighborhood (in years)	0.003*	0.001	-0.004**	0.002	-8.81E-05	6.34E-05
Log-likelihood	-133,928					
	Middle income households					
	Couple		With children (<18)		Age (in years)	
Conservation areas (km2)	-0.512***	0.097	-0.733***	0.124	0.012***	0.004
Conservation areas in surrounding neighborhoods	-0.267***	0.032	-0.125***	0.035	-0.001	0.001
Distance to the nearest concentration of 100,000 jobs (km)	-0.045***	0.013	0.020	0.014	0.003***	0.001
Distance to the nearest intercity station (km)	0.005	0.016	-0.055***	0.018	-0.001	0.001
Nature (km2)	-0.080***	0.024	-0.095***	0.027	0.002*	0.001
Nature in surrounding neighborhoods	-0.090***	0.016	-0.109***	0.019	-0.001*	0.001
Water (km2)	0.128***	0.030	0.025	0.033	-0.002*	0.001
Water in surrounding neighborhoods	0.071***	0.019	0.071***	0.020	0.004***	0.001
Age of the neighborhood (in years)	0.002*	0.001	-0.010***	0.001	-2.17E-04***	4.69E-05
Log-likelihood	-137,213					
	Low-income households					
	Couple		With children (<18)		Age (in years)	
Conservation areas (km2)	-0.426***	0.081	-0.963***	0.095	0.011***	0.003
Conservation areas in surrounding neighborhoods	-0.128***	0.028	-0.168***	0.029	0.002**	0.001
Distance to the nearest concentration of 100,000 jobs (km)	-0.031***	0.011	0.017	0.011	0.002***	0.000
Distance to the nearest intercity station (km)	0.003	0.014	-0.068***	0.015	0.000	0.001
Nature (km2)	-0.037*	0.020	-0.108***	0.021	-0.003***	0.001
Nature in surrounding neighborhoods	-0.041***	0.014	-0.094***	0.015	-0.001*	0.001
Water (km2)	0.050*	0.026	0.064**	0.027	0.001	0.001
Water in surrounding neighborhoods	0.036**	0.015	0.072***	0.016	0.001	0.001
Age of the neighborhood (in years)	0.000	0.001	-0.010***	0.001	-1.79E-04***	3.39E-05
Log-likelihood	-135,997					

Note: Parameter estimates are used to calculate the deviations from the mean indirect utility with all variables normalized to have mean zero. Significance at 90%, 95% and 99% level are, respectively, indicated as *, **, and ***. The regression results based on other specifications can be obtained from the author.

APPENDIX E. DERIVATION OF THE MARGINAL WILLINGNESS-TO-PAY

Equation (1) can be rewritten almost as a hedonic price function allowing for heterogeneity in household preferences:

$$p_j^{g(i)} = \left(\frac{\beta^{g(i)}}{\alpha^{g(i)}} \right) \sigma_j + \left(\frac{\bar{\gamma}^{g(i)} + \gamma^i (z^i - \bar{z}^{g(i)})}{\alpha^{g(i)}} \right) x_j + \left(\frac{1}{\alpha^{g(i)}} \right) \varepsilon_j^{g(i)} + \left(\frac{1}{\alpha^{g(i)}} \right) \varepsilon_j^i - \left(\frac{1}{\alpha^{g(i)}} \right) u_j^i \quad (\text{E.1})$$

where $p_j^{g(i)} = \ln(p_j^{g(i)})$. Using this equation, it is simple to compute the MWTP of each income group g and each type of household i within each group g for each of the neighborhood characteristics x_j :

$$\frac{\delta P_j^{g(i)}}{\delta x_j} = \left(\frac{\bar{\gamma}^{g(i)} + \gamma^i (z^i - \bar{z}^{g(i)})}{\alpha^{g(i)}} \right) p_j^{g(i)} \quad (\text{E.2})$$

The household characteristics are constructed to have mean zero, $(z^i - \bar{z}^{g(i)})$. This simplifies the MWTP of the average household within each income group:

$$\frac{\delta P_j^{g(i)}}{\delta x_j} = \left(\frac{\bar{\gamma}^{g(i)}}{\alpha^{g(i)}} \right) p_j^{g(i)} \quad (\text{E.3})$$

APPENDIX F. SIMULATION RESULTS

Table F.1
Counterfactual simulation: Set the conservation areas at zero in all neighborhoods

Municipalities – Districts	Standardized house price (in €)	Predicted house price (in €)	Difference in prices	High-income households (in %)	Predicted high-income house-holds (in %)
Abcoude	237,154	349,149	111,995	59.0	80.0
Amstelveen	227,539	283,357	55,818	45.3	48.4
Amsterdam:					
Stadsdeel Centrum	310,047	223,399	−86,648	32.1	24.2
Stadsdeel Noord	183,164	190,361	7197	24.7	22.5
Stadsdeel West	249,824	214,506	−35,318	23.5	18.6
Stadsdeel Nieuw-West	183,086	215,425	32,339	27.5	28.7
Stadsdeel Zuid	296,512	271,588	−24,924	37.2	35.1
Stadsdeel Oost	232,712	221,535	−11,177	29.5	28.8
Stadsdeel Zuidoost	156,902	190,791	33,889	20.2	19.3
Diemen	192,874	226,353	33,478	39.9	40.2
Haarlemmerliede	195,849	253,658	57,809	47.5	55.1
Haarlemmermeer	188,879	262,474	73,595	46.6	60.1
Landsmeer	206,782	310,377	103,594	52.1	75.2
Muiden	224,802	267,977	43,175	50.1	58.3
Oostzaan	189,357	269,137	79,781	48.6	66.1
Ouder-Amstel	222,688	286,674	63,986	51.4	58.1
Waterland	194,735	265,102	70,367	49.1	66.6
Weesp	204,458	217,276	12,817	36.1	29.3
Zaanstad	156,280	199,865	43,585	37.2	42.6

Note: The predicted house prices, taken into account the equilibrium property of the sorting framework and the scaling, are reported as a counterfactual simulation that sets all urban heritage to zero. Actual prices reflect the situation in 2009. Actual percentage high-income households reflect the situation in 2008. See [Appendix F](#) for a set of maps reflecting the simulation results.

Author statement

All authors acknowledge that the material presented in this manuscript has not been previously published, except in abstract form, nor is it simultaneously under consideration by any other journal.

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