

# Location Sorting and Endogenous Amenities: Evidence from Amsterdam\*

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This paper argues the endogeneity of amenities plays a crucial role in the welfare distribution of a city's residents by reinforcing location sorting. We quantify this channel by leveraging spatial variation in tourism flows and the entry of home-sharing platforms, such as Airbnb, as shifters of location characteristics to estimate a dynamic model of residential choice. In our model, consumption amenities in each location are the equilibrium outcome of a market for services, which are supplied by firms and demanded by heterogeneous households. We estimate the model using detailed Dutch microdata, which allows us to track the universe of Amsterdam's residents over time and the evolution of a rich set of neighborhood amenities. Our results indicate significant heterogeneity across households in their valuation of different amenities, as well as in the response of amenities to demographic composition. We show that allowing for this endogenous response increases inequality between demographic groups whose preferences are closely aligned, but decreases it if substantially misaligned, suggesting heterogeneity in the two-way mapping between households and amenities plays a crucial distributive role. Finally, we highlight the distributional implications of our estimates by evaluating currently debated policies, such as zoning, as well as price and quantity regulations in housing markets.

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# 1 Introduction

The past decade has seen an increased interest in the spatial dimensions of inequality and its determinants. Recent work has argued these spatial disparities are driven by increased sorting of different types of workers into locations that differ in their employment opportunities. Moreover, part of the literature has focused on the endogenous response of a location’s amenities to its demographics and its consequences for inequality through the reinforcement of residential sorting.<sup>1</sup>

Endogenous amenities are typically modelled as a one-dimensional object that encompasses a wide variety of locally provided services. While providing tractability, this simplification does not allow locations to be horizontally differentiated in terms of their amenities. By contrast, allowing households to have heterogeneous preferences over a *set* of amenities and each amenity to respond to location demographics in its own way leads to richer sorting patterns than what the literature has found. In this paper, we ask: How does this two-way heterogeneity shape within-city residential sorting and inequality? To do so, we build and estimate a spatial equilibrium model of a city with household preference *heterogeneity* over a *bundle of amenities*, whose supply responds differentially to changes in neighborhood demographics.

To estimate our model, we exploit the substantial increase and spatial variation in tourism flows and the entry of short-term rental platforms in the city of our empirical application, Amsterdam. We present reduced-form evidence that these two events are sufficiently important to affect housing markets and local amenities and can therefore be leveraged as shifters of location characteristics.<sup>2</sup> We start by linking web scraped Airbnb data to zipcode-level variables of interest from the Amsterdam city council’s public database, and present evidence on how tourism volume covaries with amenities and demographic composition over time and space. Next, to quantify the effect of short-term rentals on zipcode-level outcomes, we estimate a set of reduced-form models by leveraging shift-share instruments. We show Airbnb entry is a large enough shock to shift housing supply for locals in Amsterdam. We find a 10% increase in

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<sup>1</sup>See, for example, Moretti (2013), Diamond (2016), Baum-Snow and Hartley (2016), Couture and Handbury (2017), and Couture et al. (2019).

<sup>2</sup>The number of overnight stays in Amsterdam went from 8 million in 2008 to nearly 16 million in 2017, corresponding to 3 and 6 overnight stays per resident. In Amsterdam, commercially operated Airbnb listings grew to nearly 10% of the city’s rental stock in 2017 (2.5% of the total housing stock). We define commercial listings as entire-home listings that operate year-round, so locals are unlikely to live in them.

commercially operated listings leads to a 0.50% increase in rent, which accounts for 20% of the average annual rent growth between 2011-2017. For our structural estimation, we complement our data on amenities, tourism, and short-term rental listings with restricted access microdata from the Centraal Bureau voor de Statistiek (CBS), the statistics bureau of the Netherlands. These data provide us with the universe of residential movements in the country, detailed socioeconomic characteristics at the individual level, and house prices and rents at the housing-unit level.

The major obstacle in quantifying the effects of endogenous amenities on within-city inequality is that both amenities and residential choices are equilibrium outcomes and thus are simultaneously determined. To understand this relationship between residential choices and amenities, we build and estimate a dynamic model of the residential market, where amenities are the equilibrium outcome of a market for services, and heterogeneous forward-looking households choose where to live each period. The dynamic behavior of households should be taken into account for two reasons. First, the persistence in location decisions suggests the presence of moving costs. Failure to account for this dynamic behavior by estimating a static model would make agents appear to be less responsive to changes in location characteristics than they actually are, leading to biased estimates toward zero. Second, when households choose a location they form expectations about the evolution of amenities and prices in each locations. A consequence of such a dynamic model is that shocks to the city have very different effects if households perceive them as temporary as opposed to permanent, a feature that static models fail to capture.

In addition to fixed location characteristics, we model two types of endogenous amenities that vary over time: direct congestion effects from tourists and indirect effects through the market for different consumption amenities. To the best of our knowledge, existing work only models the endogenous supply of amenities as a one-dimensional function of a location's demographic composition. Instead, we contribute to the urban economics literature by providing a microfoundation for this mapping in a multi-dimensional case. More concretely, we endogenize different consumption amenities through a market where services are provided by monopolistically competitive firms and demanded by agents with heterogeneous preferences. As a result, the market's equilibrium conditions provide the mapping between the number of firms in each service and the demographic composition of a location, which includes tourists. The purpose of this micro-foundation is two-fold. First, it provides a clear inter-

pretation of how amenities depend on demographics, because they are a function of local aggregate demand. Second, and most importantly, modeling amenities in this multidimensional way allows us to recover service-specific parameters, such as different operating costs. Hence, we can perform counterfactual simulations to study service-specific interventions, such as the zoning of certain consumption amenities.

Finally, in our model, absentee landlords supply their housing unit either to locals on traditional long-term leases or to tourists on short-term leases. We assume landlords are atomistic and do not internalize the fact that tourists create externalities that are borne by residents. More importantly, despite the total housing stock being fixed and inelastic, the option to rent short term to tourists endogenizes housing supply available for *locals*.

For our structural estimation, we build upon the Euler Equation in Conditional Choice Probability (ECCP) methodology borrowing tools from the empirical industrial organization literature ([Aguirregabiria and Magesan, 2013](#); [Scott, 2013](#); [Kaloupt-sidi et al., 2018](#)). We also contribute to this literature in two ways. First, we introduce a new method to smooth conditional choice probabilities (CCP), which amounts to Bayesian smoothing with data-driven priors. Monte Carlo simulations show using our technique reduces the bias in the estimates of preference parameters caused by CCP measurement error by more than 50%. Lastly, one of the main empirical challenges in the estimation of residential demand is the presence of confounding unobservable factors. We employ a new identification strategy that combines the ECCP methodology with Arellano-Bond instruments ([Arellano and Bond, 1991](#)) to construct a set of instruments whose statistical validity can be tested in the data.

Given the estimated parameters, we first evaluate the sorting and welfare consequences of the endogeneity of amenities. We compare the equilibrium outcome of a world with exogenous location characteristics to one in which these characteristics endogenously respond to their residential composition, finding a significant increase in residential sorting across demographic groups. We find this increase in sorting leads to an increase in the welfare gap between demographic groups whose preferences for location characteristics are sufficiently aligned and a decrease for groups whose valuations are sufficiently misaligned. Intuitively, if preferences are misaligned between two groups, these groups sort into different locations, raising the supply of their most preferred amenities. Moreover, because amenities respond to demographics and preferences are misaligned, demand from the group in the other location decreases

because amenities are tilting away from them, translating into lower prices. Thus, there are two effects reducing the welfare gap across locations when preferences are misaligned: each group obtains its preferred amenities and also faces lower housing prices. Our findings complement the existing literature on residential sorting by introducing heterogeneity in the two-way relationship between households and amenities, which allows us to explain richer patterns in the effects that endogenous amenities have on welfare inequality. We continue by evaluating policies that are currently being implemented across the world to regulate tourism and its effects on the housing market through the short-term rental industry.<sup>3</sup> First, we consider the most common policy regulation for short-term rentals: a lodging tax that is levied on the nightly rate that tourists pay. Second, we consider quantity regulations in the form of night caps: restrictions on how many nights per year a short-term rental host is allowed to book. This policy began to be implemented in Amsterdam in 2017, with enforcement being carried out directly from the Airbnb platform itself. Our counterfactual simulations show that this second policy generates larger welfare gains for the most disadvantaged groups, thus playing a greater redistributive role than the lodging tax.

The paper is organized as follows. In section 2, we describe how our paper contributes to the existing literature. Section 3 describes our data. Section 4 presents the empirical evidence. Sections 5–6 present our model and estimation method. Section 7 describes our counterfactuals. Section 8 concludes.

## 2 Related literature

Spatial equilibrium models date back to Rosen (1979) and Roback (1982) and have experienced a recent comeback to address public finance questions concerning location sorting and inequality across cities (Moretti, 2013; Diamond, 2016). Although both employment opportunities and amenities are key determinants of residential choices across cities, we focus on within-city movements, thus abstracting away from the job market channel. Given that all households have access to the same labor market, observed location choices are driven by preferences for location characteristics rather than job opportunities. In this way, we argue that we separate the two channels and explicitly focus on the identification of household preferences. An extensive literature studies within-city sorting (Bayer et al., 2004; Guerrieri et al.,

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<sup>3</sup><https://www.economist.com/international/2018/10/27/the-backlash-against-overtourism>

2013; Ahlfeldt et al., 2015; Bayer et al., 2016; Diamond, 2016; Davis et al., 2018) and delivers a tractable framework for quantifying residential agglomeration and dispersion forces, but is silent on the exact mechanisms that drive changes in endogenous amenities. To the best of our knowledge, only Couture et al. (2019) uses a similar micro-foundation of amenities building on trade models, but with a one-dimensional amenity and households with homogeneous preferences. We add to this literature by extending this micro-foundation of amenities to a market with different services<sup>4</sup>, where firms within a service offer different varieties to residents with heterogeneous preferences. This heterogeneity in preferences allows us to capture richer patterns of spatial sorting of households and amenities, and to evaluate policy instruments targeting specific demographic groups (e.g., low-income households) or specific types of services (e.g., amenities catering mainly to tourists).

Our dynamic discrete-choice modelling approach has been previously used in the literature to estimate preference for locations. Bayer et al. (2016) is the first paper that estimates a dynamic model of location choice with heterogeneous households where households value price, racial composition, pollution, and crime rate. More recently Davis et al. (2017), Davis et al. (2018), and Diamond et al. (2018) estimate a dynamic discrete choice model of location choice to evaluate the effects of housing vouchers, low-income housing, and rent controls, respectively. More concretely, Davis et al. (2018) also include households that value endogenous characteristics, such as the share of black households and the share of low-income households. We add to their work by adding a market of endogenous consumption amenities that are valued by residents when making residential decisions.

In terms of methodology, our model borrows from the dynamic discrete-choice framework in the empirical industrial organization literature (Hotz and Miller, 1993; Arcidiacono and Miller, 2011; Aguirregabiria and Magesan, 2013; Scott, 2013; Kalouptsidi et al., 2018), which has been applied to answer questions in many contexts where dynamics matter, such as agricultural economics, trade, and residential choice (Scott, 2013; Traiberman, 2018; Diamond et al., 2018). We add to this literature with a novel smoothing of the CCPs that are estimated in the first stage, and a new identification strategy in the presence of unobservable confounders that combines the ECCP

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<sup>4</sup>By “service”, we mean a broad sector of amenities, such as restaurants, which may have different “varieties” within it. For example, Italian and Japanese restaurants would be different varieties within the restaurant service.

methodology with Arellano-Bond instruments.

Finally, several recent papers examine the effects of short-term rentals and tourism. [Zervas et al. \(2017\)](#) estimate the impact of Airbnb entry on the Texan hotel industry by using a difference-in-differences strategy, finding the impact on hotel revenue is in the -8% to -10% range, affecting low-end hotels most. [Sheppard et al. \(2016\)](#), [Koster et al. \(2018\)](#), [Barron et al. \(2018\)](#), and [Garcia-López et al. \(2019\)](#) estimate the impact of Airbnb entry on housing prices in New York City, Los Angeles, the United States, and Barcelona, respectively, using different identification strategies. [Farronato and Fradkin \(2018\)](#) is the first paper that takes a structural approach to study the effect of Airbnb entry on the hospitality industry, showing that short-term rentals can flexibly expand supply when hotels become capacity constrained when demand peaks, thus keeping hotel prices low. However, they are silent on the effects on local residents through the housing or amenities channel, which seems to be a central concern for policymakers, especially in the European context. We complement their work by studying the effects on residents' welfare using a structural model of a city's housing market. Finally, [Faber and Gaubert \(2019\)](#) study the spillovers of tourism on manufacturing using a structural approach. By contrast, we contribute to this literature by studying the effects of tourism on the residential market.

### 3 Data

We obtain Airbnb listings data from InsideAirbnb.com, a non-commercial, independent website that provides monthly web-scraped listings data for a host of cities around the world. Our web scrapes consist of listing-level observations with detailed information such as geographic coordinates, host identifiers, prices per night, calendar availability, and reviews. We define commercial listings as entire-home listings with sufficient booking activity (over 3 months booked per year) that a household cannot plausibly be living there permanently. Appendix D.1 provides the details of how we implement the classification.

We combine the Airbnb data with publicly available zipcode-level aggregated data from the Amsterdam City Data (ACD).<sup>5</sup> The ACD consists of an annual panel of over 700 zipcode-level variables. These variables include sociodemographics (e.g., neighborhood level ethnic, income, and skill composition) as well as a rich set of

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<sup>5</sup>These data are publicly available at <https://amsterdamsmartcity.com/>.

publicly provided amenities (e.g., schools, hospitals, commuting access, green areas), non-market amenities (e.g., traffic and noise congestion, tourist congestion, crime, street cleanliness), and private-consumption amenities (e.g., bars, restaurants, hotels, tourist-oriented businesses). We complement the ACD panel on amenities with tourism reports of the city of Amsterdam.<sup>6</sup>

We also use restricted-access microdata from the Centraal Bureau voor de Statistiek (CBS), the statistics bureau of the Netherlands. A unique feature of our data is the residential cadaster, where we can track the housing unit in which every individual lives at every point in time. Panel data covering the universe of individuals is rare, because often only censuses that take place every 10 years are available.<sup>7</sup> These data allow us to link individuals and their moving decisions to various socioeconomic variables.<sup>8</sup> Tax returns allow us to observe the income and demographics of households such as age, household composition, and country of origin. For housing units, tax and transaction records provide us with housing appraisal and transaction values, physical characteristics of all properties in the country, their geographical location, and their tenancy status. With the tenancy status, we are able to distinguish between owner-occupied, rented, and social housing units. Rent data are available from a national survey, but do not cover the universe of tenants. To overcome this problem, we link the rent survey with the universal housing tax data. We then use the matched subset to impute rents for housing units that do not appear in the rent survey, using a random forest with an out-of-sample  $R^2$  equal to 0.75. Appendix D.2 describes the details of the imputation.

## 4 Stylized facts

Before moving to our structural model, we show how tourism volume and Airbnb penetration correlate with our outcomes of interest: rents, house prices, touristic consumption amenities, and residential movements. We interpret these results as strong suggestive evidence of the overall effects of tourism and Airbnb. In what

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<sup>6</sup>All tourism reports are available at <https://www.ois.amsterdam.nl/toerisme>.

<sup>7</sup>Previous work has typically estimated static models (Diamond, 2016) from decadal census data. More recent papers estimating dynamic models only focus on a subset of individuals. For example, Bayer et al. (2016) work with a subset of home-owners and infer location choices from house transactions, whereas Davis et al. (2017, 2018), and Diamond et al. (2018) obtain non-governmental data from companies that purchase data or scrape public records.

<sup>8</sup>Unfortunately, at this stage we do not have data on workplace locations neither on occupations.

follows, we present five facts that we incorporate in our model.

### Fact 1: Tourism flows have grown dramatically in Amsterdam

Amsterdam is a city with a remarkably high number of tourists relative to locals.<sup>9</sup> Moreover, the number of visitors per capita doubled between 2008 and 2017. In absolute numbers, overnight stays grew from 6 million in 2008 to almost 16 million in 2017. During the same time period, Amsterdam also experienced a proliferation of short-term rentals and the development of a significant number of large and high-end hotels. The number of Airbnb listings grew from zero in 2008 to around 25,000 in 2017, while the number of hotels grew from 374 to 484.<sup>10</sup> Airbnb is the main player in the short-term rental industry in Amsterdam with more than 80% of the market share, and accounting for approximately 15% of the total overnight stays in 2017.<sup>11</sup> See Figure 1 for more details.

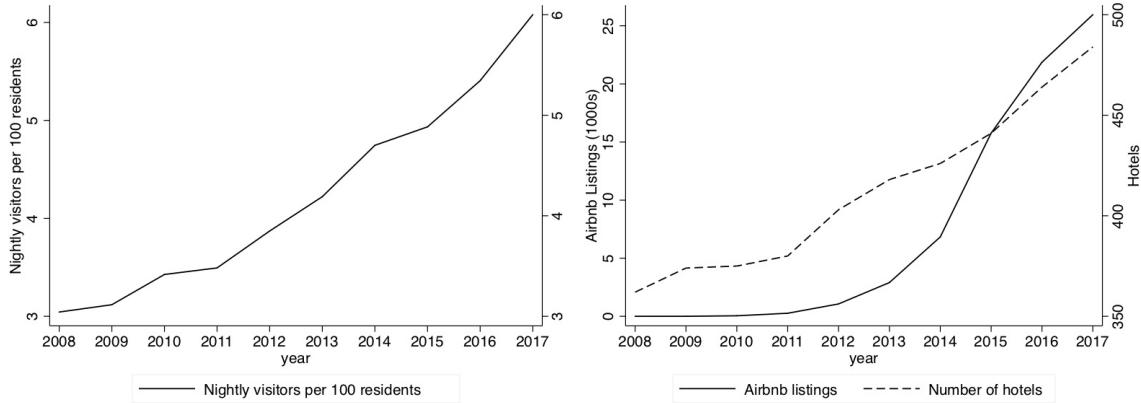


Figure 1: Volume of tourism per capita, number of hotels, and Airbnb listings.

Although both hotels and short-term rentals have experienced a surge in the last decade, their spatial distributions are significantly different. Whereas hotels tend to be concentrated in the city center due to zoning restrictions, Airbnb listings are spread out across the entire city. Figures 2 and 3 show how the number of hotel beds

<sup>9</sup> Amsterdam ranked fourth among major cities with the largest number of hotel guests per capita (5.1), only below Venice (8.1), Lisbon (5.8), and Florence (5.7). Source: <https://www.ois.amsterdam.nl/toerisme>.

<sup>10</sup> See Appendix C for more details about the hotel industry.

<sup>11</sup> Even though Airbnb entered in Amsterdam in 2008, we cannot detect any significant activity until 2011.

per capita and the evolution of the share of commercial Airbnb listings across space and time for 2011-2017.<sup>12</sup>

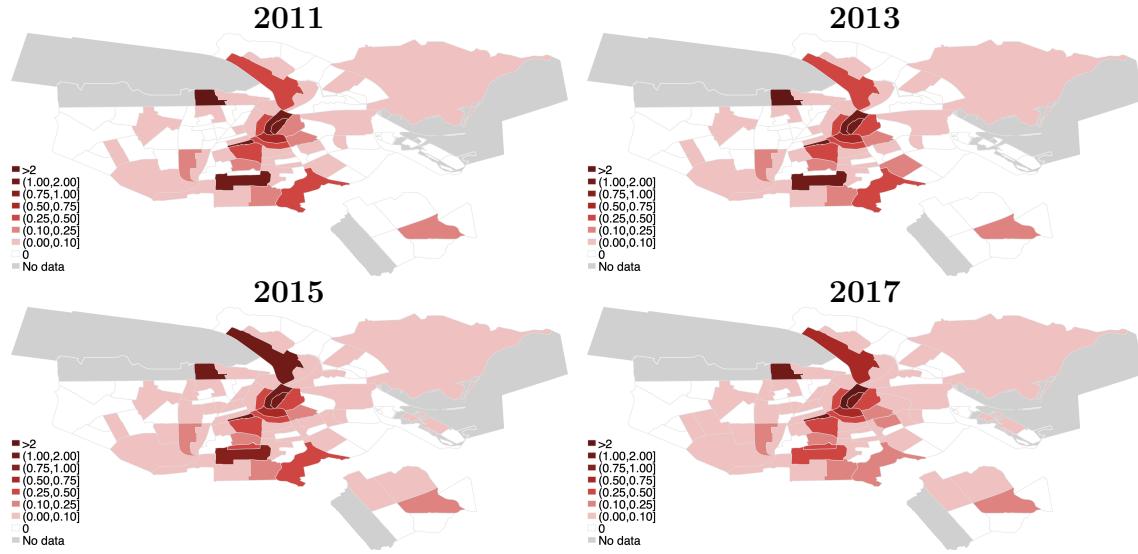


Figure 2: Number of hotel beds per capita: 2011-2017

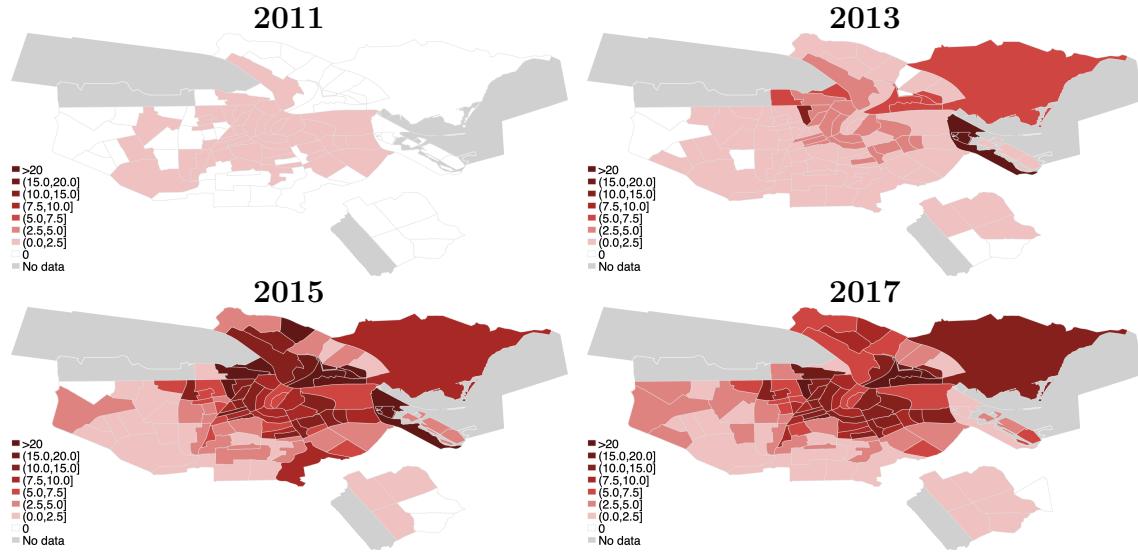


Figure 3: Commercial listings as a share of rental stock: 2011-2017

As expected, growth has been heterogeneous with central zipcodes reporting both more hotel beds per capita and higher Airbnb shares. Two main differences in the

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<sup>12</sup>We condition to neighborhoods with at least 500 inhabitants to remove industrial areas.

spatial distribution between hotels and Airbnb listings exist. First, whereas some neighborhoods have no hotels, all neighborhoods have a positive number of Airbnb listings. Second, hotels appear to be more concentrated in the city center than Airbnb listings. Our takeaway from this analysis is that Airbnb alters the spatial distribution of tourists, especially outside central Amsterdam.

### **Fact 2: Amenities are tilting towards tourists**

“Businesses related to tourism,” as defined by ACD’s classification, grew across all zipcodes during 2008-2017.<sup>13</sup> Moreover, the number of touristic services and the share of the population that corresponds to tourists are positively correlated, as shown in the top-right panel of Figure 4.<sup>14</sup> The opposite trend holds for nurseries, as shown in the bottom-left panel of Figure 4.<sup>15</sup> Moreover, as shown in the bottom-right panel, we see a negative relationship between the change in touristic businesses and the change in nurseries, suggesting the former are substituting the latter. Because touristic services cater relatively more toward tourists’ needs and nurseries more locals, we interpret these changes as a shift of consumption amenities toward tourists.

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<sup>13</sup>ACD defines touristic services as “accommodation and lodging, other restaurants, passenger reorganization and mediation, culture and recreation, marinas, sailing schools and recreational retail.”

<sup>14</sup>We define total population as the sum of the number of residents and the number of tourists.

<sup>15</sup>Nurseries represent “Kinderdagverblijf,” which is private child care.

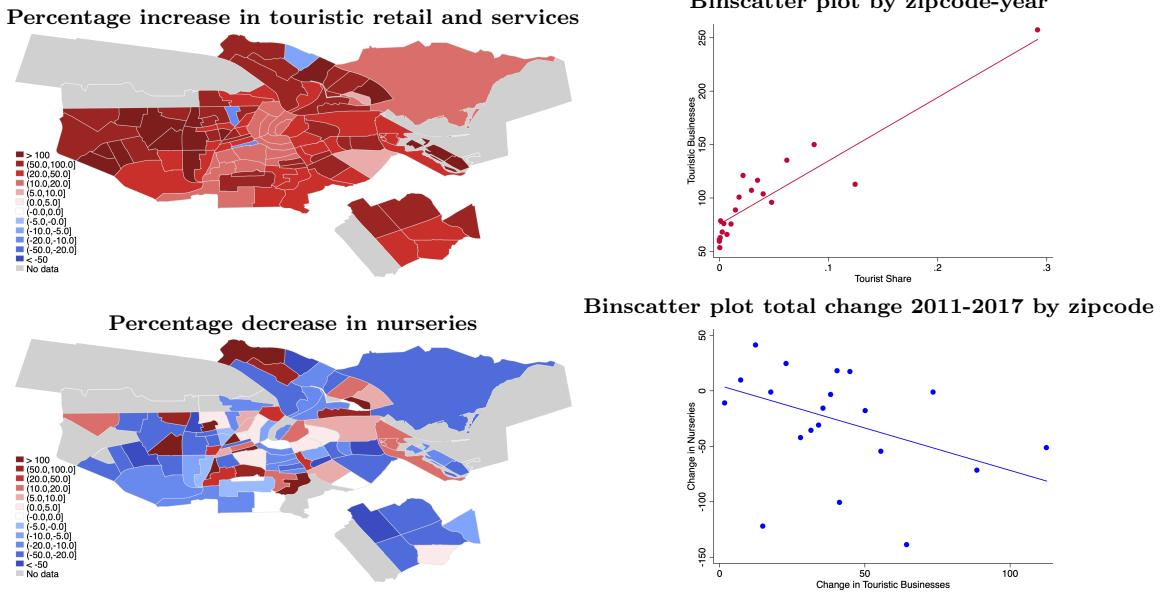


Figure 4: Growth between 2011-2017 for different consumption amenities

### Fact 3: Demographic composition is changing heterogeneously across zipcodes

Next, we want to explore the changes in the population of different demographic groups across space. In Figure 5, we plot the change in the population shares of different ethnic groups by zipcode, as defined by ACD. These demographic groups are Dutch, white non-Dutch, Moroccan, Antillean, Surinamese, Turkish, and other non-Westerns. First, substantial changes occur in the composition of neighborhoods between 2011-2017. Moreover, different groups present different trends. For example, groups with a Dutch or a Surinamese background are decreasing their size, locals with a Moroccan or Turkish background are leaving the city center, whereas groups with a white non-Dutch and other non-white background are increasing.

### Fact 4: Airbnb has a significant effect on rent and housing prices

Figure 3 shows that commercial Airbnb listings represented a large share of the rental stock, with some zipcodes above 20% as of 2017. Consequently, theory would predict an increase in rents and housing prices from a reduction in the housing supply

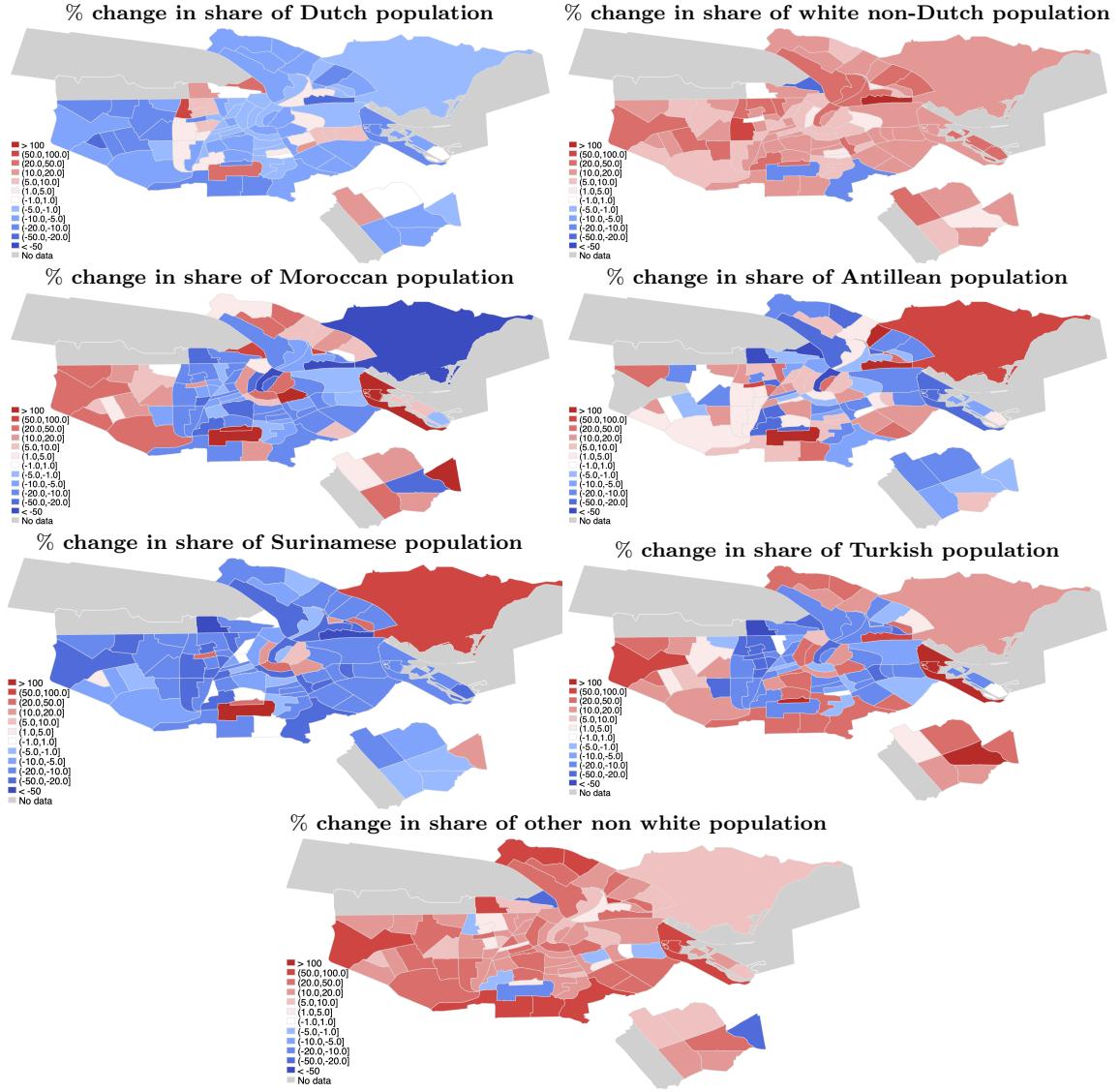


Figure 5: Percentage growth for shares of different demographic groups, 2011-2017

available to locals.<sup>16</sup> We test this hypothesis by adopting the following specification:

$$Y_{it} = \beta \text{listings}_{it} + \theta X_{it} + \eta_i + \lambda_t + \epsilon_{it}, \quad (1)$$

where  $Y_{it}$  is an outcome of interest for zipcode  $i$  in year  $t$ ,  $\text{listings}_{it}$  is the number of commercial Airbnb listings,  $\eta_i$  are zipcode effects,  $\lambda_t$  are time effects, and  $X_{it}$

<sup>16</sup>In 2015, home-owners, renters, and social housing represented 30%, 25%, and 45% of the total housing stock respectively. Therefore, a 5% and a 20% share of the rental stock allocated to Airbnb translates to a 2.3% and a 9% share of the market housing stock respectively. We exclude social housing from our analysis. See Appendix B.1.2 for the institutional details on social housing.

are zipcode-level, time-varying controls. We estimate (1) for rent and house prices. However, any time-varying unobservable variation included in  $\epsilon_{it}$  that correlates with Airbnb listings and rental prices will lead to biased OLS estimates. For example, neighborhoods that are becoming trendier could also have a higher number of Airbnb listings, because those neighborhoods would also be more attractive to tourists. We define this type of unobservable *gentrification trends*. To address this concern, we need to find an instrumental variable for  $\text{listings}_{it}$ . We follow the shift-share IV strategy from [Barron et al. \(2018\)](#) and [Garcia-López et al. \(2019\)](#), who estimate a similar specification as (1) for Airbnb listings across the entire United States and Barcelona, respectively. The “shift” part of the IV exploits time variation in global Google search volume for Airbnb, which has grown significantly in the post-2009 period. The “share” part exploits spatial variation in how touristic a zipcode is at a point in time before Airbnb entry. We build two instruments as follows:

$$Z_{it}^1 = \text{Touristic Businesses}_{i,2009} \times \text{Worldwide Google Search Index for "Airbnb"}_t$$

$$Z_{it}^2 = \text{Coffee shops}_{i,2015} \times \text{Worldwide Google Search Index for "Airbnb"}_t,$$

where  $\text{Tourism Businesses}_{i,2009}$  is the number of businesses related to tourism in 2009, and  $\text{Coffee shops}_{i,2015}$  is the number of Amsterdam coffee shops in 2015.<sup>17</sup> The exclusions restriction of this IV is that  $Z_{it}^k$  impacts  $Y_{it}$  only through  $\text{listings}_{it}$ , conditional on covariates; that is we assume the following:

$$\text{Cov}(\text{listings}_{it}, Z_{it}|X_{it}, \eta_i, \lambda_t) \neq 0 \quad (2)$$

$$\text{Cov}(\epsilon_{it}, Z_{it}|X_{it}, \eta_i, \lambda_t) = 0. \quad (3)$$

The exclusion restriction would fail if in the absence of listings growth, outcomes would have changed differently in more touristic, relative to less touristic, zipcodes. In Appendix A.1, we present evidence of the validity of our exclusion restriction by implementing the robustness checks proposed in [Goldsmith-Pinkham et al. \(2018\)](#). As for instrument relevance, in all our specifications we obtain a strong first stage relation.

Our IV specification in Table 1 shows that a 10% increase in listings leads to a 0.43% increase in house prices. It also shows that a 10% increase in commercial

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<sup>17</sup>By “coffee shops,” we mean establishments where marijuana can be purchased and consumed. These establishments are well known to be tourist-oriented and not to be frequented by locals. The first year of available observation in ACD is 2015.

Table 1: Dependent Variables: Ln House Prices and Ln Rent

	Ln House Prices		Ln Rent	
	OLS	IV	OLS	IV
<b>Ln Listings</b>	0.0233** (0.0112)	0.0434* (0.0248)	0.015*** (0.006)	0.050*** (0.014)
Housing Quality Controls	✓	✓	✓	✓
Tenancy Controls	✓	✓	✓	✓
Year Effects	✓	✓	✓	✓
Zipcode Effects	✓	✓	✓	✓
Observations	589	589	665	665
R <sup>2</sup>	0.380	0.371	0.763	0.746
F Statistic	21.73***	19.00***	164.044***	148.347***
F Statistic (1st stage)	-	186.05***	-	655.86***

*Note:* \*p<0.1; \*\*p<0.05; \*\*\*p<0.01. SE clustered at the zipcode-level.

listings leads to a 0.50% increase in rent, which is the same order of magnitude as found by [Barron et al. \(2018\)](#). Furthermore, it is economically significant, given that rents in Amsterdam were growing at approximately 2% per year during this period.

Finally, note the OLS estimates are downward biased. This finding suggests that unobservable trends that make neighborhoods more attractive to locals, and therefore drive up housing prices, are negatively correlated with Airbnb listings. We interpret this finding as suggestive evidence that neighborhoods with more Airbnb listings, and therefore more touristic areas, experience trends that make them less attractive to residents. One channel could be that consumption amenities are tilting away from locals' needs, or because congestion is being generated by tourists.

### Fact 5: Amenities correlate differently with different demographic groups

Finally, we explore the relation between the composition of neighborhoods and amenities. For the following exercise, we regress the number of touristic amenities on the number of people who belong to specific demographic groups. For this specification, we define groups by country of origin as defined by ACD, and we also include tourists as a separate group.<sup>18</sup> Table 2 shows the results for this regression, where we should interpret the coefficients as mere correlations. The results show that tourists

<sup>18</sup>We compute the total number of tourists in a neighborhood by summing the number of hotel beds and the number of Airbnb beds. The number of Airbnb beds is the number of listings multiplied by 4, because this is the average number of beds per listing. Finally, we multiply the total number of

Table 2: Log Touristic Amenities

	OLS	FE	
Log Pop Tourists	0.114*** (0.013)	0.024*** (0.011)	
Log Pop Dutch	-0.334*** (0.095)	0.164*** (0.082)	
Log Pop Antilles	-0.047 (0.070)	0.010 (0.032)	
Log Pop Morocco	-0.087*** (0.040)	0.068** (0.039)	
Log Pop Suriname	-0.200*** (0.079)	-0.096*** (0.072)	
Log Pop Turkey	0.085*** (0.041)	-0.020 (0.028)	
Log Pop White	0.118 (0.095)	0.260*** (0.129)	
Log Pop Other Non White	0.029 (0.093)	-0.080 (0.070)	
Log Total Pop	1.208*** (0.187)	-0.034 (0.073)	
Location FE		✓	
Time FE		✓	
<i>R</i> <sup>2</sup>	0.651	0.663	
Observations	713	713	
F Statistic	145.61***	65.48***	

Note: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01. SE clustered at zipcode-level.

as well as Dutch, Moroccan, and white non-Dutch residents are positively correlated with touristic amenities, Antillean, Turkish, and other non-white origin residents do not show any significant correlation, whereas residents of Surinamese descent are negatively correlated with touristic amenities. We conclude that different demographic groups determine different types of amenities.

To conclude, we have presented five facts that hold for Amsterdam during our sample period. First, Amsterdam is experiencing increasing inflows of tourists, and Airbnb alters their spatial distribution by dispatching them to areas where hotels do not enter. Second, amenities appear to be catering increasingly to tourists overs locals. Third, the demographic composition of neighborhoods is changing, and these changes are heterogeneous across zipcodes. Fourth, Airbnb has a significant effect on rents and housing prices. Finally, different demographic groups correlate in different ways with amenities.

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beds by the occupancy rate of the hotel industry for that year, where we assume that the occupancy rate for Airbnb is the same as for hotels.

## 5 A dynamic model of a residential market

To rationalize the previous findings, we build a dynamic model of a city's rental market that consists of three parts: amenities, households, and landlords.

First, we describe how amenities in a location respond to its demographic composition. For endogenous consumption amenities, we start by modelling a competitive market for consumption amenities where firms supply services, and households with heterogeneous preferences demand them. Thus, using equilibrium conditions for that market, we construct a function from the socioeconomic composition of each location, which includes tourists, to the total supply of amenities in each location. In our model, we also include exogenous amenities, such as distance to the train station, and endogenous public amenities, such as congestion generated by tourists.

Our second objective is to understand the opposite direction of the first channel: the role of endogenous amenities in residential choice. Our model consists of forward-looking households who, at the beginning of every period, choose a residential location at the beginning of every period, taking prices and consumption amenities as given. Households accumulate location capital from living in the same location over many periods, and their utility directly depends on it. Intuitively, as residents become more familiar with their surroundings over time, or develop social networks, they obtain more utility from their residential location. Every time households move, they lose their location capital and incur a moving cost. Location tenure helps us rationalize two features of the data. First, we observe a decreasing hazard rate of moving conditional on living in the same location as shown in Figure 6.<sup>19</sup>

Second, the literature commonly finds unreasonably large moving costs that rationalize the acute persistence in location decisions.<sup>20</sup> As location tenure is lost upon moving it can equivalently be seen as part of the moving cost. Hence, including location tenure gives flexibility to the moving costs and helps rationalize the observed persistence with more reasonable one-time payment moving costs.

Lastly, absentee landlords supply units of housing to households. Assuming a fixed housing stock, which we argue is reasonable in the context of Amsterdam, we allow tourism to have a direct effect on rental prices by splitting the rental market into

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<sup>19</sup>See also Diamond et al. (2018) for empirical evidence in the context of San Francisco.

<sup>20</sup>For example, we can calculate the income equivalent for the one-time payment of the psychological cost paid upon moving using the estimates found in Section 5.1 of Bayer et al. (2016). A back-of-the-envelope calculation leads to psychological costs of the order of 270,000 USD.

### Probability of changing address conditional on location tenure

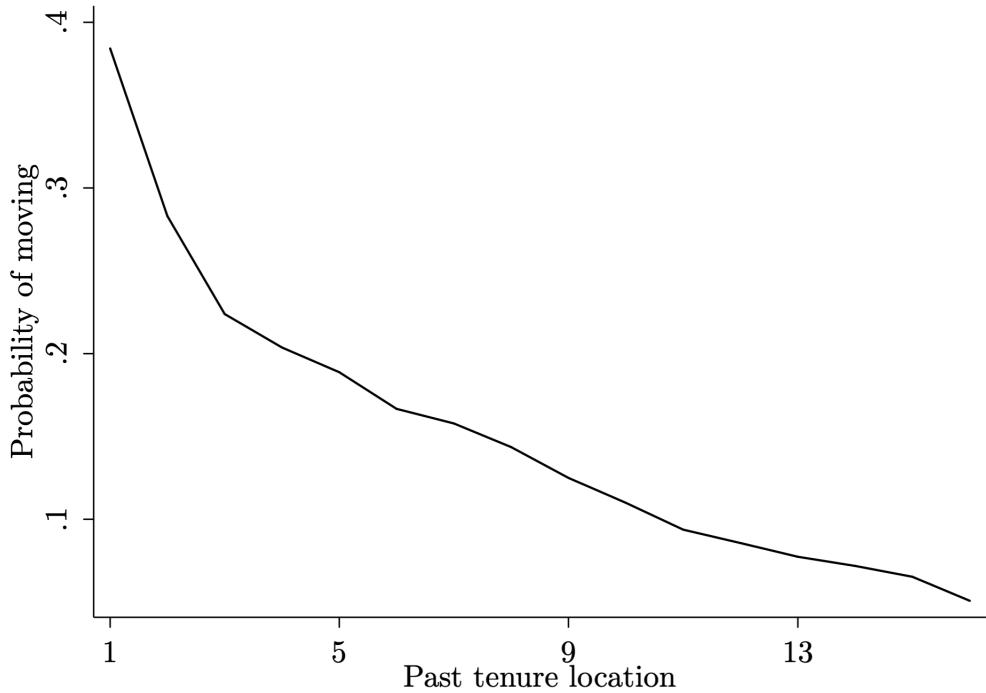


Figure 6: Decreasing hazard rate

two sub-markets: short-term rentals and long-term rentals. Every period, absentee landlords choose whether to rent their property full time to tourists in the former or to local residents in the latter. In this way, we endogenize housing supply available to locals through this binary decision. Finally, observe that both long-term housing prices as well as amenities are endogenous because they are determined in equilibrium for the residential market.

### 5.1 Endogenous amenities

In this section, we microfound how amenities respond to the demographic composition in each location. We assume  $S$  categories of services/consumption amenities (bars, restaurants, retail...) and  $K$  types of consumers representing different demographic groups, one of which is tourists. Each group has heterogeneous preferences over consumption amenities, and we assume they can only consume these amenities in

their residential location.<sup>21</sup> Within a service category, location, and time period, competitive firms offer products that are imperfect substitutes. In this way, residents experience “love-for-variety” as their indirect utility increases in the number of firms. We assume free entry, and that firms are small enough that individual pricing decisions do not affect the pricing decisions of other firms.

### 5.1.1 Amenities demand

In the following discussion, we fix the time period. Conditional on living in location  $j$ , a household of type  $k$  solves the following problem to maximize its utility over services:<sup>22</sup>

$$\max_{\{q_{is}\}_{is}} \prod_s \left( \left( \sum_{i=1}^{N_s} q_{is}^{\frac{\sigma_s-1}{\sigma_s}} \right)^{\frac{\sigma_s}{\sigma_s-1}} \right)^{\alpha_s^k} \quad \text{s.t.} \quad \sum_{is} p_{is} q_{is} = b_j^k, \quad (4)$$

where  $b_j^k$  is the budget that the household allocates to consumption amenities. We assume preferences are constant across time.

On the one hand, consumers have *CES preferences over products* with elasticity of substitution  $\sigma_s \in (1, \infty)$ . CES preferences imply a “love-for-variety” effect as utility increases in the number of firms. On the other hand, consumers have *Cobb-Douglas preferences over services*, which allows us to have different substitution patterns across different types of consumption amenities.

Demand for firm  $i$ 's good is

$$q_i^k = \frac{\alpha_s^k b_j^k}{P_s} \left( \frac{P_s}{p_i} \right)^{\sigma_s},$$

where the price index is given by  $P_s = (\sum_{i \in s} p_i^{1-\sigma_s})^{\frac{1}{1-\sigma_s}}$ . If we define  $s(p_i, P)$  as the budget expenditure shares for firm  $i$ , we can rewrite the demanded quantity from firm

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<sup>21</sup>Although this assumption is stark, evidence suggests urban residents disproportionately consume amenities, such as restaurants, that are located near their home. For example [Davis et al. \(2019\)](#) shows that commuting costs have a first order effect on restaurant consumption and that consumption segregation partly captures residential segregation. This assumption can be relaxed by allowing for commuting costs but we refrain from doing so for tractability purposes and to keep the model as parsimonious as possible.

<sup>22</sup>We can also allow households to buy a tradeable good available at all locations with normalized price equal to 1 as in [Couture et al. \(2019\)](#)

$i$  as,

$$q_i^k = \frac{\alpha_s^k b_j^k}{p_i} s(p_i, P).$$

Assuming  $M_j^k$  consumers of type  $k$  are living in location  $j$ , we can aggregate demand across consumers:

$$q_i = \sum_k M_j^k \frac{\alpha_s^k b_j^k}{p_i} s(p_i, P) = \frac{\sum_k M_j^k \alpha_s^k b_j^k}{p_i} s(p_i, P). \quad (5)$$

Hence, aggregate demand can be represented by a representative consumer with total budget  $\sum_k M_j^k \alpha_s^k b_j^k$  to spend on service  $s$ .

From the previous expression, it is easy to see that all firms in a specific location and providing service  $s$  face the same demand curve.

### 5.1.2 Amenities supply

Firm  $i$  supplying service  $s$  solves the following profit-maximization problem:

$$\max_{p_i} q_i(p_i)(p_i - c_i),$$

where  $c_i$  is the marginal cost for firm  $i$ . We assume marginal costs  $c_i$  are constant across firms selling service  $s$  in the same location and given by<sup>23</sup>

$$c_i = c_{sj}.$$

Thus, prices are set as

$$p_i = \frac{c_{sj}}{1 - \frac{1}{\varepsilon_i^D(p_i)}},$$

where  $\varepsilon_i^D(q_i)$  is the price elasticity of aggregate demand for product  $i$  at price  $p_i$ . Therefore, all firms have the same pricing functions. Provided a large number of firms are present, the pricing decision of one firm has negligible effects on the price

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<sup>23</sup>For example, if land prices (capital) as well as wages are location and service-specific, this assumption will hold true.

index, and therefore<sup>24</sup>

$$\mathcal{E}_{ik}^D(p_i) = \frac{\partial q_i^k}{\partial p_i} \frac{p_i}{q_i^k} = -\sigma_s.$$

Substituting, the pricing curve of firm  $i$  is finally given by

$$p_i = \frac{c_{sj}}{1 - \frac{1}{\sigma_s}}.$$

Observe that prices do not depend directly on types because what matters for firms is aggregate demand that is summarized by the representative consumer.

### 5.1.3 Amenities equilibrium

Given that all firms providing service  $s$  have the same pricing function and face the same demand curve, the unique equilibrium is symmetric

$$q_i = q_s \quad \text{and} \quad p_i = p_s \quad \forall i \in s.$$

In the symmetric equilibrium, it follows that consumers buy equally from all firms offering the same service,

$$s(p_i, P) = \frac{1}{N_{sj}},$$

where  $N_{sj}$  are the number of firms in location  $j$  selling product  $s$ . Quantity demanded from firm  $i$  is given by

$$q_i = \frac{\sum_k M_j^k \alpha_s^k b_j^k}{p_s N_{sj}}.$$

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<sup>24</sup>If we include the effect of  $p_i$  on  $P$ , the elasticity of demand is given by:

$$\mathcal{E}_{ik}^D(p_i) = -\left((1 - \sigma_s)\frac{\alpha_s^k b_j^k}{N_{js}} + \sigma_s\right),$$

where  $N_{js}$  is the number of firms in location  $j$  selling product  $s$ , so the first term is small when  $N_{js}$  is large. Under this more general form, we can also derive a mapping from the demographic composition to consumption amenities, but algebra becomes substantially more complicated, as the number of firms will be non-linear in the number of households for each type.

Denote location-service specific entry costs by  $F_{sj}$ . Due to free entry, there are no profits in equilibrium.<sup>25</sup> Thus,

$$q_i(p_i - c_i) = F_{sj}.$$

Recall prices are given by

$$p_i = \frac{c_i}{1 - \frac{1}{\sigma_s}}.$$

Substituting aggregate equilibrium quantities, prices, and marginal costs gives us

$$\frac{1}{p_i N_{sj}} \sum_k M_j^k \alpha_s^k b_j^k (p_i - c_i) = \frac{1}{\sigma_s N_{sj}} \sum_k M_j^k \alpha_s^k b_j^k = F_{sj}.$$

Thus, the number of establishments at location  $j$  providing service  $s$  is given by

$$N_{sj} = \frac{\sum_k M_j^k \alpha_s^k b_j^k}{F_{sj} \sigma_s}. \quad (6)$$

We define the vector of consumption amenities for each location as the vector of the number of firms in each service category:

$$a_j \equiv [N_{1j}, N_{2j}, \dots, N_{Sj}] = \mathcal{A}(M_j^1, \dots, M_j^K, M_j^T),$$

where  $\mathcal{A}$  is the mapping derived by equilibrium conditions in the amenities market as in (6). Observe that the previous mapping includes tourists, represented by  $M_j^T$ . For our application, tourists will include both tourists staying in hotels and in short-term rentals.

A novel property of this mapping is that different sectors have their sector-specific market features such as the level of competition or entry costs. This heterogeneity across sectors is summarized by the parameters  $F_{sj}$  and  $\sigma_s$ . As  $\sigma_s$  increases, products become closer substitutes, so monopoly power decreases, and incentives to enter decrease. Similarly, higher entry costs,  $F_{sj}$ , disincentivize entry. Therefore, the term  $F_{sj} \sigma_s$  represents the barriers for firms to operate in this market.

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<sup>25</sup>We implicitly assume firms are static, for tractability purposes. If firms were dynamic, part of the surplus would be their continuation values, which we can assume are discounted in the entry cost. Nevertheless, competition and free-entry implies zero profits in equilibrium. Hence, whether firms are dynamic or static has no effect on their surplus. On the other hand, below we show that households' welfare depends only on the number of firms, and not on their identity. Although introducing dynamic firms would lead to a different number of operating firms as compared to a static world, that number of firms can always be rationalized with a different entry cost. In this way, a model with dynamic firms will deliver the same total welfare as a model with static firms with the appropriate entry cost.

## 5.2 Housing demand

We now present the location-choice problem for a type  $k$  household, following a similar exposition as in [Scott \(2013\)](#) and [Diamond et al. \(2018\)](#). For the marginal utility of money in our indirect utility function, we follow a similar specification as in [Couture et al. \(2019\)](#), where households earn annual income  $w_t^k$ , pay  $r_{jt}$  for a unit of housing, leaving them with total budget  $b_{jt}^k = w_t^k - r_{jt}$  for consumption amenities.<sup>26</sup> At the beginning of every period  $t$ , a household  $i$  chooses where to live among  $J$  different locations, as well as an outside option of leaving the city.<sup>27</sup> We denote this decision by  $d_{it}$  and it is determined as follows:

$$d_{it} = \begin{cases} s & \text{if the household stays in the same housing unit, and thus location as in } t-1 \\ j & \text{if the household moves to a housing unit located in location } j \in \{1, \dots, J\} \\ 0 & \text{if the household moves outside of the city.} \end{cases}$$

To be clear, if  $d_{it} = j_{it-1}$  the household changes its housing unit but stays in the same location.

The state variables  $j_{it}$  and location tenure  $\tau_{it}$  evolve deterministically as follows

$$\begin{aligned} j_{it} &= \begin{cases} j_{it-1} & \text{if } d_{it} = s \\ d_{it} & \text{otherwise,} \end{cases} \\ \tau_{it} &= \begin{cases} \min\{\tau_{it-1} + 1, \bar{\tau}\} & \text{if } d_{it} \in \{s\} \cup \{j_{it-1}\} \\ 1 & \text{otherwise,} \end{cases} \end{aligned}$$

where we have assumed tenure can be accumulated up to a maximum absorbing state  $\bar{\tau}$ .

Preference parameters differ by household type, which we index by  $k$ . A household  $i$  of type  $k$  living in location  $j$  pays rent  $r_{jt}$ , derives utility from location capital  $\tau_{it}$ , a vector of endogenous amenities  $a_{jt}$ , which includes a vector of consumption amenities

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<sup>26</sup>This specification for the marginal utility of money has been widely used in the industrial organization literature, see for example [Berry \(1994\)](#), [Berry et al. \(1995\)](#), or [Nevo \(2000\)](#). We can also assume that the budget spent in consumption amenities is a share of  $w_t^k - r_{jt}$ ,  $b_{sjt}^k = \lambda^k \alpha_s^k (w_t^k - r_{jt})$ . In this case, our estimation procedure recovers the same coefficient but we cannot identify  $\lambda^k$  because it is absorbed by the location fixed effect.

<sup>27</sup>In our application, a location is a zipcode, “wijk,” in Amsterdam.

(services),  $services_{jt}$ , congestion from tourists,  $cong_{jt}$ , a type-specific location fixed effect,  $\delta_j^k$ , and a type-specific time-varying location's underlying quality,  $\xi_{jt}^k$ .<sup>28</sup> Upon moving, the household incurs a moving cost that depends on the distance between two locations  $dist(j, j')$ :<sup>29</sup>

$$MC^k(d, j_{it-1}) = \begin{cases} m_0^k + m_1^k dist(d, j_{it-1}) & \text{if } d \neq s \\ 0 & \text{if } d = s. \end{cases}$$

To condense notation, we denote  $\omega_t$  as the vector of global state variables:

$$\omega_t = (r_t, p_t, a_t, \xi_t),$$

and  $x_{it}$  as the individual state variables at the time of the decision:

$$x_{it} = (j_{it-1}, \tau_{it-1}).$$

Therefore, at time  $t$ , household  $i$ 's indirect utility for decision  $d$  before the idiosyncratic shock is realized is,

$$u_t^k(d, x_{it}, \omega_t) = \delta_{j(d)}^k + \delta_\tau^k \tau_{it} + \delta_w^k \ln(w_t^k - r_{j(d)t}) + \delta_a^k \ln a_{j(d)t} - MC^k(d, j_{it-1}) + \xi_{jt}^k, \quad (7)$$

which can be micro-founded using utility function 4. See Appendix E.1 for more details.<sup>30</sup> In what follows, we denote with subscript  $t$  the functions that depend on the state variable  $\omega_t$ . Household  $i$ 's value function is defined as

$$V_t^k(x_{it}, \epsilon_{it}) = \max_D \mathbb{E}_t \left[ \sum_{s \geq t}^{\infty} u_s^k(d, x_{is}) + \epsilon_{idt} | d_{it}, x_{it}, \epsilon_{it} \right],$$

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<sup>28</sup>For our empirical application, we assume congestion effects  $cong_{jt}$  are a linear function of the share of tourists in a location.

<sup>29</sup>We assume the geographic distance between neighborhoods is a good proxy for how similar those neighborhoods are given the spatial correlation across locations.

<sup>30</sup>In Appendix E.1.1, renters can also choose to supply part of their unit to tourists by subletting a fraction of it, hence benefiting from the “sharing economy.” In principle, this channel allows for redistributive effects of short-term rentals. We refrain from doing so here for two reasons. First, according to a CBRE 2017 report on the hospitality industry in America, 81% of the revenue from short-term rentals corresponds to commercial operators. This large share indicates most of the Airbnb usage comes from professional hosts. Second, from a theoretical point of view, in equilibrium, these effects are dampened as households' higher valuations for housing units increase housing demand, which finally translates into higher rental prices. Thus, the positive effects on households' welfare are diminished by higher rents, and these gains from the sharing economy will also be captured by landlords.

where the maximization is taken over policy functions  $D : \mathcal{X} \times \Omega \times \mathbb{R}^J \rightarrow \{s, 0, 1, \dots, J\}$ . Given the recursive nature of the problem, we can write

$$\begin{aligned} V_t^k(x_{it}, \epsilon_{it}) &= \max_D \mathbb{E}_t \left[ \sum_{s \geq t}^{\infty} u_s^k(d, x_{is}) + \epsilon_{is} | d_{it}, x_{it}, \epsilon_{it} \right] \\ &= \max_{d \in \{s, 0, 1, \dots, J\}} u_t^k(d, x_{it}) + \epsilon_{it} + \beta \mathbb{E}_t \left[ V_{t+1}^k(x_{it+1}, \epsilon_{it+1}) | d, x_{it}, \epsilon_{it} \right]. \end{aligned}$$

Because idiosyncratic shocks are assumed to be i.i.d. type I EV errors, the probability that a type  $k$  household chooses neighborhood  $j$  has the following closed form:

$$\mathbb{P}_t^k(j|x_{it}) = \frac{\exp \left( u_t^k(j, x_{it}) + \beta \mathbb{E}_t \left[ V_{t+1}^k(x_{it+1}, \epsilon_{it+1}) | j, x_{it}, \epsilon_{it} \right] \right)}{\sum_{j'} \exp \left( u_t^k(j', x_{it}) + \beta \mathbb{E}_t \left[ V_{t+1}^k(x_{it+1}, \epsilon_{it+1}) | j', x_{it}, \epsilon_{it} \right] \right)}. \quad (8)$$

and long-term demand from type  $k$  households is given by,

$$\mathcal{D}_{jt}^{Lk} = \sum_x \mathbb{P}_t^k(j|x) M_{xt}^k,$$

where the sum is taken over individual states  $x$ , so  $M_{xt}^k$  is the number of households of type  $k$  with individual state  $x$  at time  $t$ . Total demand for neighborhood  $j$  is obtained by summing the previous expression over all types of households  $k$ ,

$$\mathcal{D}_{jt}^L = \sum_k \sum_x \mathbb{P}_t^k(j|x) M_{xt}^k. \quad (9)$$

### 5.3 Housing supply

Each location  $j$  has a fixed supply of housing units denoted by  $\mathcal{H}_j$ .<sup>31</sup> Every period, absentee landlords choose to rent their unit in the traditional long-term market to locals, or in the short-term rental market to tourists.<sup>32</sup> The landlord's problem in

<sup>31</sup>Even though this assumption could be stark for many contexts, we believe is a credible hypothesis for the case of Amsterdam. Due to the soil quality and regulations present in Amsterdam there is very little new construction. The average growth of housing units is 0.9% with an average of 3700 new units every year from 2011 to 2018.

<sup>32</sup>We can also allow for an outside option, that is, leaving the house empty. We refrain from doing so for two reasons. First, we do not observe empty houses. Second, we expect the share of empty houses to be close to zero in the case of Amsterdam, because strict regulations prevent housing units from being vacant. See <https://www.amsterdam.nl/en/housing/obligation-homeowner/> for more details. Regardless, our analysis remains valid for the subset of landlords who do not leave

location  $j$  is given by

$$\max_{h \in \{L, S\}} \left\{ \alpha r_{jt} + \epsilon_L, \quad \alpha p_{jt} - \kappa_{jt} + \epsilon_S \right\},$$

where:

- $\alpha$  is the landlord's marginal utility of rental income.
- $p_{jt}$  is the short-term rental income and  $r_{jt}$  is the long-term rental income.
- $\kappa_{jt}$  is the differential cost between the two markets, which we interpret as differential matching and managerial costs, and occupancy rates. This  $\kappa_{jt}$  is unobservable to the econometrician and rationalizes different long-term rental shares across time and space.
- $\epsilon_L, \epsilon_S$  are idiosyncratic shocks assumed to be i.i.d. type I EV errors.

We index landlords by  $l$ . The total supply in the long- and short-term rental market in neighborhood  $j$  is given respectively by

$$\mathcal{H}_{jt}^L = \int_{l \in j} \mathbb{1}\{h_{lt} = L\} dl, \quad \text{and} \quad \mathcal{H}_{jt}^S = \int_{l \in j} \mathbb{1}\{h_{lt} = S\} dl.$$

where

$$\mathcal{H}_{jt}^L + \mathcal{H}_{jt}^S = \mathcal{H}_j.$$

Because  $\epsilon_L, \epsilon_S$  are i.i.d. type I EV errors, the share of rental units in each market is respectively given by

$$s_{jt}^L = \frac{\mathcal{H}_{jt}^L}{\mathcal{H}_j} = \frac{\exp(\alpha r_{jt})}{\exp(\alpha r_{jt}) + \exp(\alpha p_{jt} - \kappa_{jt})},$$

$$s_{jt}^S = \frac{\mathcal{H}_{jt}^S}{\mathcal{H}_j} = \frac{\exp(\alpha p_{jt} - \kappa_{jt})}{\exp(\alpha r_{jt}) + \exp(\alpha p_{jt} - \kappa_{jt})}.$$

We assume locals demand long-term rentals given the demand function derived in (9). In addition to households, tourists also demand housing for short-term stays. As suggested by empirical evidence, we assume short-term rentals average yearly prices are optimally set slightly below the prices of three-star hotels, and that the effects of the short-term rental industry on the hotel industry is small.<sup>33</sup> We argue this

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their housing unit empty.

<sup>33</sup>See Appendix C for more details.

assumption is reasonable in the case of Amsterdam for two reasons. First, in 2016, the year with the largest amount of Airbnb listings, short-term rentals accounted for 15% of overnight stays. Second, consumers' utility for up-scale Airbnb listings can be compared to the mean of mid-scale or economy hotels, so consumers perceive hotels as a different product of higher quality (Farronato and Fradkin, 2018). Given that hotels are not operating at full capacity, setting average prices above mid-scale hotels cannot be optimal for hosts.<sup>34</sup>

## 5.4 Equilibrium

A stationary equilibrium in this model is

- a set of price vectors  $\{r, p\}$  and a matrix of endogenous amenities  $a$ ,
- a policy function  $h(r_j, p_j; \kappa_j, \epsilon_l)$  for landlords,
- a policy function  $d^k(r, p, a, j_i, \tau_i; \epsilon_i)$  for each type  $k$  local, with associated value functions  $V^k(x, \omega, \epsilon)$ ,
- a stationary distribution of agent types over locations and tenure lengths,  $\pi^k(j, \tau)$ , which delivers a socioeconomic composition vector  $M_j$  for each location,

such that

- each landlord  $l$  supplies housing optimally to locals or tourists given prices  $\{r_j, p_j\}$ , by choosing  $h_l = h(r_j, p_j; \kappa_j, \epsilon_l)$ , so that long-term and short term rental supply in location  $j$  are given respectively by

$$\mathcal{H}_j^L(r_j, p_j; \kappa_j) = \int_{l \in j} \mathbb{1}\{h_l = L\} dl = \frac{\exp(\alpha r_j)}{\exp(\alpha r_j) + \exp(\alpha p_j - \kappa_j)} \mathcal{H}_j$$

$$\mathcal{H}_j^S(r_j, p_j; \kappa_j) = \int_{l \in j} \mathbb{1}\{h_l = S\} dl = \frac{\exp(\alpha p_j - \kappa_j)}{\exp(\alpha r_j) + \exp(\alpha p_j - \kappa_j)} \mathcal{H}_j,$$

- each household  $i$  of type  $k$  demands housing optimally by choosing  $d_i = d^k(r, p, a, j_i, \tau_i; \epsilon_i)$  given market state variables  $\omega = (r, p, a)$  and individual state variables  $x_i =$

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<sup>34</sup>To support prices below mid-scale hotels, demand for short-term rentals needs to be large enough. In this paper, we do not estimate this demand and any parameters needed for counterfactual simulations are borrowed from Farronato and Fradkin (2018).

$(j_i, \tau_i)$ , so that long-term rental demand in location  $j$  is given by

$$\begin{aligned}\mathcal{D}_j^L(r, p, a, j, \tau) &= \int \mathbb{1}\{j(d_i, j_i) = j\} di \\ &= M \sum_k \sum_{\tau} \left[ \mathbb{P}^k(s|j, \tau) \pi^k(j, \tau) + \sum_{j'} \mathbb{P}^k(j|j', \tau) \pi^k(j', \tau) \right],\end{aligned}$$

where  $M$  is the market size.

- prices  $r, p$  clear the short, and long-term markets in each location  $j$ ,

$$\mathcal{H}_j^L(r_j, p_j; \kappa_j) = \mathcal{D}_j^L(r, p, a, j, \tau) \quad \text{and} \quad \mathcal{H}_j^S(r_j, p_j; \kappa_j) = \mathcal{D}_j^S(p).$$

- amenities supply is equal to amenities demand, where equilibrium amenities are determined by the socioeconomic distribution through the mapping  $\mathcal{A}(\cdot)$ , as described in our amenities model,

$$a_j = \mathcal{A}(M_j^1, \dots, M_j^K, M_j^T).$$

## 6 Estimation

### 6.1 Defining heterogeneous households

Because we are interested in distributional effects, we need to define groups of households, and classify households into these groups. These groups are assumed to differ in their preference parameters, which we estimate.

Previous literature typically defines groups ex ante based on observable demographics, such as race or income (Bayer et al., 2016; Davis et al., 2018). Given the large set of household characteristics that we observe, classifying on all observables would result in a large number of groups, some with very few observations. Having many small groups leads to poorly estimated parameters for two reasons. First, as the number of groups gets large, the number of observations for each group decreases, and therefore the variance of the estimates increases, presenting a classic bias-variance trade-off. More importantly, groups with a low number of individuals imply poorly estimated CCPs with large measurement errors. These poorly estimated CCPs lead to biases in the second step of the utility parameters in the demand estimation.

Our goal is to have a few groups as possible while capturing the relevant heterogeneity. In this paper, we group households using a *k-means* classification method,

and we separately estimate demand for each group. Clustering on k-means allows us to reduce the dimensionality of demographics, while keeping groups that are significantly different from each other. See Appendix D.4 for the technical details of our classification method.

In Figure 3, we show the average demographics for the resulting 12 groups in our k-means classification. In Figures 7, 8, and 9, we plot the change in composition share for these demographic groups across all zipcodes in Amsterdam. We observe an exodus from the city center for households in the social housing groups.<sup>35</sup> A similar, although less stark tendency, is evident for home-owners. On the other hand, renters are becoming more prevalent in the city center. Finally, in Figure 10 we present evidence of a decreasing hazard rate of moving conditional on location tenure.

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<sup>35</sup>Households in the social housing groups are fully excluded from the demand estimation for locations.

Table 3: Average demographics by cluster

	Group	Name	Skill			Income				Share Children	Age	Background origin				N
			% L	% M	% H	Pctl. Tot. Inc.	Total Inc.	Pctl. Inc PP	Inc. PP			Dutch	Dutch Col.	Western	Non West.	
Home Owners	1	H skill, Young, Singles	0.01	0.03	0.95	0.34	24000	0.42	22100	0.13	32	0.57	0.08	0.17	0.18	47990
	2	L+M skill, Immigrant Families	0.40	0.58	0.01	0.50	32800	0.45	22500	0.78	47	0.37	0.22	0.11	0.29	18829
	3	H skill, High inc., Young EU Families	0.00	0.00	1.00	0.68	53700	0.67	36300	0.89	36	0.64	0.08	0.15	0.13	72568
	4	H skill, High inc., Old Dutch Families	0.01	0.00	0.99	0.77	72300	0.79	51600	0.77	55	0.79	0.09	0.08	0.04	43246
Renters	5	H Skill, Low inc., Young, EU, Singles	0.02	0.04	0.94	0.19	14900	0.23	14000	0.06	27	0.62	0.04	0.18	0.16	71805
	6	H Skill, Low inc., Young, Immigrant Families	0.04	0.07	0.88	0.33	22800	0.32	17500	0.80	31	0.50	0.06	0.22	0.22	39467
	7	H Skill, High inc., Old Dutch, Families	0.20	0.11	0.69	0.53	38400	0.56	30200	0.61	58	0.66	0.11	0.12	0.11	25740
	8	H Skill, High inc., Young, EU, Families	0.00	0.01	0.99	0.70	59000	0.74	44100	0.69	36	0.55	0.05	0.26	0.15	45855
Social Housing	9	H skill, Low inc., Young Singles	0.01	0.00	0.99	0.20	15300	0.23	13800	0.16	29	0.56	0.10	0.12	0.22	88002
	10	L skill, Low inc., Old Immigrant Families	1.00	0.00	0.00	0.40	26100	0.32	17100	0.75	50	0.17	0.12	0.10	0.61	41416
	11	M skill, Low inc., Mixed Background Families	0.00	1.00	0.00	0.37	24300	0.33	17600	0.65	40	0.29	0.37	0.06	0.28	42076
	12	H skill, Medium inc., Dutch Families	0.00	0.00	1.00	0.52	35100	0.51	25600	0.78	43	0.59	0.13	0.10	0.17	77416

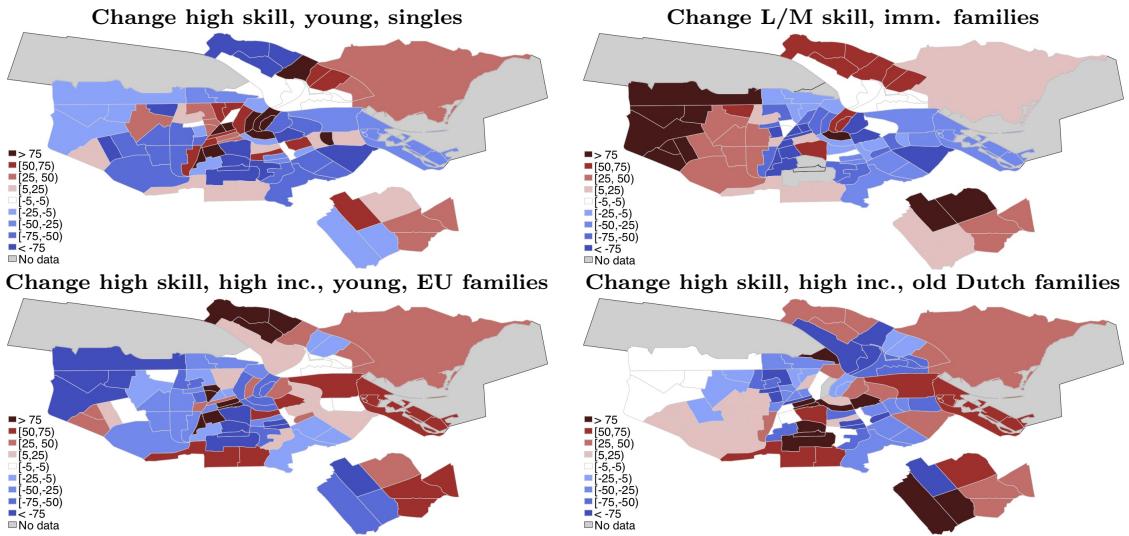


Figure 7: Percentage growth for shares of clusters of homeowners, 2011-2017

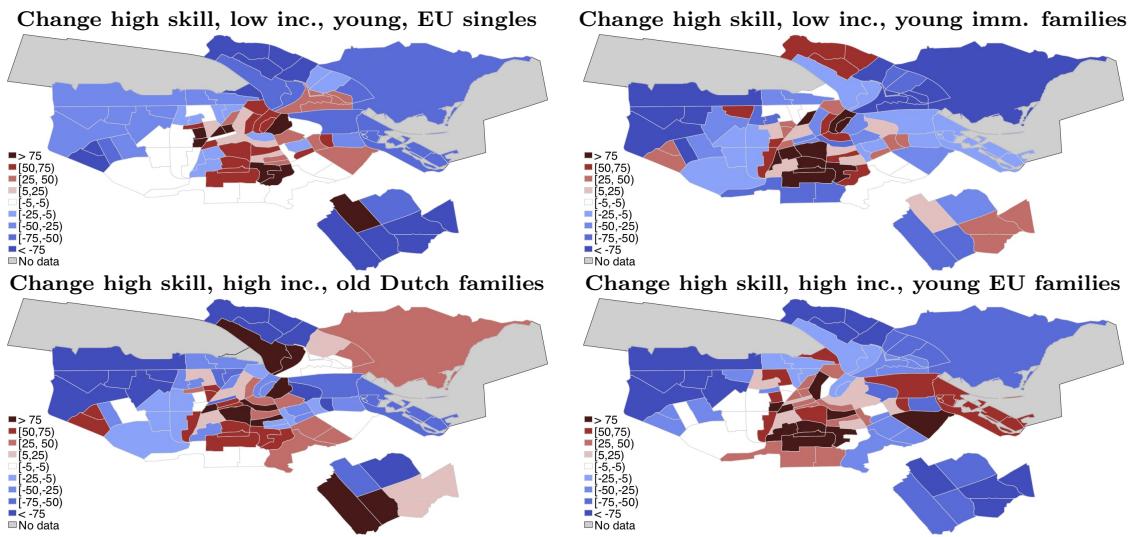


Figure 8: Percentage growth for shares of clusters of renters, 2011-2017

Probability of moving conditional on location tenure for the groups of home-owners and renters

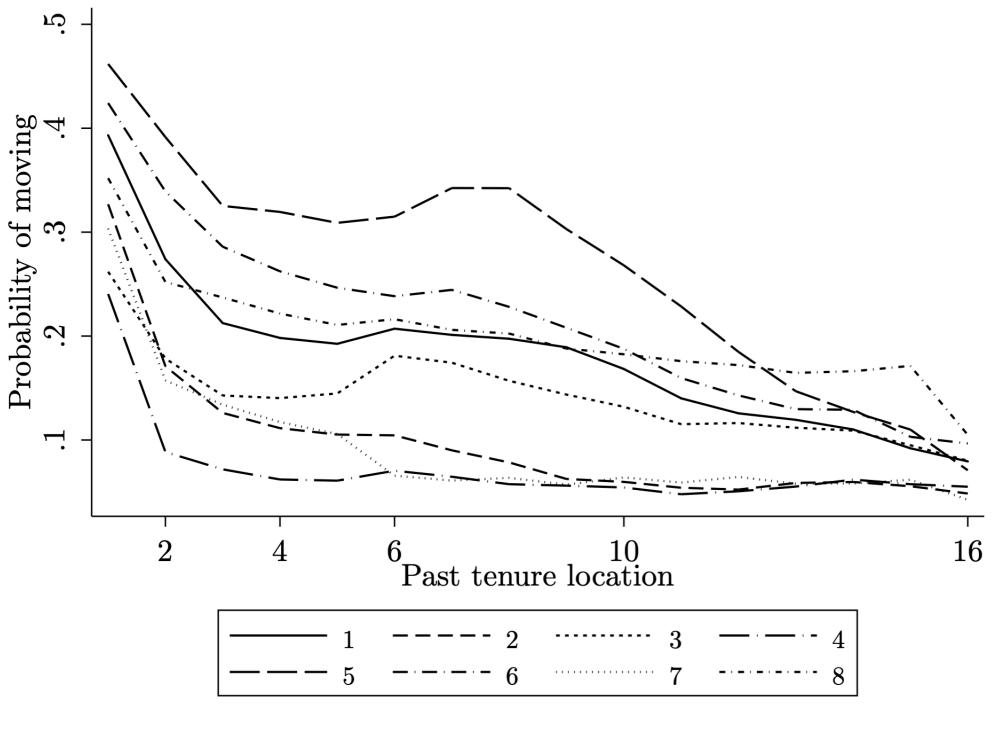


Figure 10: Decreasing hazard rate

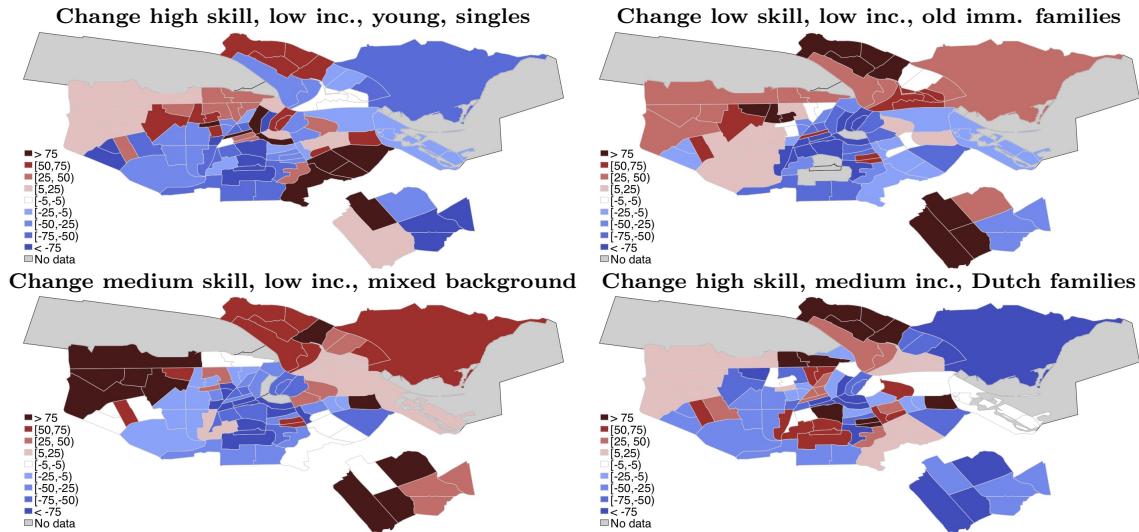


Figure 9: Percentage growth for shares of clusters for social housing, 2011-2017

## 6.2 Amenities

Following the derivation of equilibrium amenities in section 5.1, for every combination  $n = (s, j, t)$ , we can form the following equation:

$$N_{sjt} = \frac{1}{\sigma_s F_{sjt}} \sum_k M_{jt}^k \alpha_s^k (w_t^k - r_{jt}),$$

where individual types correspond to the k-means cluster types as well as tourists.

We assume fixed costs can be represented in the following way:

$$F_{sjt} = \Lambda_s \Lambda_j \Lambda_t \Psi_{sjt},$$

where  $\Lambda_s$ ,  $\Lambda_j$ , and  $\Lambda$  shift entry costs across sectors, locations, and time, respectively, and  $\Psi_{sjt}$  is an error term. Taking logs, we obtain

$$\begin{aligned} \log N_{sjt} &= -\log \sigma_s - \log F_{sjt} + \log \left( \sum_k M_{jt}^k \alpha_s^k (w_t^k - r_{jt}) \right) \\ &= \lambda_s + \lambda_j + \lambda_t + \log \left( \sum_k M_{jt}^k \alpha_s^k (w_t^k - r_{jt}) \right) + \psi_{sjt}, \end{aligned} \quad (10)$$

where  $\psi_{sjt} \equiv -\log \Psi_{sjt}$ ,  $\lambda_s \equiv -\log \sigma_s - \log \Lambda_s$ ,  $\lambda_j \equiv -\log \Lambda_j$ , and  $\lambda_t \equiv -\log \Lambda_t$ .<sup>36</sup> The parameter  $\lambda_s$ , which is service specific, can be interpreted as barriers to entry or the level of competition for service  $s$ .

The identifying assumption for the previous equation is that unobservables in  $\psi_{sjt}$  are not correlated with the total budget allocation of household  $k$  to service  $s$  for residents of location  $j$ , that is, to  $M_{jt}^k (w_t^k - r_{jt})$ . To address endogeneity concerns, we use a shift-share instrument, where the share component is motivated by the BLP instruments (Berry et al., 1995).<sup>37</sup> We take the share term as the average share of social housing *outside* of that zipcode,  $sss_{-j,t}$ . The shift term for every group is the total income for households in that group *across all* of Amsterdam,  $M_t^k w_t^k$ . The idea for the shift-share instrument,  $sss_{-j,t} M_t^k w_t^k$ , is that it predicts the share of group  $k$ 's budget,  $M_t^k w_t^k$ , that is spent in neighborhood  $j$ . The reason is that as different demographic groups qualify or do not qualify for social housing, moving the share of social housing outside neighborhood  $j$  effectively moves the share of people of group  $k$  who live in neighborhood  $j$ . This construct is analogous to the BLP instruments where moving the characteristics of other products moves the demand for the product

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<sup>36</sup>Observe that parameters  $(\lambda_s, \alpha_s^1, \dots, \alpha_s^K)$  are not separately identified. Therefore, to estimate equation 10 we make the normalization  $\sum_k \alpha_s^k = 1$ .

<sup>37</sup>Bayer et al. (2007) also use a similar instrument in a residential choice problem.

$j$  through substitution between choices. Hence, we can expect the relevance condition to be satisfied

$$\text{Cov}\left(M_t^k w_t^k sss_{-j,t}, M_{jt}^k (w_t^k - r_{jt})\right) \neq 0$$

The exclusion restriction requires

$$\mathbb{E}[M_t^k w_t^k sss_{-j,t} \psi_{sjt}] = 0.$$

The above is satisfied under the assumption that the total disposable income of group  $k$  at time  $t$ ,  $M_t^k w_t^k$ , is orthogonal to the component of entry costs,  $\psi_{sjt}$ , and that both variables are independent from the average share of social housing outside  $j$ ,  $sss_{-j,t}$ . We argue these assumptions are likely to be true because: First, we do not expect the city's total budget for group  $k$ ,  $M_t^k w_t^k$ , to be correlated with the entry cost of location  $j$ ,  $\psi_{jt}$ , because  $M_t^k w_t^k$  is a global trend that does not carry information about individual locations. Second, the share of social housing is determined by a point system that is defined *nationwide* and is *based on physical characteristics* of the housing unit.<sup>38</sup> Despite this exogenous definition, the share of social housing in  $j$  may correlate with unobservables in the entry cost; therefore, we construct the average social housing for a set of zipcodes different from  $j$ ,  $sss_{-j,t}$ . We define this set as the zipcodes outside  $j$ 's county ("Stadsdeel") to avoid spatial correlations.

To construct how many tourists "live" in each location, we take the number of hotel beds and multiply by the annual hotel bed occupancy rate. We also take the number of Airbnb commercial listings and multiply them by the average number of beds and the average commercial Airbnb occupancy rate.<sup>39</sup> We then sum both quantities. To compute expenses, we take total annual spending by tourists obtained from tourism reports and divide it proportionally to the number of tourists in each location. For local residents, the number of type  $k$  individuals can be directly computed from the micro-data. For income we use the average income by cluster and year.

Regression results for our non-linear IV specification can be seen in Table 4, where we have pooled all sectors together with the appropriate interactions. The sectors chosen for this estimation are tourism services, food stores, general retail, education establishments, restaurants, cafes, and bars.<sup>40</sup> We observe significant heterogeneity in how the supply of different amenities responds to the socioeconomic composition of

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<sup>38</sup>See Appendix B.1.2 for more details of the rental point system.

<sup>39</sup>The average number of beds in a commercial listing is four and the average occupancy rate is about 50%.

<sup>40</sup>The full definition of these services can be found in Appendix D.5.

the location as well as substantial heterogeneity across the barriers to entry for different services. For example, locations with an increase in tourists see an increase in the supply of touristic amenities, restaurants, bars, food stores, and general retail, a reduction in the supply of cafes, and no effect in the supply of education establishments or sports amenities, holding the other demographic groups constant.

Table 4: IV Estimation - Dep var: Log Amenities

	Edu. Est.	Sport Est.	Restaurants	Bars	Cafes	Tourism	Food	Retail
Amenity FE	-11.592*** (0.173)	-12.329*** (0.152)	-12.185*** (0.155)	-13.110*** (0.142)	-12.914*** (0.152)	-10.849*** (0.148)	-11.971*** (0.134)	-11.428*** (0.131)
Tourists	-0.002 (0.003)	0.008 (0.005)	0.136*** (0.025)	0.220*** (0.031)	-0.009*** (0.003)	0.090*** (0.015)	0.026*** (0.007)	0.091*** (0.015)
Group 1	-0.382*** (0.109)	-0.042 (0.069)	0.310*** (0.097)	0.451*** (0.079)	-0.161** (0.086)	0.296*** (0.050)	0.155*** (0.053)	0.254*** (0.061)
Group 2	-0.081 (0.092)	-0.044 (0.089)	0.319*** (0.093)	0.224** (0.103)	-0.632*** (0.089)	-0.129 (0.114)	0.494*** (0.094)	0.902*** (0.109)
Group 3	0.080** (0.036)	-0.028 (0.022)	-0.084** (0.030)	-0.019 (0.028)	0.067** (0.031)	-0.049*** (0.017)	-0.066*** (0.017)	-0.091*** (0.020)
Group 4	0.068*** (0.021)	0.048*** (0.015)	0.073*** (0.026)	-0.037*** (0.020)	0.026 (0.016)	0.031** (0.015)	0.027* (0.015)	0.045** (0.019)
Group 5	0.149*** (0.009)	0.117*** (0.078)	0.082 (0.104)	-0.049 (0.072)	0.014 (0.087)	0.120*** (0.039)	-0.001 (0.066)	-0.065 (0.065)
Group 6	-0.326*** (0.150)	-0.142 (0.123)	-0.345** (0.193)	0.211 (0.148)	0.056 (0.143)	-0.581*** (0.098)	-0.080 (0.127)	-0.099 (0.134)
Group 7	-0.177*** (0.072)	-0.162*** (0.054)	0.366*** (0.079)	0.683*** (0.073)	0.098* (0.058)	0.325*** (0.046)	0.336*** (0.054)	0.557*** (0.067)
Group 8	0.095*** (0.038)	0.118*** (0.033)	-0.041 (0.042)	-0.417*** (0.047)	-0.043 (0.034)	-0.068*** (0.019)	-0.024 (0.028)	-0.099*** (0.029)
Group 9	0.096 (0.078)	-0.099* (0.058)	0.159** (0.079)	0.034 (0.067)	-0.257*** (0.064)	0.252*** (0.069)	0.360*** (0.076)	0.270*** (0.066)
Group 10	-0.018 (0.030)	-0.016 (0.024)	0.045 (0.037)	0.251*** (0.045)	-0.058 (0.028)	0.026 (0.024)	-0.001 (0.024)	0.038 (0.026)
Group 11	0.455*** (0.087)	0.185*** (0.055)	0.162** (0.073)	-0.048 (0.051)	0.402*** (0.072)	0.021 (0.038)	0.007 (0.039)	0.025 (0.042)
Group 12	0.060 (0.114)	0.519*** (0.109)	0.264** (0.108)	0.352*** (0.078)	0.641*** (0.119)	0.217** (0.093)	0.304*** (0.094)	0.156* (0.086)
Location FE	✓		Time FE	✓				

Note:

\*p<0.1; \*\*p<0.05; \*\*\*p<0.01. SE in parenthesis.

### 6.3 Housing demand

In this section, we describe how we estimate the preference parameters for households. We do so by building upon the Conditional Choice Probability Estimator following [Aguirregabiria and Mira \(2010\)](#), [Scott \(2013\)](#), and [Kalouptsidi et al. \(2018\)](#). The ECCP estimator is particularly well suited for our application where we can leverage the assumption that location capital is lost whenever a household moves. The ECCP estimator allows us to recover parameters *without* solving value functions and without the need to specify beliefs.

The ECCP estimator is the discrete-choice analogue of inter-temporal Euler equations with continuous choice variables. Derivatives are replaced by differences, and the envelope theorem is replaced by results on finite dependence in the household dynamic problem as defined by [Arcidiacono and Miller \(2011\)](#). A dynamic problem exhibits finite dependence if two different sequences of choices starting from the same state lead to the same distribution of future states after  $n$  periods. If agents have rational expectations, value functions are substituted with their observable realizations plus an expectational error. Combining rational expectations with finite dependence, our household dynamic model maps to an equation in observables and an expectational error. This mapping allows us to estimate the structural model using regression equations. Moreover, this methodology does not require us to specify beliefs about the evolution of future states nor solve for value functions, exponentially reducing the computational burden.

The ECCP estimator is a two-step estimator. First, CCPs are estimated directly from the data. We use a novel smoothing approach that can reduce the bias of the second-stage preference parameter estimates by more than 50% based on the results of our Monte Carlo simulations. See Appendix [E.2.4](#) for more details about our smoothing methodology. Second, model parameters are estimated using the CCPs obtained from the first stage. The key regression equation compares differences in the log likelihood of two different paths with a common starting and finishing point with differences in utility flows along those paths. The intuition for identification follows from these two paths having a common future state, and therefore the same expected future returns from that point onward. Therefore, continuation values are the same for both paths, so that value functions cancel out. Therefore, the relative likelihood of one path compared to the other has to be explained solely by differences in the

(parameterized) utility flows along those two paths until that common point is finally reached.

### 6.3.1 Assumptions

We assume that states follow a Markov process. We also make the following standard assumptions:

**Assumption 1 Atomistic agents:** *The market states evolve according to a Markov process that is unaffected by individual decisions and states*

$$p(\omega'|d, x, \omega, \epsilon) = p(\omega'|\omega),$$

$$\forall i \in I \text{ and } \forall d \in J.$$

**Assumption 2 Conditional independence assumption:** *The transition density for the following Markov process factors as*

$$p(x', \omega', \epsilon'|d, x, \omega, \epsilon) = p_x(x'|x, \omega, d)p_\omega(\omega'|\omega)p_\epsilon(\epsilon').$$

**Assumption 3 Type I Extreme-Value errors:**  $\epsilon_{ijt}$  are i.i.d. type I Extreme-Value errors.

### 6.3.2 Renewal actions

As defined by Arcidiacono and Miller (2011), two paths of action exhibit finite dependence if after a finite number of periods, the distribution of future states is the same. In our housing demand model, finite dependence appears whenever two households living in different locations,  $j$  and  $j'$ , choose to move to the same new location  $\tilde{j}$ ,

$$j \rightarrow \tilde{j} \quad \text{and} \quad j' \rightarrow \tilde{j},$$

because their location tenure clock is reset, and hence the distribution of future states is the same for both of them. These type of actions are known as *renewal actions*, and are a subset of actions with finite dependence. Renewal actions are a common component of recent papers in the literature using ECCP estimators (Scott, 2013; Diamond et al., 2018; Traiberman, 2018).

Because expected future payoffs are not observable to the econometrician, one of the main difficulties in the estimation of dynamic models is disentangling variation in current payoffs from continuation values. Renewal actions help separate these two

components of utility, because after playing them, continuation values are equalized. Hence, variation in choices up to the renewal action should reflect variation in utility flows.

More concretely, our main regression equation is,

$$Y_{t,d,d',\tilde{d},x_{it}}^k = u_t^k(j(d), x_{it}) - u_t^k(j(d'), x_{it}) + \beta(u_t^k(j(\tilde{d}), x_{it+1}) - u_t^k(j(\tilde{d}), x'_{it+1})) + \tilde{\varepsilon}_{t,d,d',x_{it}}, \quad (11)$$

where

$$Y_{t,d,d',\tilde{d},x_{it}}^k \equiv \ln\left(\frac{\mathbb{P}_t^k(d, x_{it})}{\mathbb{P}_t^k(d', x_{it})}\right) + \beta \ln\left(\frac{\mathbb{P}_{t+1}^k(j(\tilde{d}), x_{it+1})}{\mathbb{P}_{t+1}^k(j(\tilde{d}), x'_{it+1})}\right),$$

with  $d$  and  $d'$  being actions played at state  $x_{it}$ , reaching states  $x_{it+1}$  and  $x'_{it+1}$ , respectively, and  $\tilde{d}$  being a renewal action played at time  $t+1$ . In what follows, we denote  $j = j(d)$ ,  $j' = j(d')$ , and  $\tilde{j} = j(\tilde{d})$  to simplify notation. Following our indirect utility specification,

$$u_t^k(d, x_{it}) = \delta_j^k + \delta_\tau^k \tau_{it} - \delta_r^k \log(w_t^k - r_{jt}) + \delta_a^k \ln a_{jt} - MC^k(j, j_{it-1}),$$

and so our regression equation is,

$$\begin{aligned} Y_{t,d,d',\tilde{d},x_{it}}^k &= \delta_j^k - \delta_{j'}^k + \delta_\tau^k (\tau(d, x_{it}) - \tau(d', x_{it})) \\ &\quad + \delta_a^k (\ln a_{jt} - \ln a_{j't}) - \delta_r^k (\log(w_t^k - r_{jt}) - \log(w_t^k - r_{j't})) \\ &\quad - (MC^k(j, j_{it-1}) - MC^k(j', j_{it-1})) - \beta(MC^k(\tilde{j}, j) - MC^k(\tilde{j}, j')) \\ &\quad + \tilde{\varepsilon}_{t,d,d',x_{it}}. \end{aligned} \quad (12)$$

We can interpret  $Y_{t,d,d',\tilde{d},x_{it}}^k$  as the log likelihood of path  $(x_{it}, x_{it+1}, x_{it+2})$  relative to path  $(x_{it}, x'_{it+1}, x_{it+2})$ . The intuition of the previous equation goes as follows: The relative likelihood of  $(x_{it}, x_{it+1}, x_{it+2})$  compared to  $(x_{it}, x'_{it+1}, x_{it+2})$ , that is,  $Y_{t,d,d',x_{it}}^k$ , has to be solely explained by the relative discounted utility flow of path  $(x_{it}, x_{it+1}, x_{it+2})$  compared to  $(x_{it}, x'_{it+1}, x_{it+2})$ , because after playing renewal action  $\tilde{d}$  tenure location resets and the problem from then on is identical for both paths. For full details on how to obtain this equation, see Appendix E.2.

### 6.3.3 Identification

First, as in any logit inversion trying to recover utility parameters, only differences

$$\delta_j - \delta_{j'}$$

in utility are identified. To separately identify the levels  $\delta_0$ , we make the following assumption:

**Assumption 4 Payoff to the outside option:** *The utility payoff of living outside the city, excluding moving costs and location capital, is normalized to zero.*

The previous assumption implies

$$\delta_0 + \delta_a^k \ln a_{0t} + \delta_w^k \log(w_t^k - r_{0t}) = 0.$$

Second, equation (12) requires controlling for location fixed effects  $\delta_j$ . Taking care of fixed effects by demeaning the dependent variable with respect to  $j$  will lead to biased estimates. The reason is that when demeaning, we are including variables from all time periods, because the mean is precisely taken over all  $t$ . The required identifying assumptions on expectational errors  $\tilde{\varepsilon}_{t,d,d',x_{it}}$  in this case should be

$$\mathbb{E}[\left(\log(w_t^k - r_{jt}) - \log(w_t^k - r_{j't})\right)\tilde{\varepsilon}_{t',d,d',x_{it}}] = 0 \quad \forall t', t,$$

and

$$\mathbb{E}[(\ln a_{jt} - \ln a_{j't})\tilde{\varepsilon}_{t',d,d',x_{it}}] = 0 \quad \forall t', t,$$

which is likely to fail because one can expect expectational errors at time  $t$  to be correlated with future variables  $t' > t$  of rent and amenities.<sup>41</sup> Following a similar argument as in Scott (2013) and Kalouptsidi et al. (2018), we proceed to estimate equation 12 by taking differences with the previous time period with respect to the same state,  $x_{it} = x_{it-1} = x = (j, \tau)$ , and for the same action path. In this way, everything that is time-invariant cancels out, and the final regression equation is

$$\begin{aligned} \nabla Y_{t,d,d',\tilde{d},x}^k &= \delta_j^k - \delta_{j'}^k + \delta_\tau^k (\tau(d, x) - \tau(d', x)) \\ &\quad - \left( \delta_j^k - \delta_{j'}^k + \delta_\tau^k (\tau(d, x) - \tau(d', x)) \right) \\ &\quad + \delta_a^k \nabla (\ln a_{jt} - \ln a_{j't}) + \delta_w^k \nabla (\log(w_t^k - r_t) - \log(w_t^k - r_{j't})) \\ &\quad - \left( MC^k(j, j_{it-1}) - MC^k(j', j_{it-1}) \right) - \beta \left( MC^k(\tilde{j}, j) - MC^k(\tilde{j}, j') \right) \\ &\quad + \left( MC^k(j, j_{it-1}) - MC^k(j', j_{it-1}) + \beta \left( MC^k(\tilde{j}, j) - MC^k(\tilde{j}, j') \right) \right) \\ &\quad + \nabla \tilde{\varepsilon}_{t,d,d',x}, \end{aligned}$$

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<sup>41</sup>Rational expectations only impose  $\mathbb{E}[z_{t'}\tilde{\varepsilon}_{t,d,d',x_{it}}]$  for all  $t' \leq t$ .

where  $\nabla$  is the first difference operator  $\nabla x_t = x_t - x_{t-1}$ .

Simplifying, the first difference regression equation that we take to the data is

$$\nabla Y_{t,d,d',\tilde{d},x}^k = \delta_a^k \nabla (\ln a_{jt} - \ln a_{j't}) + \delta_w^k \nabla (\log (w_t^k - r_{jt}) - \log (w_t^k - r_{j't})) + \nabla \tilde{\varepsilon}_{t,d,d',x}. \quad (13)$$

Inspection of equation 13 reveals that the unobservable component  $\nabla \tilde{\varepsilon}_{t,d,d',x}$  is correlated with regressors as the previous period expectational error  $\tilde{\varepsilon}_{t-1,d,d',x}$  is correlated with contemporary variables  $\ln a_{jt}$  and  $\ln (w_t^k - r_{jt})$ . More importantly, one of the main challenges of estimating demand parameters in residential choice is many unobservables, beyond the expectational error, are correlated with regressors and location choices. For example, gentrification trends will push up rents as well as the probability of certain sociodemographic groups to live in specific locations. Moreover, these types of unobserved components tend to be time persistent. To deal with this type of endogeneity, we propose a new identification strategy that combines the ECCP methodology with instruments in the spirit of the exclusion restrictions of Arellano and Bond (1991). First, we assume the unobserved component in equation 13 follows an ARMA structure, which allows us to capture time persistence in time-varying unobservables. Second, this assumption delivers internally consistent estimators following the same reasoning as in Arellano and Bond (1991). Appendix E.2 contains a more detailed discussion of this new approach.

Finally, to recover the time-invariant parameters, we construct the residuals from the levels in equation (12) using the parameters obtained by the first-difference regression of equation (13). We then estimate these residuals on the time-invariant components, moving costs, and location tenure. To recover location fixed-effects,  $\delta_j$ , we simply follow the standard approach of taking averages over residuals across all observations with the same location  $j$ .

#### 6.3.4 Preliminary results

This section provides an overview of our preliminary demand-estimation results for the eight groups of renters and home-owners.<sup>42</sup> Given that the estimation requires some extra exclusion restrictions (see section E.2.5 for details), we present basic OLS

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<sup>42</sup>We exclude the demographic groups in social housing as well as all the observations of households living in social housing for the other two groups because the choice of moving to social housing is very different from moving choices in the private market.

estimates in Table 5. In this estimation, we have included education establishments, sport amenities, touristic services, restaurants, bars, and cafes as our set of consumption amenities. As public amenities, we include congestion effects generated by tourists in hotels and in Airbnb listing defined as the number of each divided by the local population. We also include population density as well as location fixed effects. Finally, given the discussion in C.1, many hotel developments are being built over time. We include the number of hotels as a proxy to control for unobservable trends that are correlated with these new constructions. Recall the regression equation that we estimate is

$$\begin{aligned} Y_{t,d,d',\tilde{d},x_{it}}^k &= \delta_j^k - \delta_{j'}^k + \delta_\tau^k \left( \tau(d, x_{it}) - \tau(d', x_{it}) \right) \\ &\quad + \delta_a^k \left( \ln a_{jt} - \ln a_{j't} \right) + \delta_w^k \left( \log (w_t^k - r_{j(d)t}) - \log (w_t^k - r_{j't}) \right) \\ &\quad - \left( MC^k(j, j_{it-1}) - MC^k(j', j_{it-1}) \right) - \beta \left( MC^k(\tilde{j}, j) - MC^k(\tilde{j}, j') \right) \\ &\quad + \tilde{\varepsilon}_{t,d,d',x_{it}}. \end{aligned}$$

For specific details about the estimation procedure, see section E.2.3. All moving costs and tenure location have the expected sign, where we observe significant heterogeneity across groups. For example, home-owners have on average larger effects from location capital accumulation than renters. This result can be explained by home-owners feeling more attached to their neighborhoods than renters. All groups have the expected sign on adjusted income, except for one group that corresponds to home-owners in the top-income group. This negative sign is not uncommon in the literature and usually captures unobservable neighborhood time-varying characteristics that positively correlate with price, such as gentrification trends. We also see significant heterogeneity across income parameters. Renters are on average more sensitive to adjusted income, disposable income minus the price of housing, than home-owners, as expected. It also appears that the coefficient on adjusted income correlate with the original disposable income, with lower-income households being more sensitive than higher-income households for the two groups. Group 5, the one formed by young, high-skill, European renters without children, is an exception to this relationship, but this result can be rationalized by these households putting more weight on the characteristics of the location than on price of housing. Our income-price coefficients are of larger magnitude as those found in Diamond (2016), an expected result given that we estimate a *dynamic* model whereas Diamond (2016) estimates a *static* model.

Finally, we find significant heterogeneity across coefficients for different amenities and location characteristics. For example, older households tend to value more education establishments and less touristic services, while groups with a higher share of Dutch descendant households value more restaurants than groups with a higher share with a non-Western origin. See Figure 11 for more details.

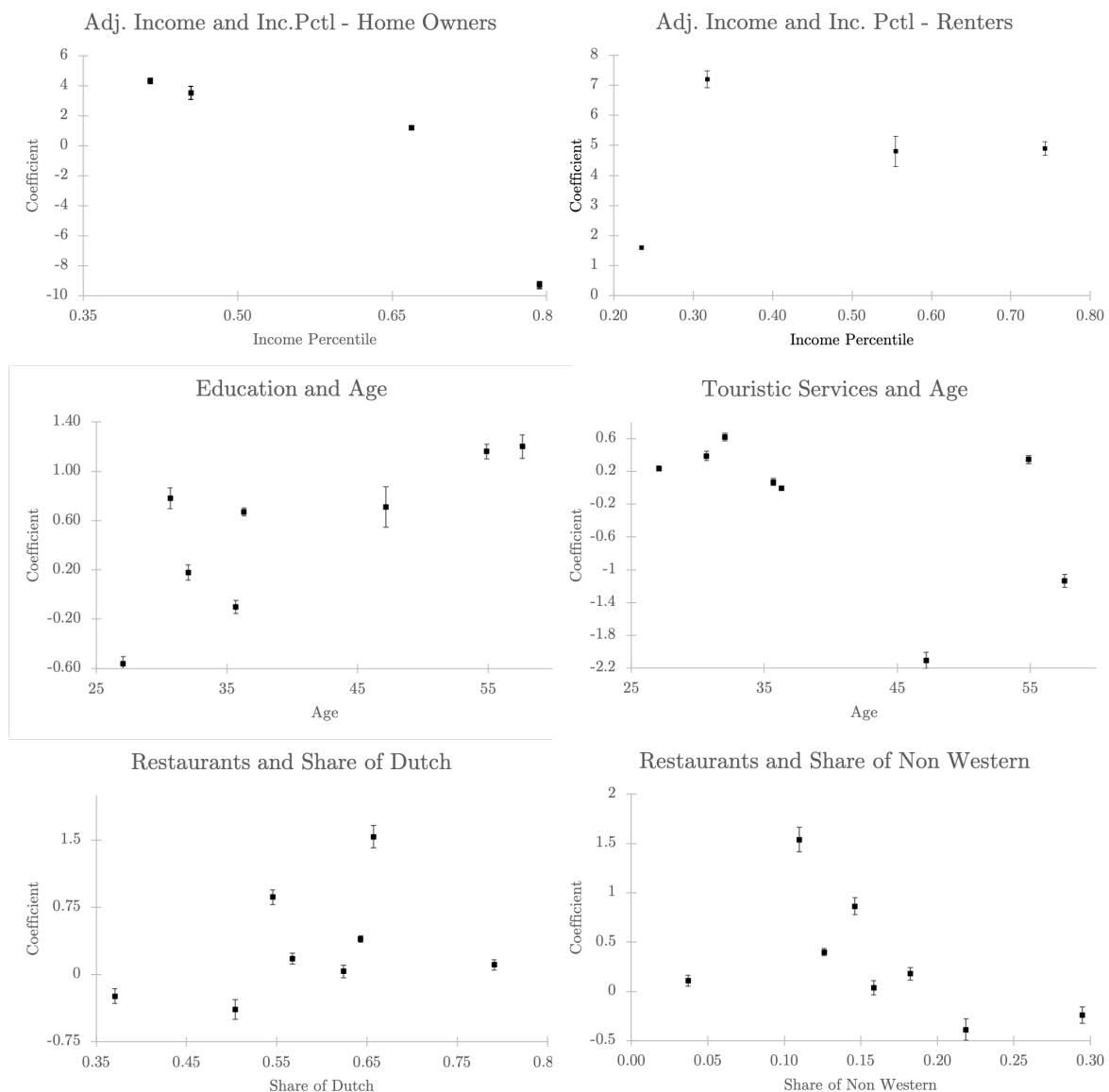


Figure 11: Relationship demand estimation coefficients and demographics

Table 5: Dep var: Log likelihood ratio of action paths for eight household groups

	Home owners				Renters			
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
Adjusted Income	4.325***	3.511***	1.234***	-9.301***	1.564***	7.185***	4.834***	4.874***
Education est.	0.176***	0.708***	0.668***	1.164***	-0.561***	0.781***	1.209***	-0.098***
Sport Est.	-0.023	0.645***	0.238***	1.000***	0.319***	0.286***	0.380***	0.124***
Hotel	0.181***	-0.737***	0.285***	0.137***	0.314***	0.158***	0.554***	0.211***
Restaurant	0.179***	-0.240***	0.398***	0.109***	0.036	-0.387***	1.538***	0.864***
Bars	-0.140***	-0.168***	-0.203***	-0.089***	0.160***	0.381***	0.068**	0.097***
Cafes	0.237***	-0.044**	0.014*	0.409***	0.171***	-0.170***	-1.057***	-0.023
Touristic services	0.617***	-2.104***	-0.005	0.343***	0.236***	0.389***	-1.136***	0.070***
Food stores	-0.115***	-2.135***	0.094***	-1.14***	0.148***	0.910***	0.580***	0.453***
Retail	-0.292***	-1.86***	-0.047***	-0.502***	-0.903***	0.036	0.912***	-0.949***
Pop. Density	-1.88***	13.846***	-2.624***	-1.337***	1.819***	-2.855***	1.887***	-1.891***
Congention Hotels	-0.007**	0.034***	0.036***	0.112***	-0.050***	-0.002	0.035***	-0.047***
Congestion Airbnb	-0.147***	-0.077***	0.100***	0.134***	-0.046***	-0.196***	-0.185***	0.005
Share social housing	0.163***	0.776***	0.228***	-0.323***	0.058***	-0.224***	-0.145***	0.024***
MC <sub>0,O</sub>	-1.164***	-2.123***	-2.081***	-2.937***	-4.430***	-3.781***	-2.527***	-1.845***
MC <sub>0,I</sub>	-1.912***	-1.648***	-2.564***	-3.228***	-3.370***	-3.243***	-2.303***	-2.765***
MC <sub>1,dist</sub>	-0.093***	-0.183***	-0.135***	-0.185***	-0.288***	-0.135***	-0.142***	-0.075***
Dummy $\tau_2$	2.380***	1.216***	2.053***	1.118***	0.454***	0.700***	0.966***	1.610***
Dummy $\tau_3$	2.374***	1.183***	1.517***	0.672***	0.711***	0.860***	0.902***	1.337***
Location FE	✓	✓	✓	✓	✓	✓	✓	✓
$R^2$ 1st-stage	0.041	0.091	0.037	0.078	0.054	0.081	0.055	0.063

Note:

\*p&lt;0.1; \*\*p&lt;0.05; \*\*\*p&lt;0.01

Table 6: Dependent variable: Log long-term share - Log short-term share

	OLS		IV	
Price gap	0.919***	(0.077)	1.646***	(0.232)
Location FE	✓		✓	
Time FE	✓		✓	
$R^2$	0.849		0.828	
Observations	655		655	
F Statistic	453.042***		352.12***	
1 stage F Stat	-		1033.82***	

Note: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01. SE clustered at zipcode-level.

## 6.4 Housing supply

Because the supply model is static, differences in the short- and long-term market shares of housing map directly to a regression equation,

$$\ln s_{jt}^L - \ln s_{jt}^S = \alpha r_{jt} - (\alpha p_{jt} - \kappa_{jt}) + \nu_{jt},$$

where  $\nu_{jt}$  is measurement error or unobservables not included in  $\kappa_{jt}$ . We parametrize  $\kappa_{jt} = \gamma_j + \gamma_t$ , where  $\gamma_j$  and  $\gamma_t$  are fixed effects:

$$\ln s_{jt}^L - \ln s_{jt}^S = \alpha(r_{jt} - p_{jt}) + \gamma_j + \gamma_t + \nu_{jt}.$$

Running OLS in the previous equation may lead to biased estimates because we are, in effect, estimating a supply equation using equilibrium outcomes, which are a function of unobserved demand and supply shocks. To correctly identify supply elasticities, we need to find an appropriate instrument. A classical instrument for supply elasticities is a demand shifter. We construct a demand shifter with predicted tourist demand, using a shift-share approach as in our reduced-form exercise of section 4. The relevance condition is satisfied because higher demand from tourists will increase the gap between short- and long-term rental prices  $p - r$ . We expect the exclusion restriction to be satisfied because predicted tourist demand is unlikely to be correlated with time-varying supply shocks. Table 6 presents estimates for the supply-side parameters. Under both OLS and IV specifications, the coefficient on price is positive and significant. Higher price gaps between long-term and short-term prices naturally lead to higher long-term market shares.

## 7 Counterfactuals

### 7.1 The role of endogenous amenities

The objective of our first exercise is to evaluate the implications of the endogeneity of amenities on the model's equilibrium. We assume that the first year of our time window, 2008, is a steady-state equilibrium. We compare the equilibrium outcome of a world with fixed exogenous amenities (fixed to their 2008 level<sup>43</sup>) to a world where amenities are a function of location demographics.

For this exercise we take the estimated utility parameters on prices, Airbnb congestion, education establishments, and bars. We set the hosting costs high enough such that the Airbnb share is less than 1% in all neighborhoods, that is, a world without short-term rentals, as was the case in 2008. This allows us to isolate the effect on private consumption amenities by leaving aside the congestion effects on residents from short-term rentals.

In the first columns of Table 7 we find the preference coefficients of our demographic groups. Groups 1, 2, 3, 6, and 7 value education establishments more than bars, whereas the opposite holds for groups 5 and 8. We call the first set of demographic groups traditional families and the second set young European expats.

Table 7: Equilibrium comparison with exogenous and endogenous amenities

Group	Coefficients				Welfare Exogenous		Welfare Endogenous	
	Rent	Cong	Educ. Est.	Bars	Log Euros	Euros (10000)	Log Euros	Euros (10000)
1	-4.30	-0.15	0.18	-0.14	0.01	1.02	0.06	1.15
2	-3.50	-0.08	0.71	-0.17	0.21	1.62	0.25	1.77
3	-1.20	0.10	0.67	-0.2	0.56	3.67	0.65	4.44
4	-0.80	0.13	1.16	-0.09	2.09	122.15	2.53	336.24
5	-1.60	-0.05	-0.56	0.16	0.05	1.11	0.02	1.05
6	-7.20	-0.20	0.78	0.38	0.01	1.03	0.01	1.03
7	-4.80	-0.18	1.2	0.07	0.01	1.01	0.00	1.01
8	-4.90	0.00	-0.1	0.1	0.15	1.40	0.18	1.53

In the following graphs we plot the equilibrium outcomes for prices and amenities, where locations have been ordered by their average fixed effect across all groups. We

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<sup>43</sup>The numbers of this analysis may differ in the future as the results are still preliminary.

see that prices slightly increase with the average fixed effect as expected, but for a few locations whose prices are well above average. The reason for these spikes in prices is the large number of education establishments in those locations, combined with the fact that the group that is less sensitive to price (group four) has very high valuations for these amenities. Hence, this group's demand for these specific areas raises the equilibrium prices. This effect is further reinforced when amenities are endogenous as this group's preference to locate in these areas increases the number of education establishments, which in turn raises prices even more as the demand from this group goes up relative to other groups. The rest of the groups have higher values for location fixed effects than group four, so they prefer to live in locations with high fixed values than this group. As a consequence, group four moves to locations with low fixed effects, but with the amenities that they really enjoy. Overall, the number of bars is going down everywhere in the city when amenities are endogeneous.

A second thing to note is that sorting across demographic groups increases. To quantify segregation, we construct the following measure

$$\text{Weighted Entropy} = \sum_{j=1}^J \pi_j E_j, \quad \text{with} \quad E_j = \sum_{k=1}^K \pi_{kj} \ln(1/\pi_{kj}),$$

where  $\pi_j$  is the share of the total population living in neighborhood  $j$  and  $\pi_{kj}$  is the share of the population in location  $j$  that belongs to group  $k$ .<sup>44</sup> In this comparison, segregation goes up when amenities are endogenous as weighted entropy decreases by 3%. Most of this increase in segregation is coming from groups five and seven moving outside the city. Group five has very negative preferences for education establishments and values bars, so when education establishments increase and the number of bars decrease in the city, it is better for them to move out. For group seven, the story is different. This group enjoys education establishments the most, but unlike group four, they are very sensitive to prices. Therefore, moving to areas with education establishments is not worthwhile for them since they would suffer considerably from high prices.

Segregation not only increases because groups five and seven are being displaced outside the city, but also within the city. In Figures 16 and 17 we see the share of each of these two groups when amenities are exogenous and when amenities are

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<sup>44</sup>Recall that entropy achieves its maximum when  $\pi_{kj} = \frac{1}{K}$  for all  $k$ , that is when all groups are represented equally and segregation is the lowest. Similarly, when there is only one group, entropy achieves its minimum and it is equal to zero.

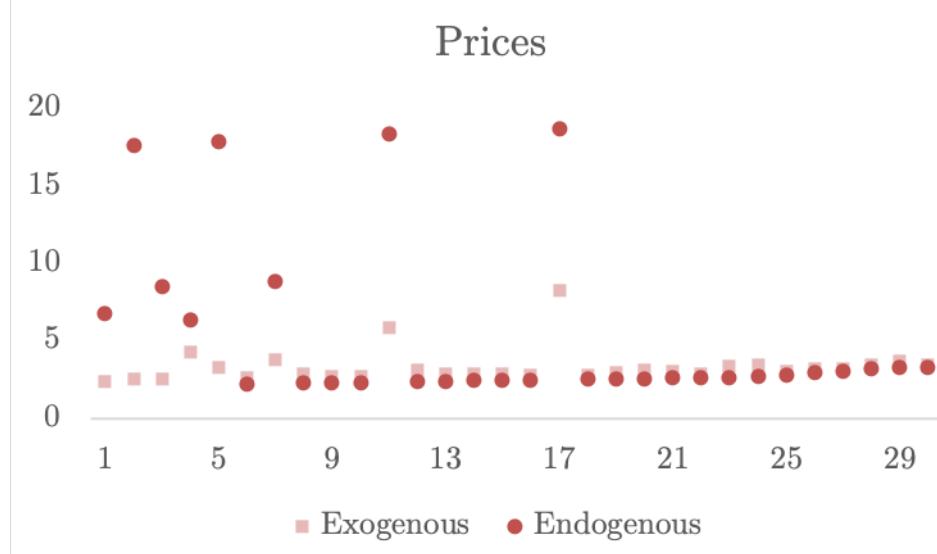


Figure 12: Prices

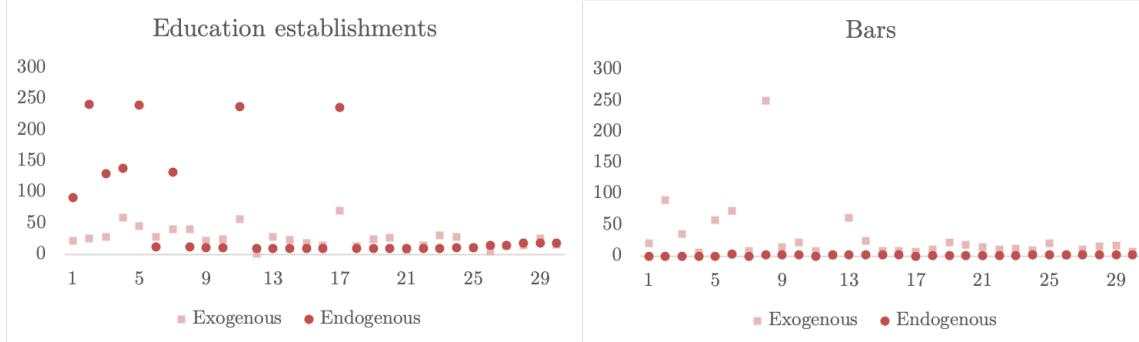


Figure 13: Education establishments

Figure 14: Bars

endogenous. The first thing to note is that there is more sorting when amenities are endogenous. Second, in the case of endogenous amenities, there are no young professionals in neighborhoods where prices are too high, which include the first five. Then we see a clear decreasing pattern that is driven by increasing prices and an increasing number of education establishments.

In terms of welfare, we observe that welfare goes up for most of the groups, but especially for group four. The main reason is that they sort into locations increasing the number of education establishments and, because they have high willingness to pay, the increase in prices does not affect them that much. For the other groups of families, groups one, two, and three, welfare goes up by 13%, 9%, and 21%, respectively, and the increase follows for the same reason. However, it is curbed by higher

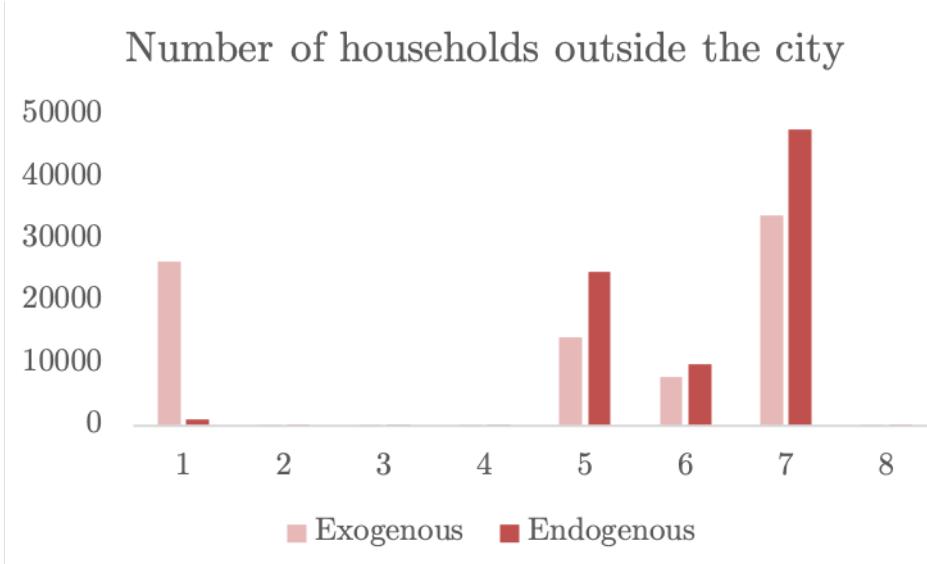


Figure 15: Population outside the city by group

prices as these groups are more sensitive to price than group four and by weaker preferences over education establishments. Finally, welfare decreases for group five by 5%. This is mainly driven by the reduction in the number of bars that makes households in this group to move outside the city.

Moreover, we also see that there are different implications for welfare inequality between an equilibrium with exogenous amenities and an equilibrium with endogenous amenities. We compare the welfare gap relative to group five, the one with the most differentiated preferences. The effects of endogenous amenities on inequality are also heterogeneous. Observe that the welfare gap increases for groups two, three, four, and eight, but decreases for the rest of the groups.

This last result complements the existing literature in location sorting and endogenous amenities. For example, Diamond (2016) finds when location characteristics adjust to demographic composition the welfare gap between low and high skill workers increases by 30% relative to a world where amenities are kept fixed. In her model, the one-dimensional endogenous amenity index is a function of the ratio of high over low skill households, and all households have increasing preferences over this index. While her results capture many interesting patterns and can explain the increase in sorting of American workers across cities over the last decades, it only allows for vertical differentiation in how households value amenities. Therefore, the

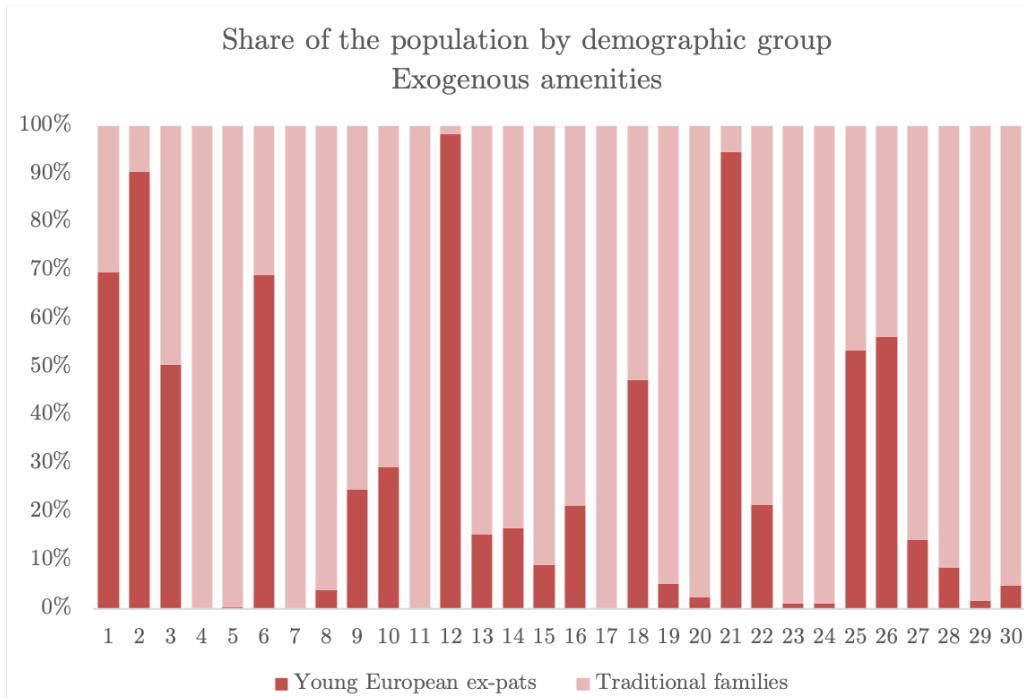


Figure 16: Share of families and young professionals with exogenous amenities

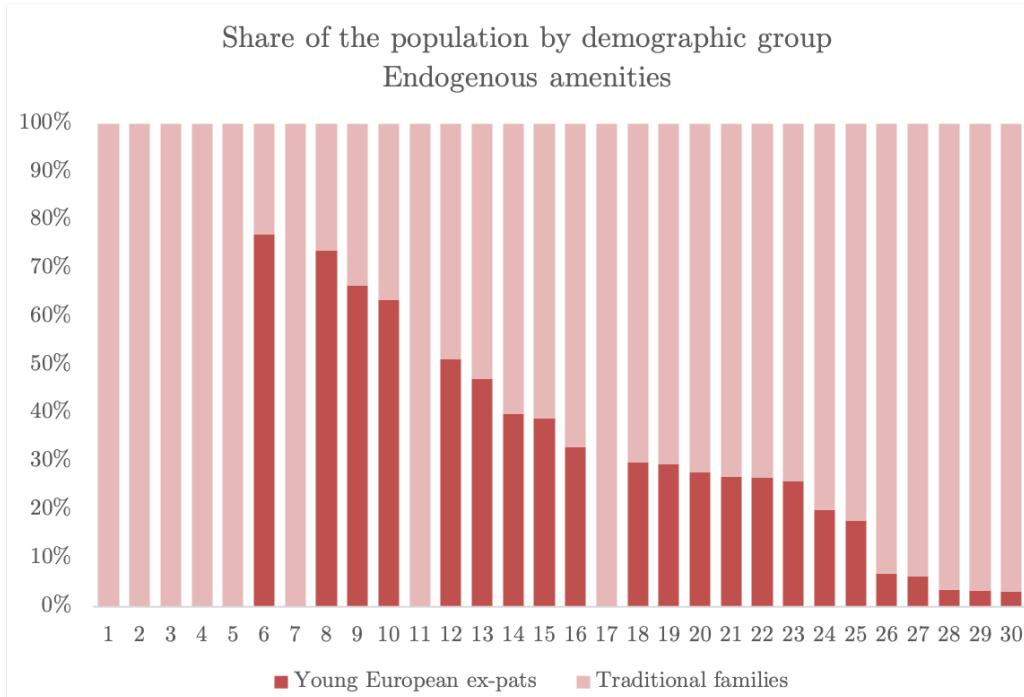


Figure 17: Share of families and young professionals with endogenous amenities

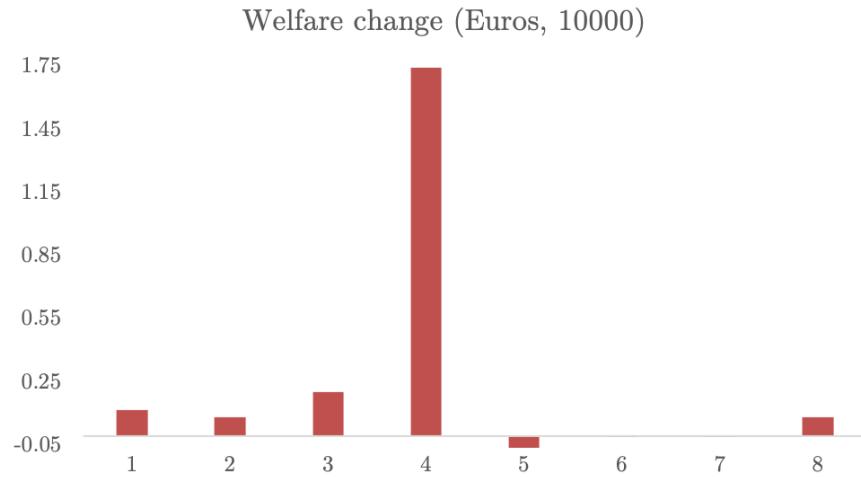


Figure 18: Welfare change

Group	Welfare gap exogenous		Welfare gap endogenous		Welfare gap change	
	Log Euros Euros	(10000)	Log Euros Euros	(10000)	Log Euros Euros	(10000)
1	0.04	0.09	-0.04	-0.10	-0.02	-2.01
2	-0.16	-0.51	-0.22	-0.71	0.38	0.41
3	-0.52	-2.56	-0.63	-3.39	0.21	0.33
4	-2.04	-121.04	-2.50	-335.18	0.23	1.77
5	0.00	0.00	0.00	0.00	-	-
6	0.03	0.08	0.01	0.02	-0.70	-0.71
7	0.04	0.10	0.02	0.04	-0.55	-0.56
8	-0.10	-0.29	-0.16	-0.48	0.63	0.66

Figure 19: Welfare gap with respect to group 5

richness in preferences and amenities of our model allows us to capture a broader set of welfare and sorting implications driven by the endogenous provision of amenities.

## 7.2 Short-term rentals entry as a reduction in hosting costs

Our second exercise is to understand the welfare effects of the entry of short-term rental platforms, such as Airbnb, on households and landlords. We begin at a benchmark equilibrium where host-tourist matching costs are high, which we interpret as a world without Airbnb.

The tourist share (the short-term rental share) of the housing stock is near zero across the whole city because matching costs are high. Next, we model the entry of short-term rentals as a reduction in matching costs and we simulate the new equilibrium under two scenarios. In the first case, amenities are not allowed to adjust, remaining fixed to the benchmark level. In this case, we simply have a reduction in housing for locals, which leads rents and the tourist share of housing to rise across the city. Because of higher rents, all households are worse off.

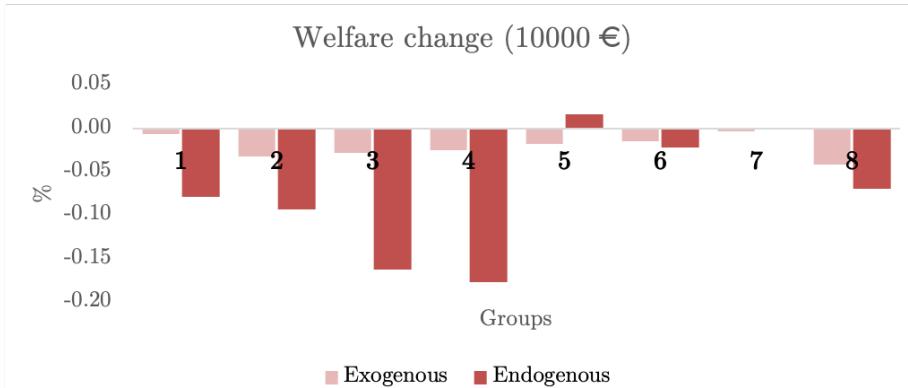


Figure 20: Welfare changes in 10000 Euros of short-term rental entry

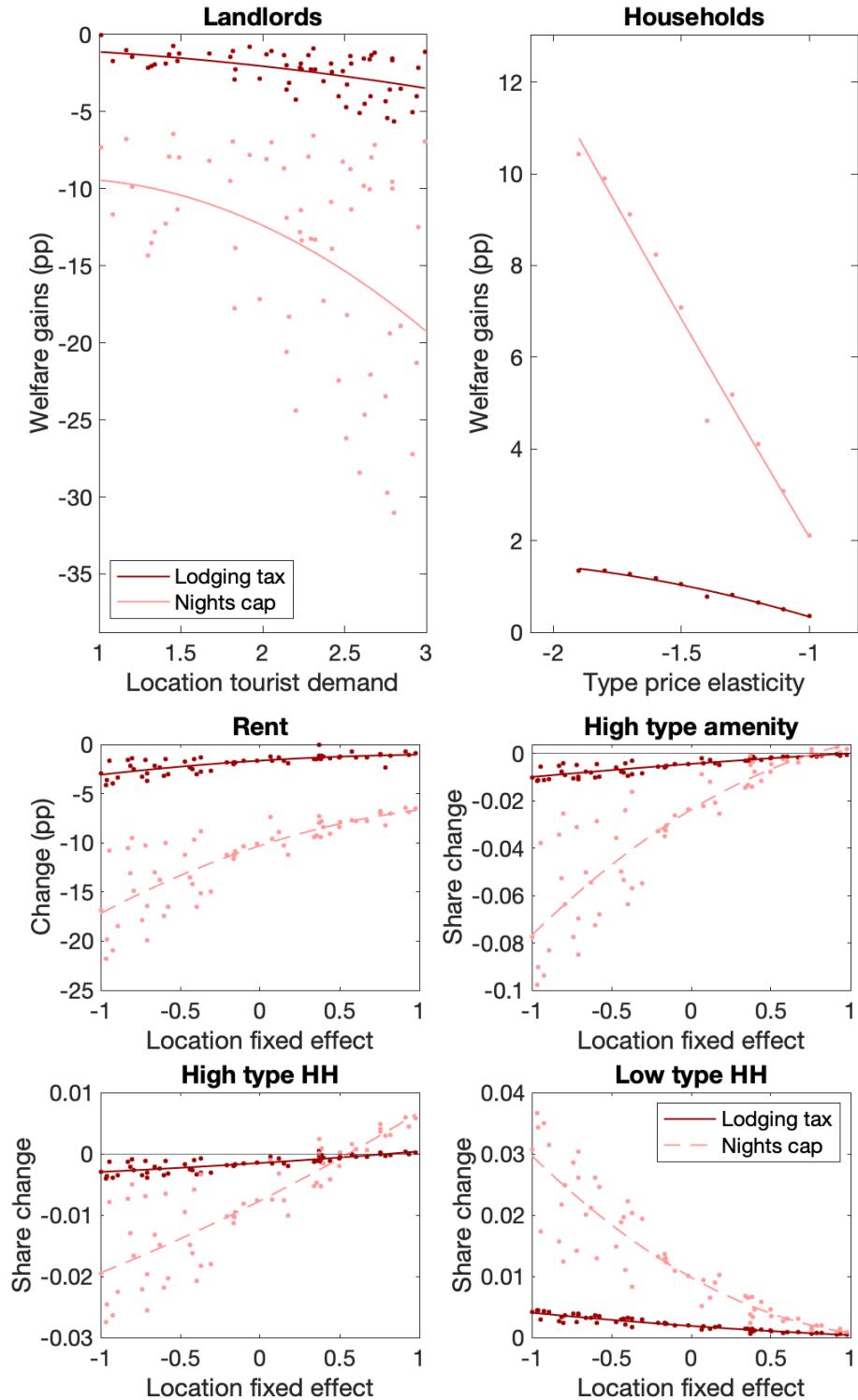
In the second case, amenities are allowed to adjust, so that we have reduction in housing for locals due to the reduction in matching costs, but also a change in the locals' demand, because the neighborhoods are changing. In this parametrization, we have assumed tourists' preferences for amenities are the same as for young European ex-pats without children (group five). Welfare results are shown in Figure 20: all households are worse off with the entry of short-term rentals due to the rise in rents. However, young European ex-pats who enjoy bars, the type of amenities that tourists bring, are partially compensated because amenities tilt in their favor. In particular, group five is better off after the entry of short-term rentals since the positive effect from amenities is larger than the effect of higher rents. On the other hand, traditional

families are hurt even more because they dislike these amenities.

### 7.3 Regulating prices vs. quantities

We test different regulatory policies for the full-fledged model with 60 neighborhoods and 12 agent types using our preliminary estimates. In the benchmark equilibrium hosting costs are relatively low, so there is a significant tourist share of housing across the city. We consider two regulatory counterfactuals motivated by real world examples: a lodging tax that is levied on the short-term rental nightly price, and a night cap that restricts landlords to a maximum number of nights hosted per year. The lodging tax shifts the housing share of each group in a predictable way and by a moderate magnitude: The tourist share falls and the low-type share rises. By contrast, the night cap has a much larger effect, with the tourist share falling nearly to zero. In Figure 21, we see that landlords lose (households gain) under both regulations, and more so with night caps. Furthermore, the top panel shows the slope of welfare gains with respect to tourist demand (for landlords) or rent elasticity (for households) is steeper under night caps. This finding is consistent with the night cap redistributing in favor of lower-willingness-to-pay households more than the lodging tax. Similarly, it penalizes landlords who were initially located in popular tourist locations more than those that were not. Thus, the night cap plays a more redistributive role.

Figure 21: Effects of different regulations



## 7.4 Zoning of tourists

A counterfactual exercise that is still work in progress is to evaluate the effect of a zoning policy of tourists. This type of policy restricts the locations in which tourists can be hosted. This type of regulation has already been implemented in some markets, for example, in Santa Monica, CA.

For this counterfactual, we take the spatial distribution of hotels equal to the one observed in 2017 and restrict the locations in which landlords can host tourists. We start by allowing short-term rentals only in areas where hotels already exist. To simulate this type of policy, we simply increase the cost to do short-term rentals in the designated locations so that landlords do not find optimal to rent their apartment in the short-term rental market. This type of policy allows different households to self-select into neighborhoods according to their preferences for touristic amenities and congestion generated by tourists. That is, the households that value touristic related amenities choose to live in the non-restricted areas together with tourists, whereas households that do not value these amenities choose to live in areas where there are restrictions to tourists. In future versions of the paper, we will explore what is the optimal zoning policy such that the choice of restricted areas maximizes a certain welfare criterion.

## 7.5 Restrictions on specific services

A final set of counterfactual analysis is to introduce restrictions on certain services by increasing their entry costs or by imposing an extra tax on those services. For example, a city regulator may want to restrict the entry of amenities that cater more to tourists than to locals with the objective of increasing the welfare of locals. The policymaker can do so by increasing the barriers to entry or by imposing a tax on the profits of specific services, such as bars or touristic amenities. Therefore, by targeting specific services the policy maker is effectively targeting the population that have stronger preferences for those amenities. In our amenities model of section 6.2, this “barriers-to-entry” parameter is represented by  $\lambda_s$  and it is pinned-down by variation in the supply of different services within a location across time. That is, these parameters cannot be recovered in models that collapse amenities to a one single object. Hence, one of the contributions of our model to the existing literature is to understand how differences in the market structure of different services, for example

different entry costs, affects the welfare of residents in a residential market where amenities are endogenous.

## 7.6 Short-run analysis

Finally, we also want to understand the welfare losses and gains in the *short-run*. A short-run analysis is important to understand the welfare gains and losses of households whose neighborhoods are going through a gentrification process until they finally adjust. To do so, we plan to simulate the *transitional dynamics* between two steady-states, where the original steady-state is hit by a shock or by a policy regulation.

# 8 Conclusion and way forward

In this paper, we study the role of preference heterogeneity over a set of endogenous location amenities in shaping within-city sorting and welfare inequality. To do so, we build a model of residential choice where heterogeneous forward-looking households consume a set of amenities that are provided by firms in a market for services. We leverage increasing tourism flows and the spatial variation in the entry of short-term rentals in Amsterdam as events that shift locations' demographic composition, and thus alter locations' amenities.

First, we show tourism flows and the entry of short-term rental platforms have led to a significant impact on rents, amenities, and within-city migration in Amsterdam. Second, to rationalize our reduced-form findings and conduct policy counterfactuals, we build a spatial equilibrium model of a city's rental market with heterogeneous forward-looking households, and show how to estimate it using tools from the empirical industrial organization literature. In contrast to most studies that assume housing supply is exogenous or provided by a single representative construction firm, we endogenize and microfound supply through landlords' decisions to rent to locals on traditional leases or full time to tourists through the short-term rental market. Moreover, we also microfound how different consumption amenities arise in equilibrium for each neighborhood.

We estimate three parts of our structural model using a set of different techniques that we borrow from the empirical industrial organization literature. On the housing supply side, we find significant heterogeneity of landlords in their operating costs

across the long- and short-term rental markets. On the demand side, we estimate location preferences for eight groups of residents, finding substantial heterogeneity across households in their utility parameters. For example, among households who rent, the lowest-willingness-to-pay renters are five times more sensitive to prices than the highest-willingness-to-pay renters. Furthermore, the preference heterogeneity across groups correlate with socio-demographic status as expected. Finally, the structural parameters of amenity supply indicate large differences in barriers to entry as well as in how different services respond to changes in their location demographics.

Armed with our estimated parameters, we explore the role of endogenous amenities in defining within-city inequality. We find the reinforcement in sorting driven by the endogeneity of amenities can go either way in shaping welfare inequality across groups. We find that the sign of this effect depends on how correlated preferences are across groups, with the welfare gap increasing between households whose preferences are substantially aligned and decreasing for those whose preferences are misaligned. Finally, we present policy counterfactuals for lodging taxes and night caps, each of which have different distributional implications. We do so for a steady-state version of the model, where we highlight how preference heterogeneity interacts with housing-supply shocks in delivering a distribution of welfare over space. Not only do these policies redistribute differently *between* landlords and households, but also importantly *within* types of households.

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## Appendix A. Appendix for Section 4

### A.1 Robustness of shift-share instruments

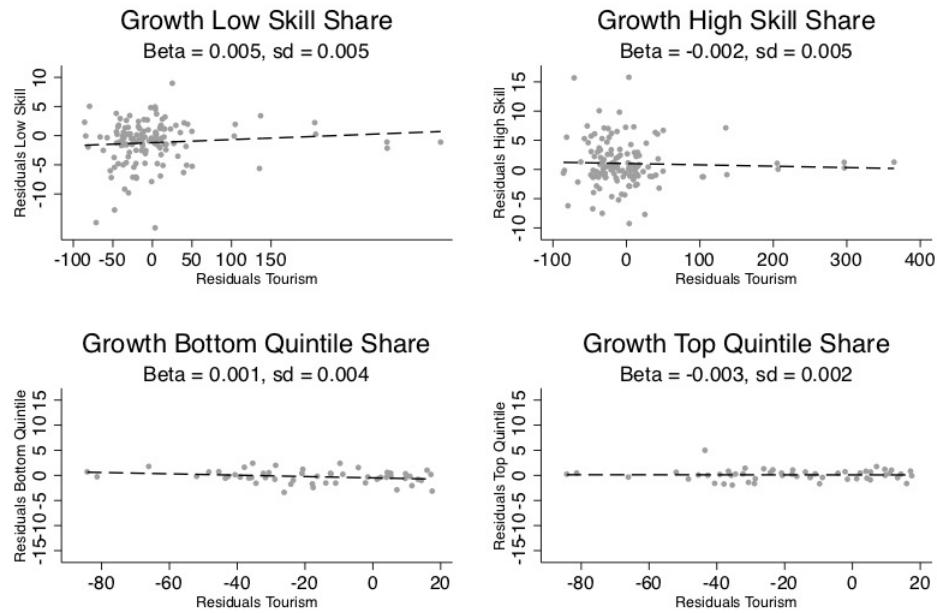
We follow Goldsmith-Pinkham et al. (2018) which propose the following robustness test for shift-share instruments. For an instrument  $Z_{it} = g_t z_i$  with asymptotics in  $i$  one should verify that  $z_i$  is uncorrelated with cross-sectional confounders  $y_i$ . In our context  $y_i$  would be any variable that proxies for gentrification. To do this we obtain residuals  $\tilde{y}_i$  and  $\tilde{z}_i$  from the following regressions:

$$\begin{aligned} y_i &= \alpha_0 + \alpha_1 X_i + \epsilon_i \\ z_i &= \beta_0 + \beta_1 X_i + \epsilon_i, \end{aligned}$$

where  $y_i$  are variables correlated with gentrification, such as the total change in the skill shares and national income quintile shares of a zipcode between 2008 and the last available time period,  $X_i$  are the covariates included in the main regression in the last time period, and  $z_i$  are the “share” component of our instruments (coffee shops and touristic businesses). Figure 22 plots  $\tilde{y}_i$  and  $\tilde{z}_i$ , the residuals of the covariates for the rent regression, and we see no evidence of correlation between the two. Although the exclusion restriction cannot be tested, this lack of correlation between gentrification indicators and our instruments provides some empirical evidence supporting its validity.

Our takeaway from this section is that Airbnb entry has had an impact on Amsterdam’s rental rates, residential choices, and neighborhood amenities. However, we cannot say anything about welfare or distributional effects, and we cannot test policy counterfactuals with the framework we currently have. In the next section we introduce a structural model to address this shortcoming.

## Tourist businesses



## Coffeeshops

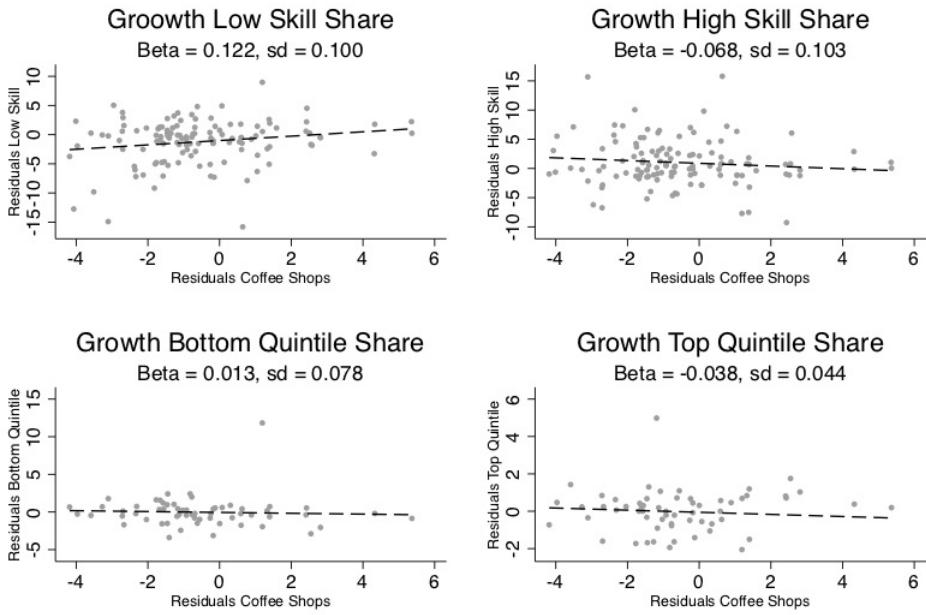


Figure 22: Robustness checks: tourism businesses and coffee shops instruments

### A.1.1 Event study and diff-in-diff results with public access data

To understand the impact of tourism we first check that the most exposed zipcodes (in the sense of being historically attractive to tourists) were not already experiencing changes in outcomes of interest prior to the touristic. To do so we construct a “tourism index” using a zipcode’s number of “businesses related to tourism” in 2009. This would include establishments such as souvenir shops, bike day-rentals, museums, etc. We then split zipcodes into “touristic” and “non-touristic” according to a threshold value of this index. Figure 23 plots our results, which suggest that both touristic and non-touristic zipcodes had similar trends before 2009, but not after. Touristic zipcode rents grow faster post-2009, and this result is robust to how one may pick the threshold to split the groups. Furthermore, the touristic premium post-2009 is both statistically and economically significant: if one runs a difference-in-difference regression with time varying controls and two-way fixed effects the resulting estimates is roughly 40 euro (nearly 10% of the average monthly rent during this period).

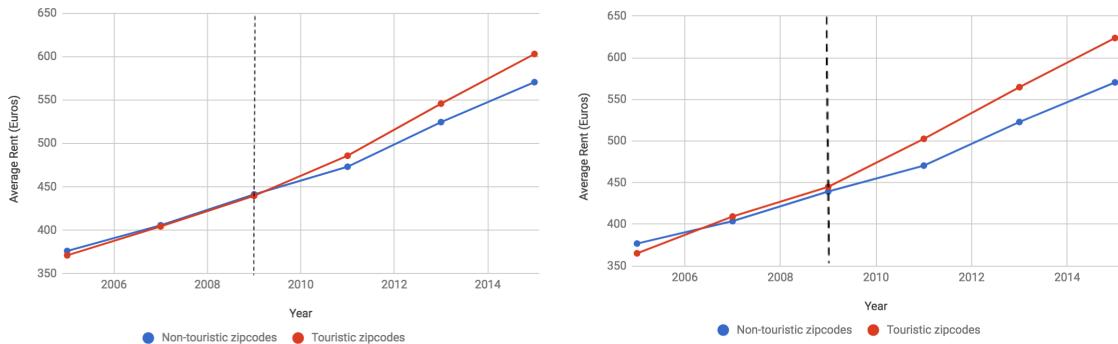


Figure 23: Average Monthly Rent, 2005-2015. In the top figure, touristic zipcodes are defined as those above the median tourism index value, and non-touristic as those below. The bottom figure uses the top quartile and the bottom quartile of the index as the cutoff value.

In what follows we generalize the above to exploit the continuity of our “treatment” variable (the tourism index) rather than splitting zipcodes into two groups at an arbitrary threshold. We conduct an event study, so that our regression of interest is as follows,

$$Y_{it} = \beta_t \text{Touristic Businesses}_i + \phi X_{it} + \eta_i + \lambda_t + \varepsilon_{it},$$

where  $Y_{it}$  is an outcome of interest such as rent,  $X_{it}$  is a vector of zipcode and time-

varying controls, and  $\eta_i$  and  $\lambda_t$  are zipcode and time fixed effects, respectively. Figure 24 plots estimates for  $\beta_t$  from 2005 to 2015 along with 95% confidence intervals, with 2009 as the omitted year. The estimates for  $\beta_t$  increase significantly above zero only after 2009. We repeat the analysis taking the share of non-Dutch residents per zipcode as our outcome variable and plot the results in Figure 24.<sup>45</sup> The results indicate that the share of immigrants is declining post-2009 in more touristic zipcodes.

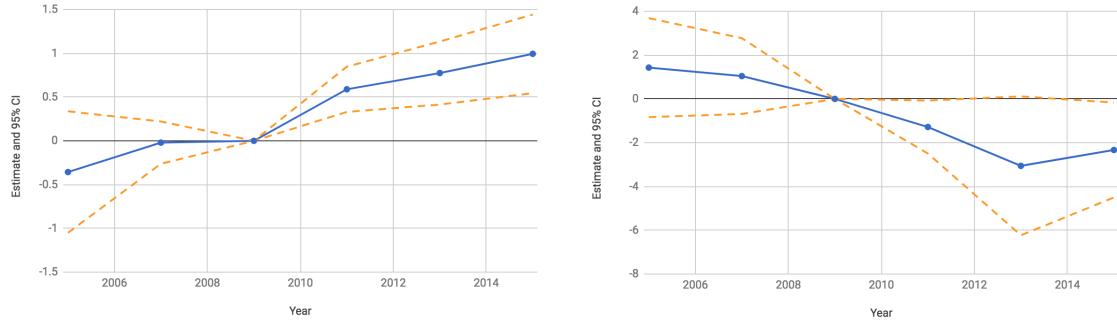


Figure 24: Event study coefficients for average monthly rent (top) and share of non-Dutch residents (bottom).

Summing up, outcomes of interest are changing in touristic relative to non-touristic zipcodes after 2009, and not before. Thus, any candidate explanation driving these outcomes must fit this time pattern. For instance, a story of urban revival and young, high-skill workers returning to cities would be ruled out by the event study unless it is happening precisely after 2009, and not before. While there could be many explanations that fit this timing, our stylized facts from previous sections suggest we propose the recent boom of tourism and Airbnb entry as a hypothesis since it fits the timing of the event study and it is sufficiently large to have a meaningful impact on the housing market.

<sup>45</sup> Amsterdam City Data defines a person to be “Dutch” if both of the person’s parents were born in the Netherlands, regardless of where the person is actually born. Thus, this is a measure of cultural or ethnic background, rather than citizenship status. We use this definition because we think the former is a better predictor of socioeconomic status than the latter.

## Appendix B. Institutional details

### B.1 The housing market in Amsterdam

In Amsterdam, 70% of housing units are rentals, and they can be classified as either social or private housing. The Netherlands is well known for having the largest social housing program in Europe, and Amsterdam is no exception to this national trend: nearly half of the city's housing stock is social housing. Classification of a unit as social or private is determined by a points system based primarily on physical characteristics (size, amenities, number of bedrooms and bathrooms, among others). If the total score of a unit is below an annually updated threshold it is by definition a social rental unit. The maximum amount of rent that can be charged for a social unit is regulated and is proportional to its total points. This implies a maximum rent for social units, and this threshold is commonly known as the “liberalization line”, which stands at 710.68 euros for 2015-2018 and 720.42 euros as of 2019. In the private market, the initial rent a landlord charges is not regulated. According to [van Dijk \(2019\)](#) eligibility requirements for social housing are generous, as the income cutoff is set at household size-adjusted median income. For example, in 2018 the total maximum income per household to qualify for social housing was 36,798 euros. As a result, the pool of applicants is large and heterogeneous, consisting of households dependent on welfare receipt as well as households in the lower half of the income distribution. Eligible households may apply through a centralized city-wide waiting list, with wait times in the range of 7-12 years. A small number of units are allocated by lottery though, so that some lucky households may avoid the long waiting times.

#### B.1.1 The role of housing associations

A “housing association” is an organization that focuses on the building, management and letting of social housing units. Roughly half of the total housing stock in Amsterdam is owned by these independent not-for-profit associations ([van der Veer and Schuiling, 2005](#)). These organizations originated in the mid-1800s with the aim of providing housing for urban workers, and were typically founded by workers’ associations or by employers as a means to avoid social unrest among their employees. A major policy shift was the Housing Act of 1901, which assigned the associations the sole objective of promoting public housing, in return for favorable loans and subsidies

for construction and management from the government. According to Musterd (2014) the associations became especially prominent after WWII due to a housing shortage induced by the baby boom. This led the Dutch state to provide the associations with further construction subsidies to increase housing supply. In the mid 1990s the housing associations were privatized as part of a nationwide strategy to encourage home ownership over renting and reducing the fiscal burden of social housing. This meant that financial support from the state ended but housing associations still remained subject to the statutory obligation to provide good and affordable houses for lower income groups (Regout, 2016). The government wrote off all outstanding loans to the associations, while simultaneously cancelling its subsidies. Government policy has been to actively encourage housing associations to sell off units to owner occupants. For example, the requirement for housing associations to obtain government permission before selling their rental properties has been removed. In Amsterdam the share of home ownership increased from 11 to 30% between 1995 and 2015, while the ratio of social rental housing declined from 58 to 44% (van Duijne and Ronald, 2018).

As of recently, two thirds of social housing is owned by housing associations, while one third is owned by private individuals or real estate management companies (recall that the “social housing” label is based on the physical features of the house, not who owns it).

### B.1.2 The points system and the determination of rents

The national points system determines if a housing unit is considered social housing, and if so, how much its rent should be and at what rate it may be increased within a tenancy (Fitzsimons, 2013). Both private owners and housing corporations have to follow this system.

The number of points a unit receives is predominantly based on physical characteristics such as room sizes, heating type, number of bathrooms, and neighborhood amenities, such as public parks and access to public transport. Therefore, two houses with identical physical features and neighborhoods, one in Amsterdam and one in a small rural town, would have the same number of points and thus the same maximum allowable rent. This failure to account for regional discrepancies has been one reason why the system has been criticized, as well as why it has recently been adjusted. Since October 2011, a market-based element has been added to the system: units in areas with housing shortage are allocated more points so that higher rents may be allowed.

This correction allows rents to adjust to the market on a regional basis: however, the units may only receive up to a maximum of 25 points based on this criterion (as of 2013, total points for a unit range between 40 and 250). Units with less than 143 points are classified as social housing and always have a rent ceiling. Those units over 143 points are classified as private market and have no rent ceiling: however, they also have no rent floor. Therefore, their actual agreed upon rent may be very low, and in the case it is below the “liberalization line” (an annually determined threshold, 681 euros in 2013) they are classified instead as social housing. This typically happens with housing units owned by housing associations in low demand neighborhoods. The unit may have enough points to be in the unregulated sector but if demand is low it is rented below the liberalization line: thus any rent increases within tenancy are restricted in the same way as a social unit (where typically increases are tied to inflation). Thus, by possibly subjecting houses with high quality physical characteristics to social housing status and rent increase restrictions, the system has crowded out investors from the market for dwellings with points in the 142 to 200 points bracket.

### B.1.3 Rent increases and contract termination

Social housing is subject to controls on initial rent levels as well as maximum within-tenancy rent increases that are set annually by the Ministry of Public Housing (typically tied to the inflation rate). Private housing is not subject to within-tenancy rent increases ([Fitzsimons, 2013](#)). Landlords may terminate contracts with their tenants on the following grounds: i) the tenant not behaving in a responsible manner, ii) in the case of temporary tenancy, the landlord can officially end the contract, iii) urgent use by the landlord himself, with the landlord’s interest in living in the house being greater than that of the tenant, iv) the tenant turning down a reasonable offer to enter into a new tenancy agreement referring to the same apartment, or v) realization of a zoning plan. In the case of disputes, the parties must submit their case for deliberation to the Rent Commission, which charges a fee for analyzing each case ([Fitzsimons, 2013](#)).

### B.1.4 Rental subsidies

Another housing affordability policy in the Netherlands are rental subsidies (huurtoeslag). Requirements to qualify a rental subsidy are more strict than for social

housing and several criteria that must be met. First, the total income in 2018 of the household should not be above 30,400 euros (22,400 if it is a single household) as compared to 36,798 maximum income for social housing. Second, rent has to be between 225,08 and 710,68 euros for 2018 with different cut-offs depending on the household composition. In any case, total rent has to be below the maximum rent allowance for housing associations.

## Appendix C. Hotels and Airbnb in Amsterdam

In this section we point out key features of the hospitality sector that we use in our analysis.

### C.1 The hotel industry in Amsterdam

The number of overnight stays in Amsterdam has almost doubled, with 6 million of overnight visitors in 2008 and 16 million in 2017. More interestingly, Amsterdam is a city with a high number of tourists by resident. According to Mastercard Visitor Index Report of 2017, Amsterdam ranked first in number of overnight visitors per capita among the top 20 most visited cities in the world as shown in Figure 25.

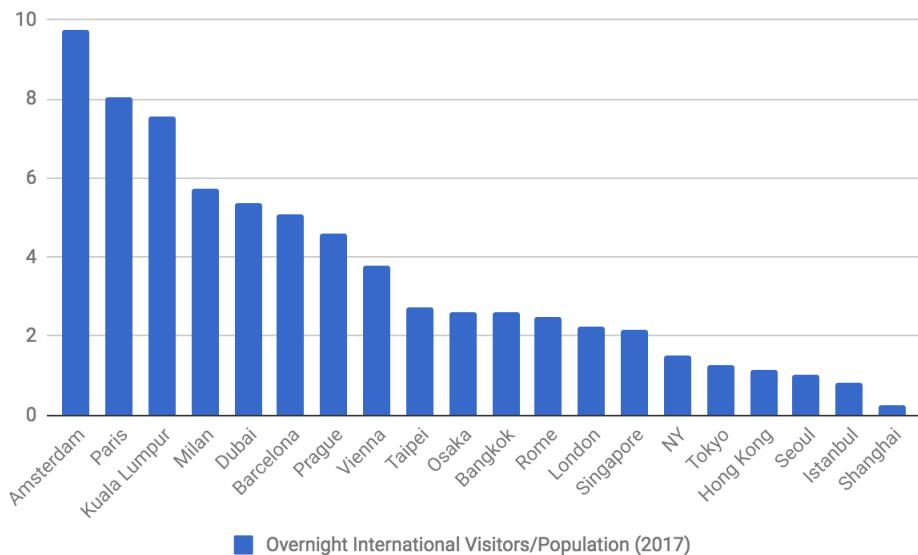


Figure 25: Tourists per resident for major global cities (2017)

This rapid growth in tourist volume has been accompanied by an expansion of the hotel industry, with more high-end hotels being constructed on average. The number of hotels, rooms and beds have increased by 34%, 65%, and 66% respectively between 2008 and 2017. The difference in growth rates is due to the opening of large-scale hotels in the last decade.

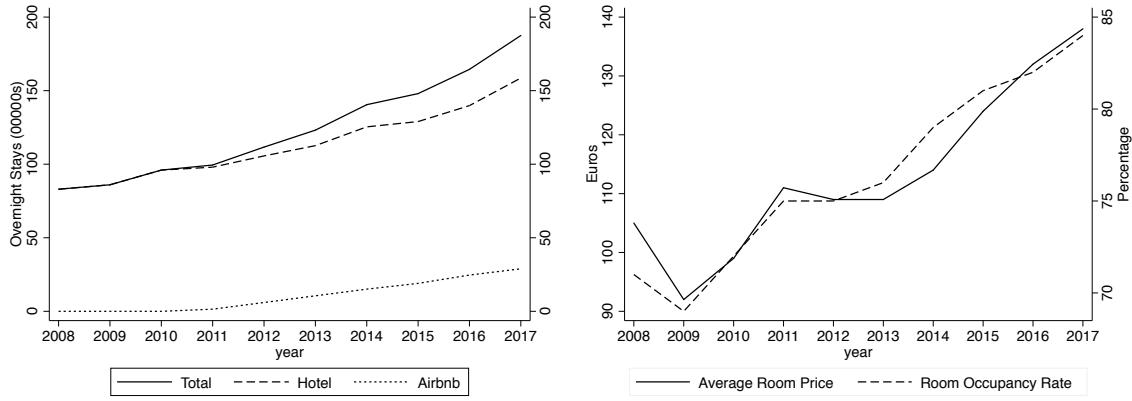


Figure 26: Hotel and Airbnb listings volume, occupancy rates, and prices.

The explosion of tourism in Amsterdam has also led to an increase in the number of jobs and businesses dedicated to this sector, increasing by 50% and 63% respectively in the same time period. Half of the jobs in the tourism sector correspond to catering services. Culture and recreation related jobs account for 16%, the same amount as jobs in the hotel sector, while transportation represent 8% of the total number of jobs dedicated to tourism.

Finally, hotel performance has also improved for the same time period. First, the average room price has followed an increasing trend, going from EUR 105 in 2009 to EUR 138 in 2017. The average annual price growth has been of 3.3% with a peak in 2015 of 8.8%.<sup>46</sup> We can see a slight drop in 2009 in both occupancy rate and average hotel rates, due to the financial crisis, followed by a fast recovery in 2010 (Figure 27). Second, occupancy rates have been steadily increasing from around 70% to 84%, a pattern that similarly holds for hotels of all quality ranges. Overall, average annual hotel revenue has had a total growth of 57% from 2008-2017.

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<sup>46</sup>Average inflation for the same time period and year are 1.4% and 0.22% respectively. Source: IMF inflation reports.

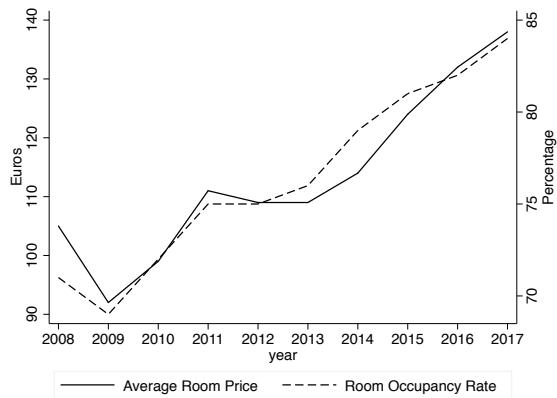


Figure 27: Room prices and occupancy rates

All these figures were obtained from tourism reports commissioned by Onderzoek, Informatie en Statistiek (Research, Information, and Statistics in English), which collects data for the Amsterdam City Data project.<sup>47</sup>

## C.2 Airbnb details

First, Airbnb hosts can rent their property in three ways: as an entire home rental, a private room rental, or a shared room rental. Entire home rentals for extended periods of time are typically associated with commercial operators, while live-in hosts are more likely to offer short, private or shared rentals. This distinction between rental types is key to understanding the degree to which the platform is being used by commercial operators and thus removing housing stock from locals, rather than simply allowing locals to make use of their idle capacity.

Second, guests and hosts have incentives to review each other after a stay has been completed due to the reputational nature of the platform. These reviews allow us to infer actual reservations, which cannot be directly observed in the InsideAirbnb data.

Third, hosts keep an availability calendar which potential guests can see and make reservations on. We argue that these calendars reflect true availability since hosts have incentives to keep them up to date. Calendars have a default “instant booking” feature, which means that a potential guest can make a reservation on an available calendar date without host approval. At the moment the reservation is made, the

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<sup>47</sup><https://www.ois.amsterdam.nl/toerisme>

guest is charged for his entire stay. If a host decides to cancel because her calendar availability was incorrectly set, she is fined, receives an automated negative review, and in some cases may have her listing removed. This provides incentives for hosts to keep their calendars updated. There is an option to turn off “instant booking”, so that any reservation has to be approved by the host before the guest is charged. However, over 60% of bookings are instantly booked since hosts can set “Instant Book” to apply only to guests with positive reviews. Furthermore, Airbnb strongly encourages hosts to use the “Instant Book” since these listings tend to appear first in search results and they streamline the reservation process for guests (some of which may only search among listings with “Instant Book”).<sup>48</sup> The reason why we stress this is that we will use calendars to measure Airbnb supply, so we want to argue that they reflect true availability.

### C.3 Host statistics

According to Airbnb the average booking in Amsterdam is for 3.9 nights in 2012-2013.<sup>49</sup> This number has decreased to 3.3, 3.2, and 3.4 nights in 2015, 2016, and 2017, respectively.<sup>50</sup> Fradkin et al. (2018) report an average review rate by guests of 67% for Airbnb worldwide.

### C.4 Policies regulating Airbnb

In order to rent an Amsterdam apartment on Airbnb the host must be the apartment’s main occupant or owner. Hosts who live in social housing owned by a housing association may not rent their apartments on Airbnb at all.

In December 2016 Airbnb agreed to enforce short-term rental regulations on behalf of the Amsterdam city council, making Amsterdam one of only two cities in the world in which Airbnb has agreed to police its hosts.<sup>51</sup> Specifically, Airbnb has agreed to put caps on the number of nights hosts are allowed to rent out their entire homes: no more than 60 nights per year per entire home listing. Exceptions to the cap are handled on a case-by-case basis and must be approved by the Amsterdam municipality. Private rooms and shared rooms listings remain uncapped. While regulations such as the

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<sup>48</sup><https://press.airbnb.com/instant-book-updates/>

<sup>49</sup><https://blog.atairbnb.com/economic-impact-airbnb/#amsterdam>

<sup>50</sup><https://www.ois.amsterdam.nl/toerisme>

<sup>51</sup><https://www.theguardian.com/technology/2016/dec/03/airbnb-regulation-london-amsterdam-housing>

nights cap exist in many Airbnb markets, enforcement by city regulators is weak due to the decentralized nature of the platform's listings. Unless enforcement is carried out directly by the platform, regulations cannot be expected to have much bite. Preliminary research from Airbnbcitizen.com suggests the regulation seems to have had a significant impact since its implementation on March 1, 2017: the number of entire homes being shared has been reduced by two thirds between May 2016 and May 2017.<sup>52</sup> Furthermore, the company has agreed to reduce the cap further to 30 nights per year beginning on January 1, 2019.<sup>53</sup> In addition to the caps being directly enforced by the site, users are required to report to the Amsterdam municipality each time the home is rented out. Failure to do so results in fines between 6,000-20,500 euros.<sup>54</sup>

## C.5 Airbnb competitors

Airbnb's main competitors are other short-term rental platforms and traditional hotels. As of 2016, Airbnb's share of total overnight stays in Amsterdam was 15%, with the rest of the market being dominated by traditional hotels. Prices of Airbnb listing lie slightly below than the average price for 3-star hotels, see Figure 28 below.<sup>55</sup> It is precisely low-end hotels that report having suffered the most from short-term rentals, while 4- and 5-star hotels report to have very little competition from this new form of accommodation.<sup>56</sup> Therefore, it seems that Airbnb competes with the hotel industry but only at mid- and low-scale hotels, as pointed also by [Farronato and Fradkin \(2018\)](#). Within the short-term rental market in Amsterdam, Airbnb accounted for 80% of total short-term rentals in 2016 and in 2017 Amsterdam.<sup>57</sup> Its main competitor is Wimdu, with 13% of the market in 2017, but there are other platforms like Booking, Homeaway, Flipkey, and 9flats. All of those accounted for 4000 listings in 2016.

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<sup>52</sup><https://www.airbnbcitizen.com/new-data-on-responsible-home-sharing-in-amsterdam/>

<sup>53</sup>[https://techcrunch.com/2018/01/10/amsterdam-to-halve-airbnb-style-tourist-rentals-to-30-nights-](https://techcrunch.com/2018/01/10/amsterdam-to-halve-airbnb-style-tourist-rentals-to-30-nights/)

<sup>54</sup><https://www.amsterdam.nl/veelgevraagd/?productid=%7B6DDDBA95B-F95C-460F-917B-08B34CBEC384%7D>

<sup>55</sup>D

<sup>55</sup>Source: 2019 Tourism Report in <https://www.ois.amsterdam.nl/toerisme>

<sup>56</sup><https://www.ois.amsterdam.nl/toerisme>

<sup>57</sup><https://www.ois.amsterdam.nl/toerisme>

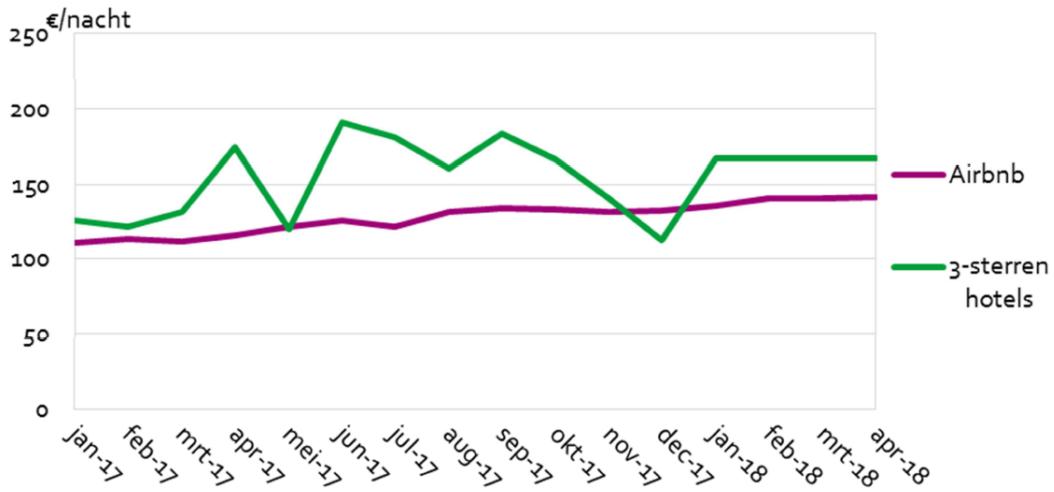


Figure 28: Airbnb and 3-star hotel prices in Amsterdam

Farronato and Fradkin (2018) also find that Airbnb utility from short-term rentals is below the mean of budget hotels. Their results suggest that Airbnb lowers hotel profits but not the number of occupied rooms. The reason is that hotels are inelastic in the short run, so during peak demand dates Airbnb overflows the market with supply and prevents hotels from spiking up their prices. However, during off-peak period they find that Airbnb has no negative effect on hotel prices.

Given that in our analysis we use average prices and quantities at the year-zipcode level, based on the evidence previously exposed, our assumption is that Airbnb hosts take the 3-star hotel prices as given, and set their prices below those. In other words, Airbnb does not have an effect in the average yearly prices of the hotel industry.

## Appendix D. Data appendix

### D.1 Airbnb supply

A challenge in working with the web scraped Inside Airbnb data is that some of the listings may be inactive, and thus would overstate Airbnb supply. For example, a listing that was created for a single hosting experience in 2015 and left idle on the site would show up in our raw scrapes after 2015 even though it never had any further reservations. To deal with this we need to define what it means for a listing to be considered “active”. To do this we use calendar availability data, which as we argued in the institutional details appendix, reflects true availability.

We say that a listing has “activity” at date  $t$  if it has been reviewed by a guest or its calendar has been updated by its host at  $t$ . A listing is considered to be operated commercially if it is an entire home listing, it has received new reviews over the past year, and it satisfies any of the following three conditions:

1. Intent to be booked for many days over the next year: the “Instant Book” feature is turned on and the listing is available for more than 90 days over the next year.
2. Frequent updates, reflecting intent to be booked even though it may not have the “Instant Book” feature turned on: the listing has shown availability for more than 90 days over the next year at least twice in the year.
3. Over 60 nights a year booked, as inferred from reviews: the listing has had over 10 new reviews, which at a review rate of 67% and an average stay of 4 nights translates into 60 nights a year.

Finally, a limitation of the listings data is that since our webscrapes begin in 2015 we need to construct Airbnb supply before 2015 using the calendar and review data, but we can only do this for listings that survived up to 2015. For example, a listing that was active in 2011 would only be detected by our methodology if it remained on the site in 2015. Thus, our measure of listings is biased downwards.

## D.2 Rent imputation

We link microdata from the universe of housing transactions and appraisal values to a national rent survey which contains property values (WOZ value) and physical characteristics, such as type of property (apartment, farm, independent house, house with office space, etc). Property values are used to calculate how much tax the household should pay. Each year, the local government assesses every property and issues its resulting WOZ value. Any owner can object to the issued valuation and request a new one. According to the Amsterdam city government, WOZ values are mostly based on market values.<sup>58</sup> To confirm this we regress property values on house transaction values. Even though property values slightly underpredict the transaction value, WOZ values explain most of the sale prices variation.<sup>59</sup> Residuals are larger on the tails of the sale price distribution. Our takeaway is that WOZ values are a good predictor of market values, and therefore informative to predict rental prices.

We use the matched subset of the rental survey with the housing property values to predict rents for housing units that do not appear in our rent survey but that do appear in the universal property value data. For robustness, we predict rental prices using several techniques. The first method that we use is a standard hedonic regression, where we regress rental prices on WOZ values, house characteristics, time and zipcode fixed effects on 90% of the sample. We leave out 10% to asses the performance of the hedonic regression on prediction of new values. For the hedonic regression, the in-sample  $R^2$  is of 0.67 while the out-of-sample  $R^2$  is of 0.62. We also predict rental prices using machine learning methods. We tried several methods, such as LASSO, KNN, local linear forest, but the algorithm that performs best is a standard random forest. We use the same inputs as for the hedonic regression, that is, WOZ values, house characteristics, time and zipcode fixed effects. Random forest outperforms hedonic regressions in-sample, with an  $R^2$  of 0.78, as well as out-of-sample, with an  $R^2$  of 0.75. Given the better performance of the second method, any individual or average rental prices throughout the paper will be imputed using a random forest following the procedure described above.

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<sup>58</sup><https://www.amsterdam.nl/en/taxes/property-valuation/>

<sup>59</sup>The exact explained variation is pending clearance from CBS.

### D.3 Description of the micro data used for estimation

The time period covered by our data is 2008-2018. Our income data comes from the tax return files. Households are uniquely identified by the id of the main breadwinner and year. Our residential data comes from the cadaster registry and contains the universe of all Dutch citizens. We only keep the cadaster data that is matched with the main breadwinner in the tax return data. We restrict to households that have lived at least once inside the city of Amsterdam between 2008 and 2018.

One of the limitations of our data is we do not observe all households for all periods of time. For example, a person who started reporting income in 2012 will appear in our sample only from that year onward. We also see some households leaving our sample, presumably because the household disappears for tax purposes. This can be driven by a change in the identity of the main breadwinner, death, or simply because the household leaves the country. To account for these movements in the tax return files, we only consider households from the first year they started reporting income until the last year they started reporting income. In some cases we also see households in the tax return files who leave and then come back again. We keep those missing years in between. Finally, we only keep households with tax return data available for at least two years.

We observe demographics of the main breadwinner, which are tenancy type (home-owner, renter, social housing), country of origin (all countries in the world), education level, gross and disposable income, income per-capita, source of income, age, households composition, and whether there are children in the household. We link this socio-demographic data with the income and cadaster data.

Given that we know the source of income for each household, we say that a household as a *working households* if its income source is not classified as social or unemployment benefits, pensions, student grants, etc. We only keep working households. Given a household, we keep all years between the first time until the last time it is classified as a working household.

We translate education level to a skill level. The Dutch system follows a non-standard system of education where children can access to several types of secondary education as well as several types of tertiary education.<sup>60</sup> We classify households as *low skill* if their maximum level of education is secondary education. We classify

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<sup>60</sup>For more details see [https://en.wikipedia.org/wiki/Education\\_in\\_the\\_Netherlands](https://en.wikipedia.org/wiki/Education_in_the_Netherlands)

households as *medium skill* is if their maximum level of education is the equivalent of the American community college. Finally, we classify households as *high skill* if their maximum level of education is college or above.

For country of origin we reduce the subset of categories to four that seem to be the most important in Amsterdam: Dutch, Dutch colonies (includes Surinamese and Antillean households), Western (European, North American, and households from Oceania), and Non-western (includes Morocco, Turkish, Nigerian, etc).

Finally, even though we keep all households for the amenities estimation, we drop all years in which households are currently living in social housing for our demand estimation. We do so because we expect households living in social housing to have very different incentives from home-owners and traditional renters. See Appendix [B.1.2](#) for more details about social housing in the Netherlands. Given a year with tenancy status different from social housing, we classify households as previously living in the outside option those who previously lived in social housing.

## D.4 Technical details for k-means clustering

In this section we describe the technical details of the k-means classification performed on the set of observations described in D.3.

First, the subset of demographics that we use to cluster households are: percentile of disposable income, percentile of per person income, ethnic background (Dutch, Dutch colonies, Western, and Non-western), skill (high, medium, and low), tenancy type (home-owners, renters, and social housing), children, proportion of time with children, and age. Choosing the optimal number of clusters is a statistically complicated task. Moreover, standard statistical criteria do not apply here. In our case, the optimal number of clusters is the one that minimizes variance and bias, but also takes into account the measurement error in the CCP estimation. To the best of our knowledge there is no statistical criterion that incorporates all of those features. Our practical solution was to start with a large number of clusters, and decrease this number sequentially until we hit a small number of cluster but still with clearly defined differences across clusters.

We use a two-step clustering algorithm, clustering first on housing tenancy using three groups. We do so, because we expect households with different tenancy status (home-owners vs. renters vs. social housing) to have significantly different preference parameters in their utility estimation. For example, we can expect home-owners to have larger moving costs than renters. Second, we use the rest of the demographics, by choosing the number of subgroups inside each tenancy-status category. Unfortunately, classifications with more than 15 clusters (5 sub-clusters) lead to groups with a low number of households. This is problematic, because the smaller the initial groups, the higher the measurement errors in CCP frequencies.<sup>61</sup> The classification with 15 clusters lead to groups without any stark differences. For example, for two groups the only difference was the skill level, where one group was low skill and the other one medium skill. Given that our goal is to have as few groups as possible, as we do not expect these groups to have extremely different preferences, we decided to cluster households using 4 sub-groups inside each tenancy status group. With this classification we see clear differences across groups. Results can be seen in Table 3.

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<sup>61</sup>Monte Carlo simulations indicate that a reasonable minimum number of households per group needs to be around 18000. The reason is that the demand estimation problem has around 180 states. Observe than with 18000 initial households and 180 states, there is an average of 100 agents per state.

## D.5 Description of consumption amenities

Table 8: Description of consumption amenities in ACD

Variable	Dutch name	English translation
Touristic amenities	<b>Vestigingen toerisme</b> Vestingen met de activiteitencodes: logies en overnachtingen, overige horeca, personenvervoer, reisorganisatie- en bemiddeling, cultuur en recreatie, jachthavens, zeilscholen en recreatieve detailhandel.	<b>Tourism branches</b> Fortresses with activity codes: accommodation and accommodation, other catering, passenger transport, travel organization and mediation, culture and recreation, marinas, sailing schools and recreational retail.
Sport amenities	<b>Voorzieningen: vestigingen sport en recreatie</b> De deelfunctie 'sport en recreatie' wordt aan een vestiging toegekend op basis van de activiteitencode (SBI) waarmee deze vestiging is geregistreerd bij de Kamer van Koophandel.	<b>Facilities: sports and recreation locations</b> The sub function 'sports and leisure' is awarded to a settlement based on the activity code (SIC) that this office is registered at the Chamber of Commerce.
Education amenities	<b>Voorzieningen: vestigingen onderwijs</b> De deelfunctie 'onderwijs' wordt aan een vestiging toegekend op basis van de activiteitencode (SBI) waarmee deze vestiging is geregistreerd bij de Kamer van Koophandel.	<b>Services: education establishments</b> The sub-function 'education' is assigned to an establishment on the basis of the activity code (SBI) with which this establishment is registered with the Chamber of Commerce.
Catering <sup>62</sup>	<b>Horecavestigingen per 1.000 inwoners</b> Aantal vestigingen horeca per 1.000 inwoners.	<b>Catering establishments per 1,000 inhabitants</b> Number of branches in the hospitality industry per 1,000 inhabitants.
Restaurants	<b>Horeca: vestigingen restaurant</b> De deelfunctie 'restaurant' wordt aan een vestiging toegekend op basis van de activiteitencode (SBI) waarmee deze vestiging is geregistreerd bij de Kamer van Koophandel.	<b>Catering: restaurant locations</b> The sub function 'restaurant' is awarded to a settlement based on the activity code (SIC) that this office is registered at the Chamber of Commerce.
Restaurants	<b>Horeca: vestigingen cafe</b> De deelfunctie 'cafe' wordt aan een vestiging toegekend op basis van de activiteitencode (SBI) waarmee deze vestiging is geregistreerd bij de Kamer van Koophandel.	<b>Catering: cafe locations</b> The sub function 'cafe' is awarded to a settlement based on the activity code (SIC) that this office is registered at the Chamber of Commerce.
Food Stores	<b>Winkelruimtes food</b> Aantal winkelruimtes voor food (dagelijkse goederen).	<b>Number of food stores</b> Number of retail space for food (daily goods).
Non-Food Stores	<b>Winkelruimtes non-food</b> Aantal winkelruimtes voor non-food (niet-dagelijkse goederen)..	<b>Number of non-food stores</b> Number of retail space for non-food (non-daily goods).

## Appendix E. Technical appendix

### E.1 Micro-foundation of the utility function

In this section we micro-found household utility for the location demand model presented in section 5.2. We also outline the connection to the demand for endogeneous amenities found in section 5.1.

We follow a similar specification for the marginal utility of money in our indirect utility as in Couture et al. (2019), where households pay  $r_j$  for a unit of housing leaving them with total budget  $b_j^k = w^k - r_j$  for consumption amenities.<sup>63</sup> We also assume that there are non-market amenities in location  $j$  that also enter utility, denoted by  $A_j$ , such as access to public transport, nuisance and congestion of public spaces generated by tourists. Finally, households derive utility from their location tenure  $\tau$ . Conditional on living in  $j$ , a household of type  $k$  solves the following nested problem to maximize its utility over services:<sup>64</sup>

$$\max_{\{q_{is}\}_{is}} A_j \tau^{\nu^k} \prod_s \left( \left( \sum_{i=1}^{N_s} q_{is}^{\frac{\sigma_s-1}{\sigma_s}} \right)^{\frac{1}{\sigma_s-1}} \right)^{\alpha_s^k} \quad \text{s.t.} \quad \sum_{is} p_{is} q_{is} = (w^k - r_j), \quad (14)$$

with  $\sum_s \alpha_s^k = 1$ .

Next, we show that the demand system in section 5.1 can be derived from the nested preferences in 4. First order conditions with respect to  $q_{is}$  gives

$$A_j \tau^{\nu^k} \alpha_s^k \left( \left( \sum_{i=1}^{N_s} q_{is}^{\frac{\sigma_s-1}{\sigma_s}} \right)^{\frac{1}{\sigma_s-1}} \right)^{\alpha_s^k-1} \left( \sum_{i=1}^{N_s} q_{is}^{\frac{\sigma_s-1}{\sigma_s}} \right)^{\frac{1}{\sigma_s-1}} q_{is}^{-\frac{1}{\sigma_s}} \prod_{s' \neq s} \left( \left( \sum_{i=1}^{N_s} q_{is}^{\frac{\sigma_s-1}{\sigma_s}} \right)^{\frac{1}{\sigma_s-1}} \right)^{\alpha_{s'}^k} = \lambda^k p_{is}.$$

Trivially, all firms within a service  $s$  face the same demand curve. Because we have assumed that firms within a service have the same marginal cost, in equilibrium  $q_{is} = q_s$  and  $p_{is} = p_s$  for all  $i$  in sector  $s$ . In equilibrium, the total quantity that a

<sup>62</sup>We convert the variables “Catering” to total number of catering establishments by location per year. It includes pubs, bars, restaurants, canteens, and others.

<sup>63</sup>This specification has been widely used in the industrial organization literature. See for example Berry (1994), Berry et al. (1995), or Nevo (2000). We can also allow for  $b_s^k = \lambda^k \alpha_s^k (w^k - r_j)$  and qualitatively results do not change.

<sup>64</sup>We can allow households to buy a good available at all locations with normalized price equal to 1 as in Couture et al. (2019).

type  $k$  consumer demands from service  $s$  is

$$Q_s^k = N_s q_s^k.$$

Now, with a bit of algebra, we can show that

$$\frac{p_s}{\alpha_s^k} N_s q_s^k = \frac{p'_{s'}}{\alpha_{s'}^k} N'_{s'} q_{s'}^k,$$

for all  $s, s'$ . Substituting inside the budget constraint, we obtain

$$Q_s^k = N_s q_s^k = \frac{\alpha_s^k}{p_s} (w^k - r_j),$$

which gives the desired result.

Under the symmetric equilibrium presented in section 5.1.3, the indirect utility that a type  $k$  household living in  $j$  at time  $t$  receives is

$$A_{jt} \tau^{\nu^k} \prod_s \left( \frac{\alpha_s^k}{p_{sjt}} (w_t^k - r_{jt}) N_{sjt}^{\frac{1}{\sigma_s}} \right)^{\alpha_s^k}.$$

We also know that in equilibrium prices are given by

$$p_{sjt} = \frac{c_{sjt}}{1 - \frac{1}{\sigma_s}},$$

so substituting inside the indirect utility yields,

$$A_{jt} \tau^{\nu^k} (w_t^k - r_{jt}) \prod_s \left( \frac{\alpha_s^k (1 - \frac{1}{\sigma_s})}{c_{sjt}} N_{sjt}^{\frac{1}{\sigma_s}} \right)^{\alpha_s^k}, \quad (15)$$

We assume that the utility obtained from non market amenities is given by

$$A_{jt} = \prod_d a_{jt}^{\beta_a^k},$$

where  $a_{jt}$  denotes a specific non-market good in location  $j$  at time  $t$ .

Substituting in 15, taking logs, and rearranging:

$$\mu_j^k + \nu^k \log \tau_t + \sum_a \beta_a^k \log a_{jt} + \log(w_t^k - r_{jt}) + \sum_s \frac{\alpha_s^k}{\sigma_s} \log N_{sjt} + \psi_{jt}^k,$$

where  $\mu_j^k = \sum_s \alpha_s^k (\log \alpha_s^k + \log(1 - \frac{1}{\sigma_s}))$ , and  $\psi_{jt}^k = - \sum_s \alpha_s^k \log c_{sjt}$ .

Finally, the utility flow for living in location  $j$  is given by

$$\mu_j^k + \nu^k \log \tau_t + \log(w_t^k - r_{jt}) + \sum_a \beta_a^k \log a_{jt} + \sum_s \frac{\alpha_s^k}{\sigma_s} \log N_{sjt} + \psi_{jt}^k + \epsilon_{ijt},$$

where  $\epsilon_{ijt}$  is a type I EV error. We divide the previous equation by the variance of the shock  $\epsilon_{ijt}$  to normalize it to 1. As in section After such normalization, the final expression for the indirect utility is

$$u_{j't}^k + \varepsilon_{ijt} = \delta_{d(j)}^k + \delta_\tau^k \tau_t + \delta_w^k \log(w_t^k - r_{jt}) + \sum_a \delta_a^k \log a_{jt} + \sum_s \delta_s^k \log N_{sjt} + \xi_{jt}^k + \varepsilon_{ijt}.$$

Observe that  $\xi_{jt}^k$  will be part of the unobservable component in our regression equation.

At time  $t$ , a household  $i$  of type  $k$  with past location  $j_{t-1}$  and tenure  $\tau_{t-1}$  chooses the location that maximizes its value function given the indirect utility values for each location  $u_{j(d)t}^k$

$$V_t^k(j_{t-1}, \tau_{t-1}) = \max_d u_{j(d)t}^k - MC^k(j(d), j_{it-1}) + \varepsilon_{ijt} + \beta EV_{t+1}^k(d, j_{t-1}, \tau_{t-1}),$$

### E.1.1 Extra household income from short-term rentals

Conditional on living in location  $j$ , assume household  $i$  has some idle capacity of their housing unit. If household  $i$  rents the apartment, it earns profits  $p_j$  while incurring cost  $c_{ij}$ . If it does not rent its idle capacity, it makes no income and does not incur any cost. Assume that  $c_{ij} \sim F(c)$ . Hence, household  $i$  rents in the short-term rental market with probability,

$$\mathbb{P}(c_{ij} \leq p_j) = F(p_j)$$

Hence, if household  $i$  rents its idle capacity, it will earn total income equal to,

$$w_i + p_j$$

and therefore, expected household total income is given by

$$w_i + F(p_j)p_j = w_i + h(p_j).$$

## E.2 Technical details of the demand estimation

In this section we sometimes drop the type superscript  $k$  to simplify notation.

### E.2.1 Expected Value Function

Using Assumption 2, we can integrate over future  $\epsilon$  to reduce the dimensionality of the problem, defining the ex-ante value function as follows:

$$\begin{aligned}\mathbb{E}_t[V_{t+1}(x', \epsilon')|d, x, \epsilon] &= \int V_{t+1}(x', \epsilon') dF_t(x', \omega_{t+1}, \epsilon'|d, x, \epsilon) \\ &= \int \left( \int V_{t+1}(x', \epsilon') dF_t(s', \omega_{t+1}|d, x) \right) dF(\epsilon') \\ &= \int \left( \int V_{t+1}(x', \epsilon') dF(\epsilon') \right) dF_t(x', \omega_{t+1}|d, x) \\ &= \int \bar{V}_{t+1}(x') F_t(x', \omega_{t+1}|d, x) = \mathbb{E}_t[\bar{V}_{t+1}(x')|d, x]\end{aligned}$$

We can also define the conditional value function

$$v_t(d, x) = u_t(d, x) + \beta \mathbb{E}_t[\bar{V}_{t+1}(x')|d, x] = u_t(d, x) + \beta EV_t(d, x),$$

where  $\bar{u}_t(d, x) = u(d, x, \omega_t, 0)$ . By assumption 3 and the properties of the logit errors we obtain

$$P_t(j, x) = \frac{\exp(v_t(j, x))}{\sum_d \exp(v_t(d, x))}, \quad (16)$$

and

$$\bar{V}_t(x) = \log \left( \sum_d \exp v_t(d, x) \right) + \gamma,$$

where  $\gamma$  is Euler's constant. Combining the two previous equations,

$$\bar{V}_t(x) = v_t(d, x) - \ln(P_t(d, x)) + \gamma. \quad (17)$$

Observe that the previous equation holds for any state  $s$ , and, more importantly, for any action  $j$ . This will be key to exploit renewal actions.

### E.2.2 Toward a demand regression equation

Our demand regression equation's starting point follows Hotz and Miller (1993), by taking differences on equation 16:

$$\ln \left( \frac{P_t(d, x_{it})}{P_t(d', x_{it})} \right) = v_t(d, x_{it}) - v_t(d', x_{it}). \quad (18)$$

Observe that  $v_t(d, x_{it}) - v_t(d', x_{it})$  is equal to a threshold value  $\Delta\epsilon_t^*$  in the error differences  $\epsilon_{idt} - \epsilon_{id't}$  which make the agent indifferent between location  $d$  and location  $d'$ . That is if  $\epsilon_{idt} - \epsilon_{id't} > \Delta\epsilon_t^*$  agent prefers location  $d$  over location  $d'$ .

Substituting for the choice specific value function,

$$\bar{u}_t(d, x_{it}) - \bar{u}_t(d', x_{it}) - \ln\left(\frac{P_t(d, x_{it})}{P_t(d', x_{it})}\right) = \beta \mathbb{E}_t[\bar{V}_{t+1}(x'_{it+1})|d', x_{it}] - \beta \mathbb{E}_t[\bar{V}_{t+1}(x_{it+1})|d, x_{it}] \quad (19)$$

The previous equation has an easy interpretation: at the indifference threshold, the surplus in utility today is equal to the loss in tomorrow's expected utility of location  $d$  compared to  $d'$ . This is the discrete version of the Euler conditions for continuous choice variables.

The expected value at time  $t + 1$  can be decomposed between its expectation at time  $t$  and its expectational error

$$V_{t+1}(x'_{it+1}) = \mathbb{E}_t[\bar{V}_{t+1}(x'_{it+1})|d, x_{it}] + \nu_t(d, x_{it})$$

Now, recall state variables  $j_{it}$  and  $\tau_{it}$  evolve deterministically, and

$$F(w_{it+1}|j_{it}, \tau_{it}, w_{it}) = F(w_{it+1}|w_{it})$$

Plugging in everything in equation 19 gives us

$$\begin{aligned} \bar{u}_t(d, x_{it}) - \bar{u}_t(d', x_{it}) - \ln\left(\frac{P_t(d, x_{it})}{P_t(d', x_{it})}\right) &= \beta \left[ \sum_{w_{it+1} \in \mathcal{W}} F(w_{it+1}|w_{it}) (V_{t+1}(x'_{it+1}) - V_{t+1}(x_{it+1})) \right. \\ &\quad \left. - \nu_t(d, x_{it}) + \nu_t(d', x_{it}) \right]. \end{aligned}$$

Using equation 17 to replace the continuation values  $\bar{V}_{t+1}$  for choice  $\tilde{d}$  gives us

$$\begin{aligned} \bar{u}_t(d, x_{it}) - \bar{u}_t(d', x_{it}) - \ln\left(\frac{P_t(d, x_{it})}{P_t(d', x_{it})}\right) &= \beta \left[ \sum_{w_{it+1} \in \mathcal{W}} F(w_{it+1}|w_{it}) \left( v_{t+1}(\tilde{d}, x'_{it+1}) - v_{t+1}(\tilde{d}, x_{it+1}) \right. \right. \\ &\quad \left. \left. - \ln\left(\frac{P_{t+1}(\tilde{d}, x'_{it+1})}{P_{t+1}(\tilde{d}, x_{it+1})}\right) \right) \right. \\ &\quad \left. - \nu_t(d, x_{it}) + \nu_t(d', x_{it}) \right] \quad (20) \end{aligned}$$

Now assume that  $\tilde{d}$  is a renewal action at time  $t + 1$ , i.e., moving to the same neigh-

borhood makes the future from period  $t + 2$  forward looks the same to the household, and hence it cancels out. The following holds

$$v_{t+1}(\tilde{d}, x'_{it+1}) - v_{t+1}(\tilde{d}, x_{it+1}) = \bar{u}_{t+1}(\tilde{d}, x'_{it+1}) - \bar{u}_{t+1}(\tilde{d}, x_{it+1}) = MC(j(\tilde{d}), j) - MC(j(\tilde{d}), \tilde{d})$$

so that plugging 20 inside gives us

$$\begin{aligned} \bar{u}_t(d, x_{it}) - \bar{u}_t(d', x_{it}) - \ln\left(\frac{P_t(d, x_{it})}{P_t(d', x_{it})}\right) &= \beta \left[ MC(j(\tilde{d}), j) - MC(j(\tilde{d}), \tilde{d}) \right. \\ &\quad - \sum_{w_{it+1} \in \mathcal{W}} F(w_{it+1}|w_{it}) \ln\left(\frac{P_{t+1}(\tilde{d}, x'_{it+1})}{P_{t+1}(\tilde{d}, x_{it+1})}\right) \\ &\quad \left. - \nu_t(d, x_{it}) + \nu_t(d', x_{it}) \right] \end{aligned}$$

Rearranging terms, the previous equation leads to the following regression equation

$$\begin{aligned} \ln\left(\frac{P_t(d, x_{it})}{P_t(d', x_{it})}\right) + \beta \ln\left(\frac{P_{t+1}(\tilde{d}, x_{it+1})}{P_{t+1}(\tilde{d}, x'_{it+1})}\right) &= \bar{u}_t(d, x_{it}) - \bar{u}_t(d', x_{it}) \\ &\quad + \beta \left( MC(\tilde{d}, j(d)) - MC(\tilde{d}, j(d')) + \nu_t(d, x_{it}) - \nu_t(d', x_{it}) \right) \end{aligned}$$

Now if we define the following,

- The operator

$$\Delta_{d,d'} x = x_d - x_{d'}$$

- The dependent variable

$$Y_{t,d,d',\tilde{d},x_{it}} \equiv \ln\left(\frac{P_t(d, x_{it})}{P_t(d', x_{it})}\right) + \beta \ln\left(\frac{P_{t+1}(\tilde{d}, x_{it+1})}{P_{t+1}(\tilde{d}, x'_{it+1})}\right)$$

- Error term

$$\tilde{\varepsilon}_{t,d,d',x_{it}} = \beta(\nu_t(d, x_{it}) - \nu_t(d', x_{it}))$$

then the final regression equation we obtain is

$$Y_{t,d,d',\tilde{d},x_{it}} = \Delta_{d,d'} \left( \delta_{j(.)} + \delta_\tau \tau_{x_{it}} - \delta_r \ln r_t + \delta_a \ln a_t + \xi_t + \beta MC(j(.), \tilde{d}) \right) + \tilde{\varepsilon}_{t,d,d',x_{it}}. \quad (21)$$

Observe the previous expression is a linear regression equation.

### E.2.3 Computational details of the estimation

The regression equation that we want to run is

$$\begin{aligned} Y_{t,d,d',\tilde{d},x_{it}} &= \ln \left( \frac{P_t(d, x_{it})}{P_t(d', x_{it})} \right) + \beta \ln \left( \frac{P_{t+1}(\tilde{d}, x_{it+1})}{P_{t+1}(\tilde{d}, x'_{it+1})} \right) \\ &= \Delta_{d,d'} \left( \delta_{j(.)} + \delta_\tau \tau_{x_{it}} - \delta_r \ln r_t + \delta_a a_t + \xi_t + \beta MC(j(.), \tilde{d}) \right) + \tilde{\varepsilon}_{t,d,d',x_{it}}. \end{aligned}$$

Observe that the previous equation is valid for any two different actions  $d, d'$ , any  $\tilde{d}$  such that  $\tilde{d}$  is a renewal action for  $d$  and  $d'$ , any state variable  $x_{it}$  and any time period  $t = 1, \dots, T-1$ . The number of actions is equal to the number of locations plus 2 ( $d = \text{outside option}$  or  $d = \text{stay}$ ). We collapse 100 zipcodes to 60 locations because many zipcodes contain very few households. The collapsing criterion requires that there are at least 30 households for every state  $x_{it}$ . In our practical application, the maximal tenure composition  $\bar{\tau}$  is set equal to three:

$$\bar{\tau} = 3.$$

Given that  $\bar{\tau}$ , the number of state variables is 168. Considering that we have 10 time periods (from 2008 until 2017) and 62 choices, the total number of possible combination of the previous equation is equal to

$$\binom{62}{2} \times 59 \times 178 \times 9 \approx 179 \times 10^6$$

Running a regression with  $179 \times 10^6$  millions of observations may be computationally problematic if we use standard techniques.<sup>65</sup> In order to reduce the number of path combinations, we construct  $(d, d', \tilde{d})$  tuples using *empirical probabilities* for each household  $i$  as follows:

- For any individual  $i$ , take  $d$  as the realized decision

$$d = d_{it}$$

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<sup>65</sup>There are big data techniques that partition the data into blocks, runs separate regression, and appropriately combines the estimated parameters in a Map-Reduce type of algorithm. We leave this method as a future alternative venue to estimate the parameters.

- For the counterfactual action  $d'$ , use moving to the outside option which never has zero probability in the data.
- Set  $\tilde{d}$  using the joint empirical cdf

$$\begin{aligned}\tilde{d} &\sim \hat{F}(d_{t+1} = d | x_{it+1}, x'_{it+1}, d \neq d_{it}, 0) \\ &= \hat{F}(d_{t+1} = d | x_{it+1}, d \neq d_{it}, 0) \hat{F}(d'_{t+1} = d | x'_{it+1}, d \neq d_{it}, 0),\end{aligned}$$

where independence follows from the Markovian nature of the dynamic problem.

Finally, we set

$$\tilde{d} = \arg \max_d \hat{F}(d_{t+1} = d | x_{it+1}, x'_{it+1}, d \neq d_{it}, 0).$$

After constructing the  $(d, d', \tilde{d})$  tuple for each of the  $(i, t)$  sampled observations, we estimate parameters using a standard regression procedure.

We also keep states  $(j_{t-1}, \tau_{t-1}, k)$  with at least 150 households in them. The reason for it is to make sure that empirical CCPs probabilities,  $\hat{\mathbb{P}}^k(d | j_{t-1}, \tau_{t-1})$ , are constructed with enough observations. However, according to Monte Carlo simulations, directly using empirical frequencies as the estimated CCPs can lead biased second stage estimates with an average bias of up to 30%. In the next section, we explain where this bias is coming and construct a new smoothing technique for the first-stage non-parametric CCPs that reduces the bias by more than 50%.

#### E.2.4 Bayesian smoothing with data-driven priors

Assume  $\hat{p}$  is the frequency estimate of  $p_0$  after  $N$  realizations:

$$\hat{p} = \frac{1}{N} \sum_{i=1}^N y_i,$$

where  $y_i = 1$  with probability  $p_0$ , and  $y_i = 0$  with probability  $1 - p_0$ , that is, each  $y_i$  is i.i.d. distributed following a Bernoulli with parameter  $p_0$ . The Taylor expansion of order 3 of  $\log(\hat{p})$  around  $p_0$  is given by:

$$\log(\hat{p}) = \log(p_0) + \frac{1}{p_0}(\hat{p} - p_0) - \frac{1}{p_0^2}(\hat{p} - p_0)^2 + \mathcal{O}(\hat{p} - p_0)^3 \quad (22)$$

Taking expectations with respect to realizations  $\{p_i\}_i$  we obtain<sup>66</sup>

$$\mathbb{E}[\log(\hat{p})] = \log(p_0) - \frac{1}{2N} \frac{1-p_0}{p_0} + \mathcal{O}_p(N^{-2}).$$

Observe the bias may be substantial when  $p_0$  is close to 0 and  $N$  is small. Unfortunately, this is commonly the case in our residential leave choice setting, with a large amount of choices with almost all the probability concentrated in one choice (staying in the same house).<sup>67</sup> Therefore, the remaining 61 choices have in general very small probability to be chosen. This is not a particular feature of our framework, but it arises in any problem with a large number of decisions in which there is large persistence in choices, such as, residential choice (Bayer et al., 2016; Davis et al., 2017; Diamond et al., 2018; Davis et al., 2018), occupational choice (Traiberman, 2018), etc.

Our approach to circumvent this difficulty is smooth the empirical frequencies in a way that is informed by the data. The intuition is that the probability of action  $a$  conditional on state  $s$  correlated with the probability of action  $a$  in state  $s'$  for a particular time period. We leverage this correlation by constructing a prior distribution of CCPs. To be more precise, for a given action  $a$  and a given state  $x$ , we collect all  $\hat{p}(a|x')$  across all states  $x' = (j_{t-1}, \tau_{t-1}) \in \mathcal{X}$ , where  $\hat{p}_t(a|x')$  is the empirical CCP given by frequencies. Next, we use the set of probabilities

$$\{\hat{p}_t(a|x')\}_{x'}$$

to construct a prior distribution for  $p(a|x)$ . We assume that this prior distribution follows a Beta( $\hat{\alpha}, \hat{\beta}$ ), where we recover  $\hat{\alpha}, \hat{\beta}$  solving the following equations:

$$\mathbb{E}\hat{p} = \frac{1}{|\mathcal{X}|} \sum_{x'} \hat{p}_t(a|x') = \frac{\hat{\alpha}}{\hat{\alpha} + \hat{\beta}} \quad (23)$$

$$\text{Var}[\hat{p}] = \frac{1}{|\mathcal{X}|} \sum_{x'} (\hat{p}_t(a|x') - \mathbb{E}\hat{p})^2 = \frac{\hat{\alpha}\hat{\beta}}{(\hat{\alpha} + \hat{\beta})^2(\hat{\alpha} + \hat{\beta} + 1)}. \quad (24)$$

Then, we treat our observed decisions as Bernoulli draws from the true distribution,

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<sup>66</sup>We can also derive the exact analytical expression of the bias by using the full Taylor expansion for the case  $\frac{1}{(N+1)p_0} < 1$ , which will always be true as  $N$  grows large. After some algebra the final expression is given by

$$\mathbb{E}[\log(\hat{p})] = \log(p_0) + N \log\left(1 + \frac{1}{N}\right) + N p_0 \log\left(1 - \frac{1}{(N+1)p_0}\right)$$

<sup>67</sup>The average probability of staying in the same house hovers around 80%

Bernoulli( $p_0$ ), and update our prior probability with them. The resulting posterior is again a Beta distribution with parameters:

$$\hat{\alpha}_P = \hat{\alpha} + \sum_i \{d_i = a\} \quad (25)$$

$$\hat{\beta}_P = \hat{\beta} + N - \sum_i \{d_i = a\}, \quad (26)$$

where  $N$  is the number of individuals in state  $x$ . We take the mean of this posterior distribution as our first-stage CCP. The final expression for our smoothed CCP is given by:

$$\hat{p}^{Smooth} = \frac{N}{N + \hat{\alpha} + \hat{\beta}} \hat{p} + \frac{\hat{\alpha} + \hat{\beta}}{N + \hat{\alpha} + \hat{\beta}} \mathbb{E}\hat{p}.$$

It is easy to see

$$\hat{p}^{Smooth} \xrightarrow{N \rightarrow \infty} p_0,$$

so it is still a consistent estimator. Moreover, this method allows us to deal with the “many-zero” problem that is ubiquitous in this literature, because the prior distribution puts mass on the non-zero probability range. Therefore, both the mean of prior as well as the mean of the posterior will always be strictly positive.

Finally, Monte Carlo simulations show that this smoothing can reduce the bias by more than 50%. Table 29 contains the results of 100 Monte Carlo model simulations and estimations, where we show the percentile of the distribution of parameters and the mean. We compare the mean of each Monte Carlo exercise to the true parameters. For the model without any smoothing, we obtain a bias of 30.22%. When we apply the Bayesian smoothing and the 2nd order bias correction derived in the previous section, we obtain a bias of 13.56% and 13.22% respectively, a reduction of more than 50% of the original bias.

True Coefficients								
	2.5	-3	-2	0.5	-0.1	-0.5	0.35	
	Raw Model							
	(Intercept)	MC1	MC2	MC tau	MC dist	r	a1	a2
Pctl 0.5%	-1.08	-3.83	-2.18	0.63	-0.13	-0.64	0.10	-0.34
Pctl 2.5%	-0.86	-3.70	-2.15	0.66	-0.12	-0.57	0.16	-0.33
Pctl 5%	-0.68	-3.65	-2.14	0.71	-0.12	-0.54	0.17	-0.32
Mean MC Coeff	0.88	-3.39	-2.01	0.85	-0.09	-0.35	0.26	-0.23
Pctl 95%	2.33	-3.10	-1.87	0.99	-0.06	-0.15	0.34	-0.14
Pctl 97.5%	2.38	-3.05	-1.83	1.00	-0.06	-0.12	0.36	-0.12
Pctl 99.5%	3.13	-2.98	-1.81	1.06	-0.05	-0.07	0.37	-0.08
<b>Approx. Bias</b>	0.65	0.13	0.00	0.70	0.12	0.30	0.26	0.25
Bayesian smoothing								
	(Intercept)	MC1	MC2	MC tau	MC dist	r	a1	a2
Pctl 0.5%	1.41	-3.26	-2.27	0.52	-0.08	-0.61	0.24	-0.34
Pctl 2.5%	1.57	-3.20	-2.26	0.54	-0.07	-0.56	0.27	-0.33
Pctl 5%	1.62	-3.17	-2.24	0.56	-0.07	-0.55	0.27	-0.33
Mean MC Coeff	2.44	-2.98	-2.17	0.62	-0.05	-0.45	0.32	-0.28
Pctl 95%	3.19	-2.81	-2.09	0.69	-0.04	-0.34	0.36	-0.23
Pctl 97.5%	3.41	-2.76	-2.08	0.70	-0.03	-0.34	0.37	-0.23
Pctl 99.5%	3.86	-2.69	-2.05	0.72	-0.03	-0.32	0.39	-0.21
<b>Approx. Bias</b>	0.02	0.01	0.09	0.25	0.46	0.10	0.09	0.07
Bayesian smoothing + 2nd order analytical bias correction								
	(Intercept)	MC1	MC2	MC tau	MC dist	r	a1	a2
Pctl 0.5%	1.54	-3.29	-2.41	0.30	-0.08	-0.60	0.23	-0.33
Pctl 2.5%	1.71	-3.23	-2.37	0.33	-0.07	-0.56	0.26	-0.32
Pctl 5%	1.75	-3.20	-2.36	0.37	-0.07	-0.54	0.26	-0.32
Mean MC Coeff	2.47	-3.03	-2.28	0.45	-0.05	-0.44	0.31	-0.27
Pctl 95%	3.21	-2.86	-2.19	0.51	-0.04	-0.36	0.35	-0.23
Pctl 97.5%	3.37	-2.82	-2.18	0.51	-0.04	-0.35	0.36	-0.22
Pctl 99.5%	3.82	-2.73	-2.16	0.52	-0.03	-0.34	0.39	-0.20
<b>Approx. Bias</b>	0.01	0.01	0.14	0.10	0.45	0.12	0.13	0.10

Figure 29: Monte Carlo simulation results

### E.2.5 Exclusion Restrictions

To be able to identify the parameters with regression 13 we need extra structure on the time-varying unobservables which. We introduce a new approach combining Arellano-Bond estimators (Arellano and Bond, 1991) with the ECCP methodology. In the following discussion we present an example in which we impose that the unobservable component in equation 12 follows an AR(1) process. For simplicity we present the example on the levels equation, but similar arguments carry through the equation in

differences. That is:

$$\begin{aligned}
Y_{t,d,d',\tilde{d},x_{it}}^k &= \delta_{j(d)}^k - \delta_{j(d')}^k + \delta_\tau^k \left( \tau(d, x_{it}) - \tau(d', x_{it}) \right) \\
&\quad + \delta_a^k \left( \ln a_{j(d)t} - \ln a_{j(d')t} \right) - \delta_r^k \left( \log r_{j(d)t} - \log r_{j(d')t} \right) \\
&\quad + MC^k(j(d), j_{it-1}) - MC^k(j(d'), j_{it-1}) + \beta \left( MC^k(j(\tilde{d}), j(d)) - MC^k(j(\tilde{d}), j(d')) \right) \\
&\quad + \xi_{jt} - \xi_{j't} + \tilde{\varepsilon}_{t,d,d',x_{it}} \\
&= \Theta' X_{d,d',\tilde{d},s_{it},t} + \Delta \xi_{t,d,d'} + \tilde{\varepsilon}_{t-1,d,d'}, \tag{27}
\end{aligned}$$

with

$$\xi_{jt} = \rho \xi_{jt-1} + \nu_{jt} \quad \text{and} \quad \text{where } \nu_{jt} \stackrel{i.i.d.}{\sim} (0, 1),$$

where  $\nu_{jt}$  is orthogonal to the vector of observable covariates. In this way, we introduce time persistence in the unobservable component of utility in a parsimonious and tractable way. It follows that differences across locations

$$\Delta \xi_{t,d,d'} = \xi_{dt} - \xi_{d't} = \rho(\xi_{jt-1} - \xi_{j't-1}) + \nu_{jt} - \nu_{j't},$$

also follow  $AR(1)$  process. Observe that

$$\Delta \xi_{t,d,d'} = Y_{t,d,d',\tilde{d},x_{it}} - \left( \Theta X_{d,d',\tilde{d},x_{it},t} + \tilde{\varepsilon}_{t,d,d'} \right).$$

Substituting inside the regression equation 27

$$\begin{aligned}
Y_{t,d,d',\tilde{d},s_{it}} &= \Theta' X_{d,d',\tilde{d},x_{it},t} + \Delta \xi_{t,d,d'} + \tilde{\varepsilon}_{t,d,d'} \\
&= \Theta' X_{d,d',\tilde{d},s_{it},t} + \rho \left( Y_{t-1,d,d',x_{it-1}} - \left( \Theta X_{d,d',\tilde{d},x_{it-1},t-1} + \tilde{\varepsilon}_{t-1,d,d'} \right) \right) + \Delta \nu_{t,d,d'} + \tilde{\varepsilon}_{t,d,d'} \\
&= \Theta' X_{d,d',\tilde{d},s_{it},t} + \rho Y_{t-1,d,d',x_{it-1}} - \rho \Theta X_{d,d',\tilde{d},x_{it-1},t-1} + \rho \tilde{\varepsilon}_{t-1,d,d'} + \tilde{\varepsilon}_{t,d,d'} + \Delta \nu_{t,d,d'}.
\end{aligned}$$

By assumption  $\Delta \nu_{t,d,d'}$  is uncorrelated with the covariates. Also, by the rational expectations assumption

$$\mathbb{E}[\tilde{\varepsilon}_{t,d,d'} | X_{d,d',\tilde{d},x_{it-1},t-1}, X_{d,d',\tilde{d},x_{it},t}] = 0 \quad \text{and} \quad \mathbb{E}[\tilde{\varepsilon}_{t-1,d,d'} | X_{d,d',\tilde{d},x_{it-1},t-1}] = 0.$$

so we only need to find instruments for  $X_{d,d',\tilde{d},x_{it},t}$  as this is correlated with  $\tilde{\varepsilon}_{t-1,d,d'}$ . Similar to [Arellano and Bond \(1991\)](#), the rational expectations assumption yields the following orthogonality conditions

$$\mathbb{E}[\tilde{\varepsilon}_{s,d,d'} X_{d,d',\tilde{d},x_{it},t}] = 0 \forall s \leq t,$$

so any  $X_{d,d',\tilde{d},x_{is},s}$  for all  $s \leq t - 2$  is a valid instrument for  $X_{d,d',\tilde{d},x_{it},t}$ .<sup>68</sup>

The final set of assumptions for  $\xi_{jt}$  is still under discussion. For robustness, in the final draft the structural estimation will be carried under different sets of assumptions, and we will also test their statistical validity.

### E.2.6 Recovering structural parameters

Recall the amenities regression equation:

$$\log N_{sjt} = -\log \sigma_s - \log F_{sjt} + \log \left( \sum_k M_{jt}^k \alpha_s^k (w_t^k - r_{jt}) \right) \quad (28)$$

$$= \lambda_s + \lambda_j + \lambda_t + \log \left( \sum_k M_{jt}^k \alpha_s^k (w_t^k - r_{jt}) \right) + \xi_{sjt}, \quad (29)$$

and the location demand equation:

$$\begin{aligned} Y_{t,d,d',\tilde{d},x_{it}}^k &= \delta_{j(d)}^k - \delta_{j(d')}^k + \delta_\tau^k (\tau(d, x_{it}) - \tau(d', x_{it})) \\ &\quad + \delta_a^k (\ln a_{j(d)t} - \ln a_{j(d')t}) + \delta_r^k (\log(w_t^k - r_{j(d)t}) - \log(w_t^k - r_{j(d')t})) \\ &\quad - (MC^k(j(d), j_{it-1}) - MC^k(j(d'), j_{it-1})) - \beta (MC^k(j(\tilde{d}), j(d)) - MC^k(j(\tilde{d}), j(d'))) \\ &\quad + \tilde{\varepsilon}_{t,d,d',x_{it}}. \end{aligned} \quad (30)$$

It is easy to see from 29 that the recovered parameters are the estimates of the Cobb-Douglas preferences for consumption services. Moreover, following the micro-foundations of these two equations in Section E.1, the parameter  $\delta_r^k$  is the inverse of the variance of the logit shocks:

$$\delta_r^k = \frac{1}{\sigma_\epsilon^k}.$$

Finally, observe that the rest of the  $\delta$  parameters in ?? are estimates of the following function of structural parameters:

$$\delta_a^k = \frac{\alpha_s^k}{\sigma_s \sigma_\epsilon^k},$$

therefore we can recover the elasticity of substitution  $\sigma_s$  using the previous estimates:

$$\hat{\sigma}_s = \frac{\hat{\alpha}_s^k}{\hat{\delta}_a^k \hat{\sigma}_\epsilon^k}.$$

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<sup>68</sup>Observe that neither  $X_{d,d',\tilde{d},x_{it},t}$  or  $X_{d,d',\tilde{d},x_{it-1},t-1}$  can be used as instruments as they are part of the regression equation.