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Abstract

We use a quantitative spatial equilibrium model to evaluate the distributional and welfare impacts of a recent temporary rent control policy in Berlin, Germany. We calibrate the model to key features of Berlin's housing market, in particular the recent gentrification of inner city locations. As expected, gentrification benefits rich homeowners, while poor renter households lose. Our counterfactual analysis mimicks the rent control policy. We find that this policy reduces welfare for rich and poor households and in fact, the percentage change in welfare is largest for the poorest households. We also study alternative affordable housing policies such as subsidies and re-zoning policies, which are better suited to address the adverse consequences of gentrification.

JEL-Codes: R000, R210, R300, R310.

Keywords: rent control, housing market, gentrification.

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1 Introduction

Spurred by immigration and gentrification, large cities in developed countries have seen sharp increases in housing prices and rents over the last decades (Knoll et al., 2017). These trends have sparked widespread concern of residents and policymakers alike about the affordability of housing. Indeed, rising housing costs have led politicians to call housing "the new social issue of our time" (Sagner et al., 2020). Policy responses have included a range of affordable housing policies. Among these, rent control policies stand out as a policy that directly aims to limit price increases in growing housing markets.

In this paper, we use local data on household incomes, housing rents, and amenities to quantify a discrete choice model where heterogeneous households choose where to live and their housing consumption. We use counterfactual policy simulations to study the effects of gentrification and a range of affordable housing policies on the welfare of households, housing consumption and housing prices. Among others we run a counterfactual simulating the introduction of a rent control policy that mimics the rental cap (Mietendeckel) temporarily introduced in Berlin. This city-wide rental cap essentially set a maximum permissible rent for incumbent as well as new rental leases with the exemption of newly built dwellings. While the inefficiencies of rent control policies have been the subject of economic and policy discussion for a long time (see below), our main focus is on the effect on the distribution of household welfare.

We find that gentrification benefits more affluent, home-owning households and hurts poorer renter households in the lower half of the income distribution. The rental cap in our simulation does not succeed in addressing these patterns. Importantly, we find that it reduces welfare across all income groups; in fact, welfare falls most for the poorest households who were supposed to be protected from rising rents. One criticism of the rent control policy is that it reduces rents exactly in the gentrifying inner city locations favored by richer households. Nonetheless, more affluent residents are made worse off, since they are more likely to own housing and thus bear the burden of reduced rental income. Poorer households also lose, even though they are less likely to own housing. However, they are made worse off by the distortion of the housing market, while they do not substantially benefit from reduced rents. Counterfactual simulations of alternative affordable housing policies such as the partial residential development of the old city airport Tempelhof and a targeted housing subsidy suggest that these policies are more successful in addressing rising housing prices and, at least to a certain extent, the distributional consequences of gentrification.

The developments of gentrification and rising house prices in developed cities have been studied extensively over the last years in an American context. Hwang and Lin (2016), Couture and Handbury (2020) and others have documented the increase in the number of college educated households in American cities. Baum-Snow and Hartley (2020) and Couture and Handbury (2020) show that these trends can be explained by demand for central city amenities. A central concern of analysts and advocates has been the potentially harmful effect of gentrification on poor residents' welfare. A number of papers have examined this issue empirically. For instance, Vigdor (2002) documents that low-status households experienced increased housing costs without discernible changes in self-assessed housing unit quality, public service quality, or neighborhood quality. In line with this, Couture et al. (2019) quantify a spatial sorting model which shows how increasing incomes at the top of the distribution lead to gentrification due to the demand of rich households for central city amenities. This hurts poor residents who are either displaced or end up paying higher rents for amenities they do not value highly. Favilukis et al. (2019) build a quantitative dynamic model with incomplete risk sharing and show that affordable housing policies (especially targeted at the poor) can increase welfare relative to rent control policies by providing insurance against housing price increases. Brummet and Reed (2019), on the other hand, document positive effects of gentrification on a range of subjective well-being measures and school outcomes of original residents and their children.[1]

In recent years, policy makers across the globe have responded to gentrification with a range of affordable housing policies, such as rent control, tax credits, housing subsidies or re-zoning policies. In the United States rent control measures are a strongly debated topic in local ballots, particularly in larger agglomerations such as the San Francisco Bay area, New York, New Jersey or Maryland and have been in place in some areas for multiple decades (Diamond et al., 2019). In Europe, rent control has become an equally topical issue. Many countries such as Spain, the Netherlands or Germany have highly protected rental sectors and have recently increased rental protection by introducing additional rent control measures in areas with tight housing markets. A large economic literature has analyzed the economic impacts of rent control. Findings include a negative impact on tenants' mobility (Diamond et al., 2019), misallocation in housing markets (Glaeser and Luttmer, 2003), price appreciation in decontrolled housing market segments (Autor et al., 2014) as well as a negative impact on housing investment and residential construction in the controlled segments of the market. However, recent papers such as Mense et al. (2019) also highlight an increase in construction activity and investment in the unregulated segments of the market.

Hahn et al. (2021) present reduced-form evidence on the short term impact of the rental cap introduced in Berlin which we consider. They find a decrease in the number of advertised dwellings as well as a decrease in rental prices directly after the rental cap was enacted. Their findings are corroborated by our counterfactual simulation. However, due to the short-lived nature of the rental cap, Hahn et al. (2021) can not provide evidence on longer term impacts of the policy, such as long-run supply changes, household relocation and changes in (endogenous) amenities. Conversely, our model simulates the counterfactual long term consequences of the rental cap when all margins of adjustment have been exploited. Consequently, we can assess the impact on a range of outcomes such as supply, prices, amenity consumption, the spatial distribution of households and ultimately welfare.

Overall, we document patterns of gentrification in Berlin between 2013 and 2019 that benefited households at the upper end of the income distribution and reduced welfare for lower income households. We provide evidence that the temporarily enacted rental cap in

[1] Chetty and Henderson (2018a) more broadly document that exposure to relatively rich or poor neighbourhoods during childhood years plays an important role for inter-generational mobility and later labour market outcomes such as earnings and human capital accumulation.

Berlin, would not have succeeded in addressing the consequences of gentrification in the long-term. We also compare the welfare and distributional effects of the rental cap to alternative housing policies, in particular, targeted housing subsidies and an increase in housing supply by re-zoning land and recreational areas for housing. More specifically, we assess the impact of the residential development of a large green space in the centre of the city, the Tempelhofer Feld, a policy that is strongly debated in Berlin's local politics. Ultimately, we find that both the targeted housing subsidy and the partial residential redevelopment of the old airport are better suited in addressing the welfare consequences of gentrification than the rental cap, which disproportionately reduces welfare for lower income households.

Our paper contributes to the existing literature in several ways. First, we add to the quickly developing strand of research that examines and quantifies patterns and causes of gentrification and spatial sorting, see e.g. Brummet and Reed (2019); Couture and Handbury (2020); Baum-Snow and Hartley (2020); Couture et al. (2019). Second, we contribute to the literature on affordable housing polices by providing counterfactual long-run evidence on a range of affordable housing policies such as rent control, subsidies and re-zoning policies. In particular, we provide novel counterfactual long-term evidence on the impact of a unique rental cap temporarily enacted in Berlin. Finally, this is one of the first studies that presents and quantifies evidence for gentrification and affordable housing policies for Europe in a comprehensive spatial sorting model.[2] This is particularly interesting as housing prices in many major cities across Europe have surged in recent decades and are catching up with their American counterparts.

The remainder of the paper is structured as follows. Section 2 presents the model and its theoretical foundations. Section 3 gives a brief overview of the German housing market and its institutional setting. Section 4 presents the data and the calibration of the model. Section 5 and 6 quantify and present a range of counterfactuals as well as corresponding model extensions and senistivity checks, while Section 7 concludes.

2 The Model

We develop a discrete choice model of a stylized city, accounting for agent and preference heterogeneity. The model setup is as follows.

There are K discrete regions or parts of the city (ZIP codes in our example) indexed $k = 1, ..., K$. Households differ in their income, indexed by $j = 1, ..., J$, and their preference, where i indexes the household's preference type (see below). A household of type i, j who lives in part k of the city has a utility function of the Stone-Geary type,

$$u^j_{ik} = (A^j_k)^\beta (q^j_{ik} - q_0)^\alpha (c^j_{ik})^{1-\alpha-\beta} \eta^j_{ik}, \quad q_0 > 0, \tag{1}$$

where q is housing consumption in square metres and q_0 is minimum floorspace, c is consumption of a composite good, A is a composite amenity index, and η^j_{ik} is household i, j's

[2]For a related application to the Dutch city of Amsterdam see Almagro and Dominguez-Iino (2021).

idiosyncratic taste parameter which governs its preference for living in part k of the city. The composite amenity index is given by

$$A_k^j = Z_k (n_k^H)^{\zeta^j}, \tag{2}$$

where Z is a measure of amenities such as bars, restaurants and shops in region k. Further, households may benefit from living together with high income households, see e.g. Couture et al. (2019), Diamond (2016) and Guerrieri et al. (2013). Our model captures this endogenous amenity via the term $(n_k^H)^{\zeta^H}$, where n_k^H is the total number of households of the higher income groups living in region k. In the baseline model, we assume that only high-income households benefit from amenities, so $\zeta^j = 0$ for all lower-income types, but in an extension, we assume that there is also a cross-type externality, which implies that low-income households also benefit from mixing with high-income types, perhaps because of positive neighborhood effects in schooling or social capital (see Section 6.4).

The household's budget constraint is

$$w^j + a^j R = c_{ik}^j + p_k q_{ik}^j, \tag{3}$$

where p_k is the housing rent per square meter, R is the average aggregate housing rent per household in the city, a^j is the share received by a type-j household, i.e. the home-ownership rate for that household type, and w^j is the household's labour income.[3]

Maximizing utility subject to (3) gives optimal housing consumption and indirect utility, v:

$$q_k^j = \frac{(1-\alpha-\beta)p_k q_0 + \alpha(w^j + a^j R)}{(1-\beta)p_k} \tag{4}$$

$$v_{ik}^j = (A_k^j)^\beta (w^j + a^j R - p_k q_0)^{1-\beta} p_k^{-\alpha} \eta_{ik}^j \tag{5}$$

The Stone-Geary utility function has several attractive properties. First, the budget shares for housing,

$$\frac{p_k q_k^j}{w^j + a^j R} = \frac{(1-\alpha-\beta)p_k q_0 + \alpha(w^j + a^j R)}{(1-\beta)(w^j + a^j R)}, \tag{6}$$

are decreasing in income. This is in line with observation (see below).

Second, the marginal willingness to pay for amenities

$$\frac{dp_k^j}{dA_k^j} = \frac{\partial u_{ik}^j / \partial A_k^j}{q_{ik}^j \partial u_{ik}^j / \partial c_{ik}^j} \tag{7}$$

$$= \frac{\beta p_k (w^j + a^j R - p_k q_0)}{A_k^j ((1-\alpha-\beta)p_k q_0 + \alpha(w^j + a^j R))} \tag{8}$$

is increasing in income. The LES function thus captures a key aspect of gentrification as the

[3]Note that we do not explicitly distinguish between renter and owner-occupier households.

demand for inner city amenities has been identified as an important driver of gentrification (Brueckner et al., 1999; Couture et al., 2019)

In the spirit of the discrete choice literature, individuals have heterogeneous tastes for which part of the city to live in. In line with the recent literature, an individual's idiosyncratic taste parameter η_{ik}^j for living in part k of the city is drawn from an independent Fréchet distribution

$$G(\eta_{ik}) = e^{B_k^j (\eta_{ik}^j)^{-\epsilon^j}} \tag{9}$$

where the scale parameter B_k^j gives the average utility of living in part k of the city for individuals of type j, and the shape parameter $\epsilon^j > 1$ controls the dispersion of idiosyncratic utility for each household type. After observing their idiosyncratic taste parameter, individuals choose their residence to maximize utility, for given attributes of the locations. Note that the variance of idiosyncratic tastes decreases with ϵ^j, which implies that individuals become more responsive to policy changes when ϵ^j increases.

The choice probabilities conditional on household type for living in part k of the city are given by

$$\pi_k^j = \frac{B_k^j ((A_k^j)^\beta (w^j + a^j R - p_k q_0)^{1-\beta} p_k^{-\alpha})^{\epsilon^j}}{\sum_{\ell=1}^K B_\ell^j ((A_\ell^j)^\beta (w^j + a^j R - p_\ell q_0)^{1-\beta} p_\ell^{-\alpha})^{\epsilon^\ell}}, \quad k, \ell = 1, ..., K. \tag{10}$$

Housing supply in part k of the city is produced by profit maximizing housing firms under perfect competition. We assume a reduced form profit function

$$\Pi_k = \Theta_k^{\frac{1}{\theta}} p_k Q_k - \frac{\theta}{1+\theta} Q_k^{\frac{1+\theta}{\theta}} - R_k, \tag{11}$$

where Q_k is housing quantity supplied, θ is the housing supply elasticity and Θ an underlying profitability parameter of region k. Producers have costs $\frac{\theta}{1+\theta} Q_k^{\frac{1+\theta}{\theta}}$ and pay land rent R_k. Solving the profit maximizing problem and using the zero profit condition $\Pi_k = 0$ gives housing supply Q_k and land rent

$$Q_k = \Theta_k p_k^\theta \tag{12}$$

$$R_k = \frac{1}{1+\theta} \Theta_k^{\frac{1+\theta}{\theta}} p_k^{1+\theta}, \tag{13}$$

with the average land rent

$$R = \frac{1}{N} \sum_{k=1}^K R_k. \tag{14}$$

The housing market clearing conditions are

$$Q_k = \sum_{j=1}^J n_k^j q_k^j, \quad k = 1, ..., K, \tag{15}$$

where n_k^j is the number of type j residents in part k of the city. Using (4), the set of equations (15) define the equilibrium housing prices in regions $k = 1, ..., K$.

Total city population of type j is exogenous and given by N^j. To close the model, the location equilibrium is defined by the following equations:

$$n_k^j = \pi_k^j N^j, \quad j = 1, ..., J, k = 1, ..., K-1. \tag{16}$$

Given (5), (10), and (15), the equilibrium is defined by the $J \times (K-1)$ equations in (16). This pins down the number of individuals in each part of the city.

In order to compute the welfare effects of housing policies, in the counterfactual simulations, we will compute the expected welfare of a type j resident

$$\mathbb{E}(u^j) = \Gamma\left(\frac{\epsilon^j - 1}{\epsilon^j}\right)\left[\sum_{k=1}^{K} B_k (v_k^j)^{\epsilon^j}\right]^{1/\epsilon^j}, \tag{17}$$

where $\Gamma(\cdot)$ is the gamma function, and the expectation is taken over η_{ik}^j.

In order to calibrate the model we use a range of small scale housing and socioeconomic data for the German capital, Berlin. Before describing the data and the calibration in more detail, however, the following section will give a brief overview of the German housing market, with a particular focus on Berlin.

3 Institutional Background and the German Housing Market

In comparison with most OECD countries, the German housing market has a relatively large rental sector, which accounts for approximately half of dwellings (Voigtlaender, 2010). In large cities the rental sector is even larger, with a home-ownership rate of only 17 per cent in Berlin (Bundesamt für Statistik, 2019).

The corner stone and most commonly used basis of rent setting and capping in the German system is the so called "*Mietpreisspiegel*" or "rental price barometer". The "*Mietpreisspiegel*" is essentially a survey of characteristic regional rents conducted or recognised by the municipality or by tenants' and landlords' associations. It serves to derive a comparable local reference rent and is legally required to be updated every two years (Kholodilin et al., 2016, p.8). The local reference rent is calculated as an average of new and existing contract rents concluded in the previous four years. The reference rate derived in this manner sets the maximum limit for rent increases within existing contracts.[4]

There is strong regional variation within the German housing market. In rural and

[4]If the calculation of the "*Mietpreisspiegel*" is not possible, the local reference rate is derived by an expert's reported estimate or by rents in at least three comparable dwellings owned by other landlords (Kholodilin et al., 2016, p.8).

suburban areas, especially in eastern Germany, the housing market has been relatively stable. In contrast, in urban agglomerations and college towns, strong demand and supply shortages have dominated local housing markets, putting upward pressure on housing prices (Kholodilin et al., 2016). However, even within big cities, substantial variation in local housing markets exists. While some districts are characterised by high levels of housing demand and supply shortages, other more peripheral areas show relatively stable housing markets (BMF, 2017, p.5). The regional differences in the German housing market are also reflected in rent and housing price developments. Particularly since 2007/2008, housing prices have strongly increased in popular urban areas such as the Big Seven cities[5] and stagnated or only increased marginally in many rural areas.

Rent changes have been particularly pronounced in the capital city Berlin, which is the focus of our quantitative exercise below. In Berlin, quality-adjusted nominal rental prices of new rental leases have almost doubled between 2007 and 2020, as shown in Figure A.1 in the Appendix [6]. As a consequence of quickly rising housing prices, affordable housing, especially for low- and middle income households, has become a salient political topic in Berlin. In 2020 the state government of Berlin passed a rental cap for new rental contracts as well as existing rental contracts, effectively setting maximum permissible rents for most segments of the city's rental market, in the hope to address concerns about rising housing costs.[7] However, the rental cap was declared unconstitutional by Germany's Constitutional Court in April 2021 and hence was only in place for less than a year.

In our simulation, we will take Berlin as a case study to analyse the effects of gentrification on the distribution of welfare across households and the effect of various policies intended to mitigate the rise in housing prices and rents that comes with this gentrification. In particular, we will study whether a rent control policy modelled along the lines of the enacted one can effectively address the problem of housing affordability for lower income households.

4 Data and Calibration

4.1 Data

In order to calibrate the model, we need small scale regional information on current numbers of households, rental prices, the income distribution and amenities for Berlin. We employ a range of different data sets to collect the required data.

Firstly, we use the GFK Demographic data set which, among others, provides information on the number of households and their approximate net household wage income across the ZIP codes of Berlin. In total the data allows to differentiate between seven income types. The income groups and the relative size of each group for the city of Berlin are depicted

[5] Berlin, Hamburg, Munich, Cologne, Duesseldorf, Frankfurt am Main and Stuttgart.

[6] Note that over the same time period, the average annual inflation rate was relatively low with 1.29%. Thus real rental prices also increased substantially over the same period. (see Website Federal Office for Statistics).

[7] Properties built from 2014 onwards are exempt from the rental cap. See Section 5.3 for more detail.

in Table 1. For the calibration of the model we use the midpoint of each income bracket.[8] Table 1 shows that more than half of all households living in Berlin belong to the the lowest three income brackets and above thirty per cent of all households are part of the highest three income groups.

Table 1: Household Distribution across Income Groups 2019

Type	1	2	3	4	5	6	7
Net Income	850	1300	1750	2300	3300	5750	9000
Share of HH	19.5	14.7	17.8	14.9	18.3	12.9	1.9

Source: GFK Demographic Data 2019; Share of households expressed in percentage terms.

Figure B.1 in the Appendix depicts the spatial distribution of all households types of the lower three income groups across Berlin's ZIP code areas as a share of total ZIP code population. In particular, in the richer districts of Berlin in the southwest, households of the lower three income brackets constitute the minority of the total ZIP code population. In contrast, in the city centre the shares of low and high income type households are fairly similar. Districts such as Neukoelln, parts of Tempelhof, Wedding, Spandau and Marzahn and Hellersdorf in turn have a relatively high proportion of households in the lower three income brackets.

For each ZIP code, we then calculate an amenity index value using Open Street Map data. We do so by collecting the number of available amenities, such as restaurants, bars, cinemas, nightclubs, ATMs, shops and parks within each ZIP code. Using these values we then construct an index employing principal component analysis.[9] The results are depicted in Figure B.2 in the Appendix, showing that high amenity levels, as expected, are predominantly found within the central districts of Berlin.

Lastly, we need information on average rents within each cell. Most studies analysing housing prices and rent control measures focus on transaction or advertisement prices only and hence capture only the prices of new rental contracts. However, stricter protection of existing rental contracts in Germany implies that there is a fundamental wedge between new and existing contract prices. Therefore exclusively focusing on transaction prices would bias price estimates upwards and would hence not reflect the actual average rental prices within each ZIP code. In order to obtain rent price estimates that reflect prices of existing rental contracts as well as new lease prices, we therefore make use of the aforementioned rental barometer and geo-coded data. The rental barometer separates Berlin into different residential area classifications, differentiating between "simple", "medium" and "good" residential areas. For each category, the rental barometer then lists different square metre prices. The rental barometer differentiates further between the dwelling's overall floor space and the dwelling's age thereby providing regional estimates for different housing categories. Making

[8]For the highest and lowest income bracket we use values of 9000 Euro and 850 Euro which are the median income values of households above/below the respective threshold derived from the GSOEP data.

[9]For more detail see Appendix A.

use of openly available geo-data, we obtain information on buildings' age, average square metres per dwelling and the residential classification across Berlin.[10] Using this information, we can interpolate average values for each ZIP code across Berlin. We thus obtain estimates of average floor space size, dwelling age and residential area classification for each ZIP code. Ultimately, using the interpolated averages and the metrics of the 2019 rental price barometer, we construct estimates of average rental price levels for each ZIP code. Figure B.3 in the Appendix depicts the distribution of rents per square metre across Berlin, showing that prices are higher in central and western Berlin, whereas prices particularly in many less central, eastern parts of Berlin are still comparatively low.[11]

4.2 Calibrating the Model

Using the price and amenity index estimates for each ZIP code as well as the share of each of the seven household types living in each ZIP code, we can calibrate the model as follows.

For the composite amenity index A_k, we use two data components as described above. First, we use the index calculated from the Open Street Map data, Z_k. Second, we account for endogenous amenities accruing to high-income types, as shown in (2). For households of the highest four income groups, we assume that the value of amenities is re-enforced by the number of other high income type households living in ZIP code k. We set the parameter governing the strength of endogenous amenities to $\zeta^j = 0.01$ for the four highest income types, and for the three lowest income types, we set $\zeta^j = 0$. However, since not much is known about the "true" value of this parameter, we will vary it in our sensitivity analysis in Section 6.2. In Section 6.4, we further assume that endogenous amenities also accrue to low-income households, which potentially impacts the efficiency effects of gentrification and rent control policies.

Next, we obtain values for the parameters q_0, a^j, α, β and Θ. First, we infer the home-ownership rate for each income group in Berlin, i.e. a^j, from the German Socioeconomic Panel (GSOEP) for the year 2018. The GSOEP is an annual representative household survey with more than 18,000 households. We use the data for households living in Berlin, but in order to have sufficient observations we include Hamburg and Bremen (the two other federal "city states" in Germany) and calculate the average home-ownership rate for each income group. Results are shown in Table 2. Berlin has a comparatively low ownership rate with only 17.4 per cent owning property (Investitionsbank, 2019). Based on the GSOEP data we find a slightly lower average home-ownership rate of approximately 16 percent. The table shows that homeownership increases from around 10 percent or less for the lowest four income groups to 75% for the highest income earners.

[10] See FIS-Broker, an online catalogue for Berlin-specific geo-data.

[11] Note that these estimates are only approximations of the "true" rental prices in each post code. In order to obtain the actual average rental prices of each ZIP code we would require access to very detailed data on existing rental contracts or large scale survey data for a large enough number of households in each ZIP code, which is not available. However, our estimates should be more accurate than those relying on new contract rents only.

Table 2: Home-Ownership across Income Brackets

Type	1	2	3	4	5	6	7
Income Bracket	850	1300	1750	2300	3300	5750	9000
a	0.0138	0.0919	0.1176	0.1090	0.2182	0.4051	0.7568

Source: German Socioeconomic Panel 2018.

For q_0 we assume a value of 30 square metres, which we then use to estimate β and α in a method of moments approach to target the average housing expenditure share out of net household incomes across the city.

We target an average expenditure share of 28.5 per cent, see e.g. Investitionsbank (2019). Choosing α and β to match the moments of this expenditure share we obtain values of $\beta = 0.215$ and $\alpha = 0.1229$. Table 3 provides an overview of our model parameters.

We then numerically solve for Θ_k using equation (15). For θ, the housing supply elasticity, we base our calibration on structural estimates for Germany calculated in Mense (2020). Mense (2020) finds a nation-wide housing supply estimate of 5.8 in the medium run between 2011 and 2017. This estimate is in line with Green et al. (2005)'s findings for the metropolitan areas in the US but lies above Saiz (2010) who finds an average elasticity of 1.75 of urban centres in the US. Since the estimates in Mense (2020) contain results for all of Germany, and large cities typically have lower supply elasticities, we use a slightly lower value of $\theta = 3.5$, which lies between the averages from Mense (2020) and Saiz (2010).

We estimate the Fréchet parameter, ϵ, using IV regressions to address endogeneity concerns, as described in more detail in Appendix A. Since the above equations vary by household types j, we obtain seven separate estimates for the dispersion parameter, one for each type of household. As shown in Table A.1, the estimates range between 1.75 and 4.79, which seems in line with other recent estimates such as Monte et al. (2018), Ahlfeldt et al. (2015) and Heblich et al. (2020).

Finally, we solve the model numerically. The model is exactly identified, so given the distribution of types by ZIP codes and the values of the parameters described, we can solve the location equilibrium in (16) numerically for the level parameters, B_k^j. That is, by construction, our model perfectly replicates the distribution of types for each ZIP code.[12]

5 Results

In this section, we first present our baseline results and then run a range of counterfactuals to compare the results of our baseline calibration to key outcomes of the counterfactual simulations. More precisely, we compare the developments of housing prices, floor space and rental income in our counterfactual to their baseline values. Additionally, we use equation (17) to calculate the average expected welfare for each household type. Using the expected

[12] For a proof of existence and uniqueness in a similar model, see e.g. Monte et al. (2018).

Table 3: Parameter Overview

Parameter	Value	Source
Demand Parameters		
q_0	30	by assumption
α	0.1229	calibrated using housing expenditure shares
β	0.2150	calibrated using housing expenditure shares
Scale Parameter		
B	by ZIP code	calculated in model
Shape Parameter		
η	varies by household type; see Table A.1 in Appendix A	calculation described in Appendix A
Endogenous Amenities		
ζ	0.01 for high income households; 0 for low income households	alternative values in robustness check
Supply Parameters		
Elasticity		
θ	3.5	literature; see Mense et al. (2019); Green et al. (2005)
Productivity Parameter		
Θ	by ZIP code	calculated in model

welfare values we can then calculate the corresponding equivalent variation (EV) denoted in Euros for each household group and each counterfactual.

5.1 Baseline Results

Table 4: Results Basic Calibration

	Type 1	**Type 2**	**Type 3**	**Type 4**	**Type 5**	**Type 6**	**Type 7**
Budget Share	39	30	26	24	21	19	18
Price	7.86	7.85	7.85	7.84	7.86	7.96	7.93
Floor Space	42.56	52.98	62.47	73.46	95.36	146.37	217.88
Rental Income	12.14	80.88	103.49	95.93	192.03	356.51	666.02
Amenity	21.43	20.21	19.96	29.92	29.78	30.92	29.34

Source: Own model calculations. Budget share expressed in percentage terms. Prices denoted in Euros. Floor space denoted in sqm.

Table 4 depicts the results of our baseline calibration. Average floor space increases with income. On average we find an average floor space size of roughly 78 square metres for each household. Precise data on the accuracy of these estimates is difficult to find. Based on a projection of 2011 census data, the government-sponsored *Annual Report on the Berlin Housing Market 2019* finds an average dwelling size of 73.2 square metres for residential dwellings across Berlin (Investitionsbank, 2019, p. 72) which is slightly below the value predicted by our model. Housing prices per square metre vary slightly with income. Households of the five lowest income groups pay similar per square metre prices ranging from 7.86 to 7.84. The highest two income types pay a slightly higher average price per square metre with the highest income type paying 7.93 Euros on average. Figure B.3 in the Appendix depicts the spatial distribution of prices across ZIP codes. Further, the model replicates the fact that average expenditure on housing decreases with income and approximates estimates for Berlin rather well (Investitionsbank, 2019, p. 83). Average rental income by income group increases in income which reflects the higher home-ownership rates among higher income groups. The average rental income for the highest income bracket is 666.02 Euros and households with a representative income of 850 Euros on average earn a rental income of just above 12.14 Euros, as the large majority of this income group consists of tenants. Lastly, the final column depicts the population weighted type specific average mean value of the amenity index, A_k^j. The average amenity index is higher for the four highest income groups which is driven by the additional endogenous amenity component described above.

5.2 Gentrification

In the first counterfactual, we try to assess the effects of gentrification. Gentrification is usually defined as an increase in the number of highly-educated, high income households in central districts of cities with an originally large share of poorer households, see e.g. Couture et al. (2019). In order to analyze the effects of gentrification in Berlin, we solve the model using the city-wide household distribution of income groups for the year 2013 instead of 2019.[13] This period has often been associated with strong gentrification (see Döring and Ulbricht (2018)). More precisely, we use the 2013 values for the number of household by income group and solve the location equilibrium for the number of households by type in each ZIP code.[14] That is, the only difference to our baseline simulation is the distribution of the total number of households for each income groups. The main driver of gentrification is then the change in the city wide income distribution. This is similar to the analysis of gentrification in Couture et al. (2019).

Figure 1 shows the change in the share of households of the highest four income bracktes between 2013 to 2019 in each ZIP code relative to the average change of these household types across ZIP codes. Our model predicts the actual shares of household types across ZIP codes relatively well with a correlation coefficient between actual and predicted shares of 0.96 (see Figure B.4 in the Appendix). Overall the share of households in the upper four income brackets increased across all ZIP codes. Increases were particularly pronounced in central and western Berlin, in districts such as Schoeneberg and Mitte where they ranged from six to nine percentage points; substantially higher than the average of apprroximately 5.34 percentage points. Also central eastern areas such as Mitte and Prenzlauer Berg experienced an above average increase in the share of high income households. In addition, some more peripheral, already relatively wealthy ZIP codes particularly in southern Berlin also experienced above average increases in their share of high income households.

We now look at the effect of gentrification on income segregation. To this end, let n_k^P and n_k^R be the number of poor (lowest three income brackets) and rich (highest four income brackets) households in zip code k. Let $d_k = \left|\frac{n_k^P}{n^P} - \frac{n_k^R}{n^R}\right|$, where $n^J = \sum n_k^J$ for $J = P, R$. The dissimilarity index is defined as

$$D = \frac{1}{2}\sum_{k=1}^{M} d_k.$$

For each zip code, d_k describes how the zip code's income mix deviates from the city's aggregate income mix. Below, we assume that this will affect poor households' welfare. For now, the overall dissimilarity index measures the fraction of rich (or poor) households that

[13] The city-wide distribution for 2013 is contained in the GFK data.

[14] We solve for the housing market equilibrium using an interpolation of (15).

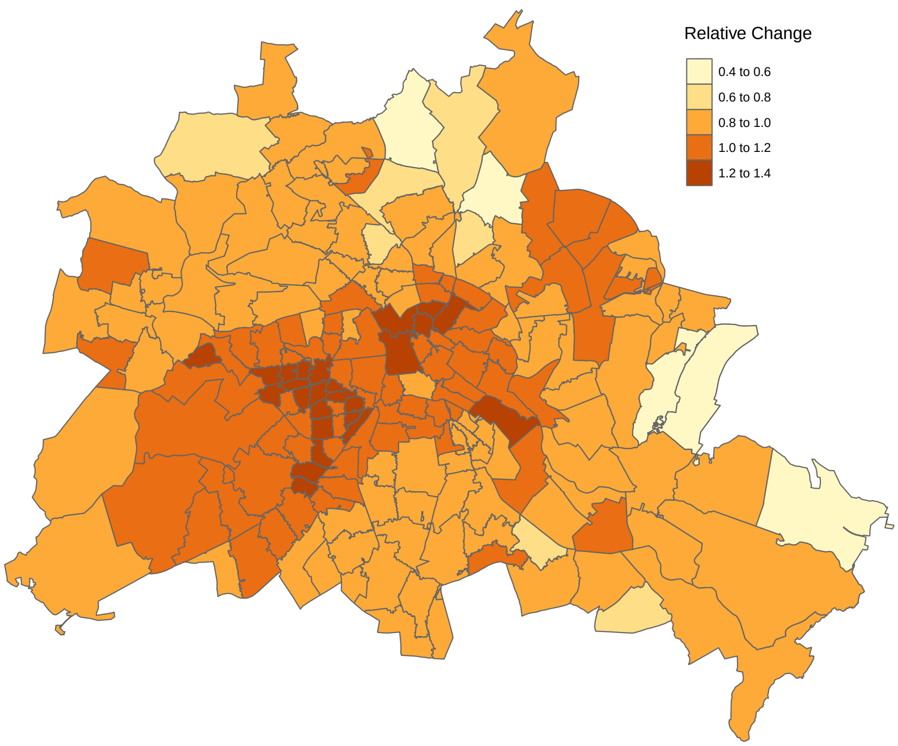


Figure 1: Change in share of high income households per ZIP code relative to average ZIP code change in high income households

Note: The figure depicts the percentage point change in the share of households of the highest four income brackets in each ZIP code relative to the average percentage point change across ZIP codes.

would have to change zip code in order for rich and poor to be evenly distributed throughout the city.

For 2013, we find a value of $D = 0.2230$. In 2019, the index increases to 0.2323, which suggests a rise in city-wide segregation. To get a glimpse at which parts of the city experienced changes in concentration, Figure 2 shows the values of d_k per zip code. An increase from 2013 to 2019 shows that the zip code experienced a greater concentration of either rich or poor households, relative to the city average. The figure shows that this is indeed the case in wealthier outskirts but also in central areas such as Mitte, Friedrichshain and Prenzlauer Berg. These districts had relatively large shares of low income households in 2013[15] and experienced an above average increase in the share of high income households (see Figure 1). Areas with an even larger share of low income households such as Neukölln, in contrast, experienced an influx in the share of high income households but also a fall in the concentration measure, suggesting an increase in income dispersion.

These different patterns might indicate different stages of gentrification. In the early stage of gentrification, the income distribution becomes more dispersed, as high income households move into areas with initially high shares of low income households. In a more advanced stage of gentrification, however, the concentration of high income households increases, as poorer households are successively displaced. Overall, the findings document patterns that have frequently been attributed to gentrification such as an increase in the concentration of rich households in central areas with an initially high share of low income households.

Table 5: Counterfactual: Gentrification 2013-2019

Change in %	**Type 1**	**Type 2**	**Type 3**	**Type 4**	**Type 5**	**Type 6**	**Type 7**
Sqm Price	1.5252	1.6080	1.7270	1.8641	2.4405	2.5586	3.2510
Floor Space	-0.5584	-0.5465	-0.7134	-0.9880	-1.4735	-1.7288	-2.4177
Amenity Index	-0.0567	-0.0265	-0.0135	0.1579	0.1922	0.1913	0.2014
Rental Income	9.3077	9.3077	9.3077	9.3077	9.3077	9.3077	9.3077
Welfare	-0.5451	-0.0155	-0.0053	-0.0734	-0.0289	0.0257	0.0197
EV	-4.35	-0.22	-0.11	-2.02	-1.2	1.92	2.37

Source: Own model calculations; values expressed in percentage changes. Equivalent variation (EV) expressed in Euros. The above table lists the change in relevant outcomes of all counterfactuals in relation to the baseline calibration.

[15] See Figure B.5 in Appendix B.

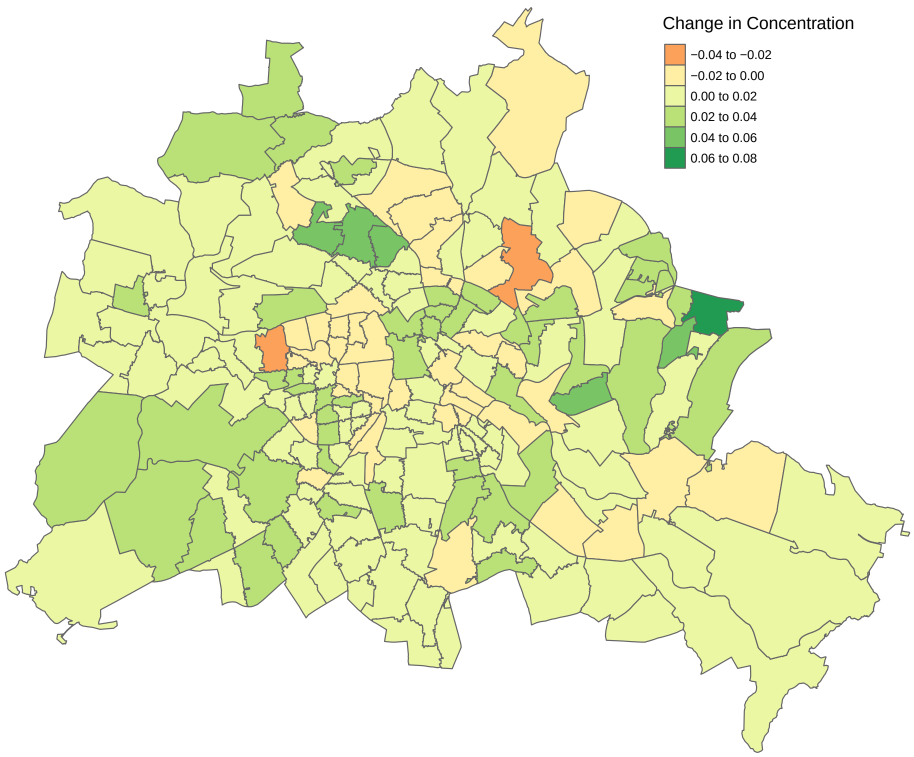


Figure 2: Change in Concentration per ZIP Code

Note: The figure depicts the change in the within ZIP code concentration from 2013-2019.

In a final step, we quantify the impact on the different types of households. Table 5 summarizes the results of the counterfactual relative to the baseline. From 2013 to 2019 prices rose between 1.53 percent for households of the low income group and 3.25 for households in the highest income bracket. Average floor space decreased across all income brackets, with slightly larger decreases for the higher income groups. The type specific amenity index decreased for the lower income households. In contrast, it increased across household types four to seven. This reflects two separate effects of gentrification: first, high income households tend to move to gentrifying areas with lots of bars, restaurants etc., whereas low income households tend to move out of these areas. Second, for high income households, this is reinforced by the growing shares of other high income households in these areas. Average rental income earned by homeowners rose by approximately 9.3 percent. Ultimately, the change in the income distribution results in a reduction of expected welfare for households of the lowest five income brackets. Households of the lowest income bracket suffer the greatest welfare loss of approximately 0.55 percent. This corresponds to an equivalent variation of minus 4 Euro and 35 Cent per month. For the other income groups, welfare changes are relatively small. The highest two income groups slightly benefit, since the increase in rental income and endogenous amenities outweigh the increased housing prices.

In order to address the consequences of gentrification and housing affordability, the city state of Berlin has passed a rental cap, as described above. In the following section we implement a counterfactual which mimicks this rental cap. We also look at alternative policies. We can thus analyze whether and which groups benefit from these policies.

5.3 Rental Cap

As described above, in 2020 Berlin passed a city-wide rental cap which applied to new as well as existing rental contracts.[16] In April 2021 the policy was declared unconstitutional by Germany's federal constitutional court and ceased to apply effective immediately. However, popular support for this policy as well as other interventions (such as the proposed expropriation of large housing companies) remains strong. Our counterfactual is intended to simulate the long-run equilibrium consequences of a strict rental cap modelled along the lines of the policy that was introduced in Berlin.

Under the rental cap, reference rents for maximum permissible rents were based on the dwelling's age and type, as well as the category of the residential area where the dwelling is located. Reference rents were calculated based on a table published by the state government of Berlin.[17] Existing contract rents were allowed to lie above the reference rent by a maximum of 20 per cent, whereas new rental contracts were strictly bound by the reference rent.

In our counterfactual analysis we take the reference rate as the maximum permissible rent without the buffer of 20 per cent. In order to emulate the maximum permissible rent

[16] Rents could increase with the inflation rate by up to 1.3 per cent p.a. Moreover, rents could increase following the modernization of a dwelling. The law did not apply to dwellings that were completed after Jan. 1, 2014.

[17] See Berliner Mieterverein, accessible at Website Mieterverein Berlin.

according to the rental cap for each ZIP code, we again use freely available geo-data from the FIS-Broker (see above). We can then obtain values for the average age of dwellings and the category of the residential area as well as the predominant dwelling type in each cell. This enables us to approximate the maximum permissible average rent within each ZIP code. Newly built dwellings, i.e. those that were built after 2013, are exempt from the regulation. Figure 3 shows areas where the rental cap applies.[18] In particular, popular central areas in the districts Mitte, Prenzlauer Berg, Kreuzberg and Schöneberg, but also the outskirts of Western Berlin are affected. We then analyse how rent control affects welfare and the housing market within our model, by simulating a new equilibrium subject to rent control.

With rent control, the housing market equilibrium conditions are replaced by

$$\bar{Q}_k = \Theta \hat{p}_k^{\theta}, \tag{18}$$

where $\bar{Q}_k$ is the aggregate quantity of housing, and the rent per sq. meter is defined as

$$\hat{p}_k = \min[p_k^*, \bar{p}_k],$$

where $\bar{p}_k$ is the controlled rent in k and p_k^* the equilibrium rent in case the cap is not binding.

We assume that when rent control binds, housing is allocated to households in proportion to their share in total housing demand at the regulated rent. Denoting household j's housing consumption in k by $\bar{q}_k^j$:[19]

$$\bar{q}_k^j = \frac{q_k^j(\hat{p}_k)}{Q_k(\hat{p}_k)} \bar{Q}_k.$$

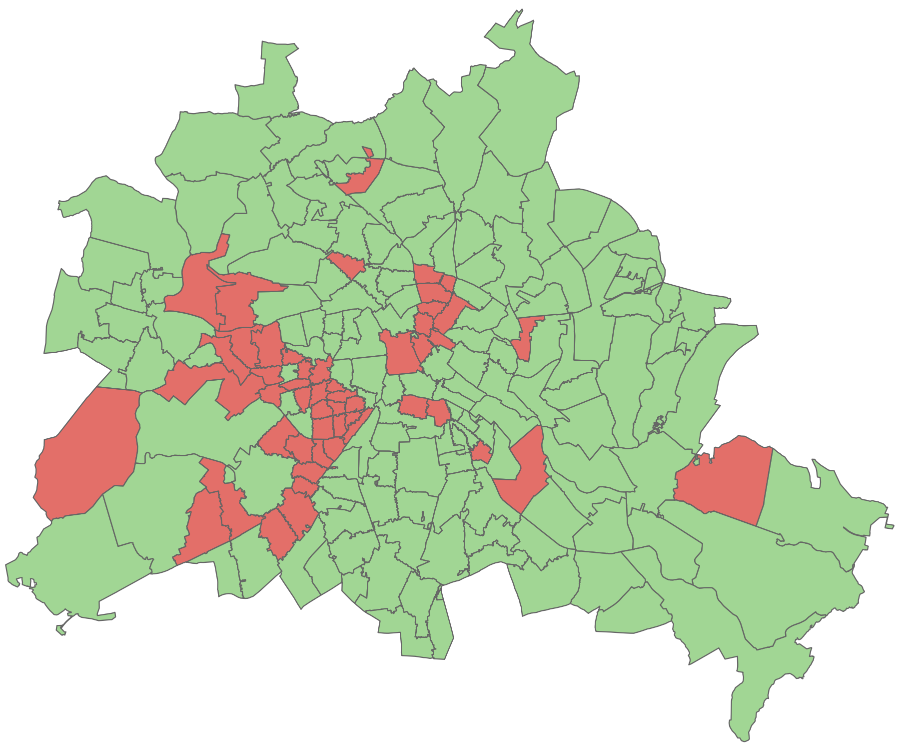
Further, note that p_k^* is a function of n_k^j, which we can interpolate using equation (15). Combining the above, we use the definitions of $\hat{p}_k$ and $\bar{q}_k^j$ to solve equation (16) for n_k^j to obtain the counterfactual allocation of households across ZIP codes.

Table 6 shows the results of the counterfactual simulation relative to the baseline. The table shows that average rents fall across household types. The fall in rental prices ranges from 1.5% to 2.5%, and interestingly, is most pronounced for richer households. This is due to the fact that the rental cap reduces rents most strongly in areas that are inhabited by mostly rich households (see Figure 3). In response to the fall in rents, supply decreases, which leads to a reduction of housing floor space between 1.1% and 5.3%. Further, the type specific average amenity index falls across income types one to five. Only the highest two income types experience a slight increase in their average amenity consumption. The rental cap thus seems to redistribute amenity consumption from poor to rich, since the rich move into high-amenity areas where the rental cap applies.

Ultimately, rent control results in a reduction of welfare for all household types. Importantly, low income households suffer the greatest relative welfare loss in percentage terms. For example, expected welfare on average decreases by about 2.62 percent for households

[18] This is obviously a simplification, since we assume that within ZIP codes, all dwellings are the same.

[19] This assumption implies that there is misallocation of housing under rent control, since dwellings are not necessarily allocated to the households with the highest willingness to pay (Glaeser and Luttmer, 2003).



Note: Free market rent lies above maximal permissible rent in red grid cells.

Figure 3: Application of rental freeze across Berlin

Table 6: Counterfactual: Rental Cap

Change in %	**Type 1**	**Type 2**	**Type 3**	**Type 4**	**Type 5**	**Type 6**	**Type 7**
Sqm Price	-1.9879	-1.5556	-1.5144	-1.5049	-1.7643	-2.4070	-2.5469
Floor Space	-1.0973	-3.5945	-3.8701	-3.9099	-4.3408	-5.4621	-5.3158
Amenity Index	-0.9403	-0.3070	-0.2434	-0.1126	-0.0430	-0.0018	-0.0029
Rental Income	-4.6582	-4.6582	-4.6582	-4.6582	-4.6582	-4.6582	-4.6582
Welfare	-2.6153	-0.8689	-0.5720	-0.3103	-0.2639	-0.1898	-0.2209
EV	-20.71	-12.65	11.7703	-8.53	-10.94	-14.18	-26.52

Source: Own model calculations; values expressed in percentage changes. Equivalent variation (EV) expressed in Euros. The above table lists the change in relevant outcomes of the rental cap counterfactual in relation to the baseline calibration.

in the lowest income bracket and by only about 0.22% for the two richest household types. The equivalent variation corresponds to 20.71 Euros per month for the poorest and to 26.52 Euros for the richest households. For homeowners, welfare losses are compounded by the decrease in rental income, which amounts to 4.66 percent. Nonetheless, this is not sufficient to outweigh the smaller welfare loss of rich households due to the lower fall in housing rents. In summary, it appears that in the long run, capping rents in Berlin would be regressive, as richer households suffer proportionately less than poorer ones.

We find that rent control leads to an increase in segregation: compared to the baseline, the city-wide dissimilarity index rises from 0.2323 to 0.2606. When looking at the ZIP code specific change in concentration, we find that the increase in concentration is particularly driven by an increase in the concentration of high income households in the regulated central city ZIP codes (see Figures B.6 and B.7 in Appendix B). This effect is driven by the larger willingness to pay for central amenities of high income households, as the rental cap mainly reduces prices for housing in central, high-amenity ZIP codes. Conversely, the concentration measure decreases in less central areas with fewer amenities. This finding stands in contrast to popular arguments which view rent control as a measure to preserve a relatively even income mix in central cities.

In the following, we look at two alternative affordable housing policies, namely a targeted housing subsidy and re-zoning policies.

5.4 Housing Subsidy

An alternative measure to implement affordable housing, particularly for lower income households, is a targeted housing subsidy. We hence run a counterfactual policy that redistributes income from high income households to low income households and requires the subsidy to be spent on housing. More precisely, the counterfactual policy subsidizes 30 square metres of housing for each tenant household of the first three income brackets, i.e. our q_0 in the model. All households with an income below 2300 Euros are eligible to receive housing benefits. The subsidy in turn is financed by a flat tax levied on households of the upper four income brackets. In our example we implement a flat tax of 20 Euros per month which implies a subsidy of 62 cents per sq. meter for the first thirty square metres of eligible households.

Table 7: Counterfactual: Housing Subsidy

Change in %	**Type 1**	**Type 2**	**Type 3**	**Type 4**	**Type 5**	**Type 6**	**Type 7**
Net Sqm Price	-5.4534	-4.4086	-3.7484	-0.0031	-0.0003	0.0017	0.0020
Floor Space	0.8603	0.6965	0.5924	-0.5445	-0.4199	-0.2715	-0.1840
Amenity Index	0.0135	0.0035	0.0013	-0.0018	-0.0009	-0.0004	-0.0002
Rental Income	-0.0018	-0.0018	-0.0018	-0.0018	-0.0018	-0.0018	-0.0018
Welfare	2.3096	1.2638	0.8949	-0.7273	-0.4827	-0.2680	-0.1669
EV	18.52	18.49	18.48	-19.98	-20.00	-20.02	-20.05

Source: Own model calculations; values expressed in percentage changes. Equivalent variation (EV) expressed in Euros. The above table lists the change in relevant outcomes of the subsidy counterfactual in relation to the baseline calibration. Note that the change in average prices for the subsidized households is derived as the weighted average of the subsidzed price for the first 30 sqm and the unsubsidized price for any sqm in excess of 30 sqm.

Table 7 shows the counterfactual results. As a consequence of the subsidy, net prices per sqm for subsidized households fall. The fall is most pronounced for households of the lowest income bracket as the subsidized 30 sqm constitute a larger share of Type 1's average housing demand than for the other subsidized households. The lower housing rents in turn induce an increase in average floor space for the subsidized households. In addition, the subsidized households on average benefit from better amenities. Ultimately, lower net rental prices and the increase in housing consumption as well as amenities spark an increase in welfare for the subsidized households, which ranges from 0.89 percent for Type 3 households to 2.31 percent for the poorest households.

For high income households, lower net wages reduce housing consumption. The changes in average rental income induced by general equilibrium effects are small but negative. Thus the negative effect on rental income stemming from a decrease in average floor space for the higher income households slightly dominates the positive effect on rental income stemming from an increase in housing demand for the subsidized households. Welfare for richer households falls by between aprroximately 0.17 percent for the richest households and just above 0.73 percent for Type 4 households. City-wide segregation is essentially unchanged. Overall, as expected, welfare is redistributed from rich to poor households.[20]

5.5 Re-zoning: Residential development of the Tempelhofer Feld

Another policy that is often proposed to address rising housing prices is to increase housing supply through more construction. Since space for new construction projects in cities is scarce, re-zoning policies play a key role for housing supply in urban agglomerations.

We run a counterfactual in which the former city airport in Tempelhof (currently a recreational green space) is used for the construction of new affordable housing. A partial residential development of the Tempelhofer Feld was subject to a referendum in 2014 but was ultimately rejected by the majority of voters. Parties such as the Christian Democrats (CDU), the Liberals (FDP) and Social Democrats (SPD), however, have expressed support for a new referendum. In our counterfactual we simulate a scenario where 9000 flats are built at the periphery of the Tempelhofer Feld.[21] Existing proposals for the partial development of the Tempelhofer Feld impose the construction of affordable dwellings.[22] In an attempt to mimic this, we calculate housing prices for the new dwellings based on the adjacent ZIP code's parameters, i.e. Θ and B. The housing prices for the new flats on the Tempelhofer Feld thus reflect rental barometer rents of similar adjacent regions which tend to be lower than market rents for exclusively newly-built dwellings.

In the new counterfactual equilibrium accommodations for 9000 households are provided at an average rent of 7.91 Euro which lies above the city-wide average of 7.87 Euro. Table 8 shows the percentage changes in rents, floor space, rental income and welfare. As theory suggests, rental prices for all income types decrease slightly as housing supply increases and average floor space consequently also increases slightly. The change in rental income is small but negative. Thus, the negative effect on rental income from the reduction in rental prices marginally dominates the positive effect of the increase in total floor space in the city. Overall welfare increases across all income groups. The partial redevelopment of the Tempelhofer Feld leads to a fall in rents across the city. This makes living in ZIP codes previously predominantly inhabited by richer households more affordable for less affluent

[20] Note, however, that the policy is still partially regressive, as among the rich households the welfare loss is proportionately smallest for the richest households. Obviously, combining the subsidy with financing via the existing progressive income tax could undo this effect.

[21] Proposals by the political parties in support of the policy range from 6000 to 12000 flats.

[22] For example, the electoral program of Social Democrats suggests exclusive construction rights for state-owned housing associations.

Table 8: Counterfactual: Rezoning Tempelhofer Feld

Change in %	**Type 1**	**Type 2**	**Type 3**	**Type 4**	**Type 5**	**Type 6**	**Type 7**
Sqm Price	-0.1064	-0.1068	-0.1073	-0.1068	-0.1091	-0.1153	-0.1176
Floor Space	0.0419	0.0527	0.0604	0.0669	0.0755	0.0897	0.0942
Amenity Index	-0.0389	-0.0336	-0.0324	-0.0296	-0.0319	-0.0345	-0.0470
Rental Income	-0.0691	-0.0691	-0.0691	-0.0691	-0.0691	-0.0691	-0.0691
Welfare	0.1422	0.1256	0.1522	0.1132	0.1385	0.1737	0.4590
EV	1.12	1.40	1.95	2.57	6.26	11.00	23.00

Source: Own model calculations; values expressed in percentage changes. Equivalent variation (EV) expressed in Euros. The above table lists the change in relevant outcomes of the supply counterfactual in relation to the baseline calibration.

households, which reduces segregation. The dissimilarity index slightly falls from 0.2323 to 0.2313 after rezoning.

Welfare effects are largest for the lowest income group and the upper three income groups. The highest income groups experience the largest reduction in prices, while the decrease in rental income is relatively small. The lowest income group experiences a reduction in rental prices similar to the other types, but benefits proportionately more because of their large budget share. Further, these households don't suffer much from the reduction in rental income. The average amenity index falls across income types. This effect is partially mechanic, as the amenity index for the newly constructed housing on the Tempelhofer Feld derived from the adjacent ZIP code lies below the type-specific average values with a value of 10.92 for the lower income households and a value of 21.92 for Types four to seven.[23]

5.6 Interpretation of Results

Our results suggest that the observed patterns of gentrification in Berlin had distributional consequences, as has been argued by various advocates and policy makers: affluent households who own a home benefit, while poor households lose. According to our simulations, rent control cannot solve these issues. While we do find that rents decrease across the board, this does not help poor households, even though the budget share of housing decreases with

[23] Note that the different values for low and high income types stem from the endogenous amenity component which in the main calibration is only modelled for Type four to seven.

income. Rather, poor households' welfare falls due to the misallocation of housing.

Alternative affordable housing policies such as re-zoning policies and housing subsidies appear better suited to address the consequences of gentrification. The housing subsidy by construction directly redistributes income from rich to poor households. The re-zoning measure of a partial residential development of the old Tempelhof airport suggests that an increase in housing supply reduces average housing prices across the city and across income groups, which leads to an increase in average welfare across income groups.

The following section presents a number of sensitivity analyses and model extensions. Most importantly, we extend the model by including additional adjacent regions, which may be important since clearly mobility is not restricted by city borders. We also analyze the consequences of absentee home-ownership. Moreover, we introduce a source of market failure by assuming an externality stemming from income segregation. This reflects the belief of some advocates that gentrification has adverse consequences by altering the composition of households in city quarters.

6 Model Extension and Sensitivity Analyses

6.1 Adjacent ZIP codes

We now extend the model by including adjacent ZIP codes outside the city in the state of Brandenburg. Including Berlin's peripheral regions is potentially important. As they lie outside the city limits, the rules of the rental cap did not apply there, so analyzing the consequences of the policy should take account of the potential mobility between restricted and unrestricted regions.

Obtaining price estimates for these ZIP codes based on the Berlin rental barometer and geo-coded housing features as before is not possible. We hence use the rough estimates of advertised rents listed in Investitionsbank (2019). Further, we adjust these estimates in order to account for the upward bias contained in advertised rents in order to mimic the mix of new and existing contract rents that reflect the price estimates based on the Berlin rental barometer.

Table B.1 in Appendix B shows the new baseline calibration results for Berlin and the included regions in Brandenburg. In comparison to the baseline calibration without adjacent regions, average rental income is slightly higher across income groups in Berlin. Budget shares marginally increase and average floor space by income group slightly increases.

Table 9 shows the calibration results relative to the new baseline calibration.[24] Overall, the results for Berlin are similar to the counterfactual results without adjacent regions. As before, welfare decreases across all income groups and the welfare losses in relative terms are larger for lower income households.

[24]We calculate the respective outcomes for all ZIP codes in Berlin and all ZIP codes in Brandenburg seperately. Note that the total number of households in Berlin and in Brandenburg can change between baseline calibration and counterfactual, as households can move between these two regions.

In addition to our previous results, we can now assess to what extent Berlin's surroundings are affected by the rental cap. There is an increase in demand for unregulated housing outside Berlin among income groups of the five lowest income brackets.[25] In contrast, a very small fraction of households of the richer income groups move to Berlin. In sum, due to the higher demand in the unrestricted segment, prices in Berlin's adjacent regions increase for all income groups (see Figure 4). As prices increase, housing supply increases, however, average floor space per household decreases due to the influx in households moving to Berlin's adjacent regions.

Our counterfactual results are consistent with recent findings on the impact of locally-restricted rent control measures. Mense et al. (2019) highlight an increase in investment and construction activity in unregulated segments of the housing market, as the demand for unregulated dwellings increases due to the shortage of supply in the regulated segment. Hahn et al. (2021) analyze the short-term effects of Berlin's rental cap. They find an increase in advertised rents in the unregulated market of Berlin's adjacent regions indicating substitution away from regulated housing supply in Berlin towards unregulated housing supply in the city's periphery.

6.2 Choice of ζ^H

In this section we vary ζ^H, the parameter which governs the strength of the endogenous amenity that affects rich households' utility. This seems prudent, since we don't have any external information about this parameter. In order to find a unique equilibrium, ζ^H needs to be sufficiently small. We now rerun our counterfactual simulations, where we increase ζ^H from 0.01 to 0.1. Thus we weight the endogenous amenity component for richer households more heavily. Table B.2 in Appendix B shows the results. The subsidy counterfactual largely remains unchanged: key outcomes such as floor space, rental price, amenity index and welfare are barely different from the previous estimation.

For the other counterfactuals we find slightly different results. First, for the gentrification counterfactual, the results hardly change for the lower three income groups, and all three groups experience a reduction in welfare. However, for the higher four income groups we find strong positive welfare effects. The explanation is intuitive: as shown above, gentrification led to higher concentration of rich households in central city areas. With a higher value of ζ^H, this benefits the rich households even more. This is further supported by the substantially more pronounced percentage increase in the amenity index of the four highest income groups.

For the rent control counterfactual, we find slightly less negative welfare effects with a value of $\zeta^H = 0.1$ for the high income groups.[26] As shown in Section 5.3, the compositional effect stemming from rent control tends to favor rich households, and this effect is stronger with a larger ζ^H.

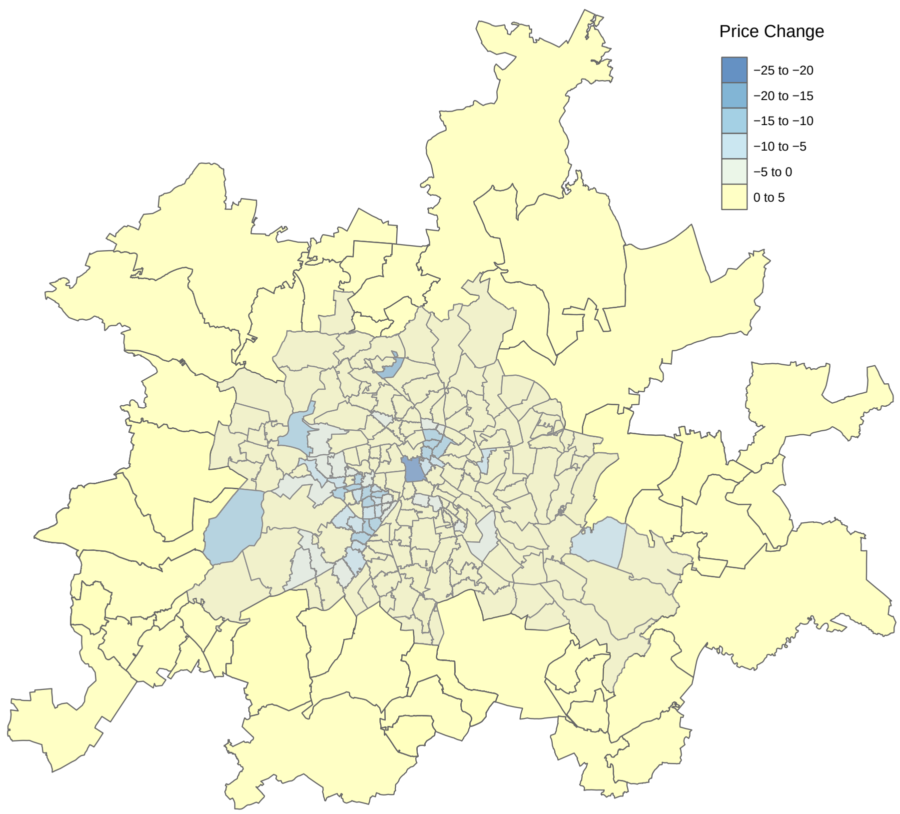
[25] Average welfare effects for different regions can only be derived under the assumption that households living in Berlin and Brandenburg are different household types.

[26] This does not hold for Type 7 households.

Table 9: Counterfactual: Rental Cap in Berlin and adjacent Regions

Change in %	**Type 1**	**Type 2**	**Type 3**	**Type 4**	**Type 5**	**Type 6**	**Type 7**
Berlin							
Sqm Price	-2.0396	-1.6098	-1.5749	-1.5625	-1.8096	-2.4464	-2.5743
Floor Space	-2.4502	-5.0086	-5.0205	-5.0081	-4.9232	-4.7909	-4.7771
Amenity Index	-0.9377	-0.2910	-0.1844	-0.1416	-0.0500	-0.0081	-0.0106
Number of HH	-1.0025	-0.2857	-0.1133	-0.0907	-0.0303	0.0389	0.0281
Welfare	-2.4714	-0.7763	-0.4961	-0.2833	-0.2368	-0.1655	-0.1954
EV	19.88	11.6090	10.4753	7.986	10.06	12.67	24.10
Percentage Point Difference in Welfare Change to Berlin-Only Counterfactual							
Welfare	-0.1439	-0.0926	-0.0758	-0.0270	-0.0271	-0.0243	-0.0255
Brandenburg							
Sqm Price	0.2118	0.2068	0.1894	0.1642	0.1133	0.1040	0.0740
Floor Space	0.1261	-0.0056	-0.0255	0.0039	-0.0651	-0.1049	-0.1605
Amenity Index	-0.0011	-0.0012	-0.0010	-0.0005	-0.0007	0.0000	0.0005
Number of HH	10.8795	2.0237	0.7409	0.4182	0.0839	-0.0891	-0.0440
Welfare	-0.1377	-0.2745	-0.2442	-0.1743	-0.2078	-0.2103	-0.2364
EV	1.18	4.24	5.27	4.98	8.92	16.21	29.26

Source: Own model calculations; values expressed in percentage changes. Equivalent variation (EV) expressed in Euros. The above table lists the change in relevant outcomes of the rental cap counterfactual for Berlin and adjacent regions in Brandenburg in relation to the baseline calibration.



Note: The map compares prices after the rental cap counterfactual with prices before. Price changes are denoted in percentage terms.

Figure 4: Price changes due to rental cap in Berlin and adjacent areas in Brandenburg

Under the rezoning counterfactual, amenity levels slightly fall. With a higher value of ζ^H, this in turn implies a lower increase in welfare, particularly for the high income households.

In the next step, we look at an alternative rezoning policy where supply across all regions of the city is increased.

6.3 Alternative Re-zoning Policy: Increasing Supply across the City

In Section 5.5, we found that the effect of allowing construction on the recreational area Tempelhofer Feld leads to increases in welfare across groups. However, since the area under consideration is small compared to the entire city, the welfare effects are obviously limited. In this section, we consider an alternative counterfactual. In particular, we assume a city-wide shock in the profitability of housing across all ZIP codes. An example might be the lifting of restrictions for the construction of new housing. In our framework, Θ_k measures the underlying profitability of housing supply in a region. Increasing Θ_k can hence simulate an increase in this underlying profitability. In the next counterfactual we assume that profitability, and hence Θ_k is increased by five percent across all ZIP codes.

Table 10: Counterfactual: Rezoning across the City

Change in %	**Type 1**	**Type 2**	**Type 3**	**Type 4**	**Type 5**	**Type 6**	**Type 7**
Sqm Price	-1.1463	-1.1523	-1.1538	-1.1523	-1.1466	-1.1455	-1.1376
Floor Space	0.0070	0.0031	0.0017	0.0018	0.0013	0.0006	0.0004
Amenity Index	0.0070	0.0043	0.0029	0.0022	0.0011	0.0007	0.0009
Rental Income	1.2827	1.2827	1.2827	1.2827	1.2827	1.2827	1.2827
Welfare	0.5033	0.3898	0.3291	0.2789	0.2568	0.2293	0.2224
EV	-4.02	-5.69	-6.79	-7.68	-10.66	-17.15	-26.73

Source: Own model calculations; values expressed in percentage changes. Equivalent variation (EV) expressed in Euros. The above table lists the change in relevant outcomes in relation to the baseline calibration.

Table 10 shows the results of the counterfactual simulation. Intuitively, rents fall for all income groups as housing supply is expanded. Consequently, average floor space increases, average amenity consumption and ultimately welfare increases across all types. Interestingly, average welfare increases are most pronounced for households of the lower income groups, despite the fact that rental income increases, which predominantly benefits richer households. However, the poorer households benefit most from the reduction in rents, since their budget share is largest.

6.4 Externality for Lower Incomes

Up until now, we have assumed that only rich households benefit from endogenous amenities through the number of other rich households in their neighborhood. Absent this endogenous amenity, the model assumes perfectly competitive housing markets, so the market outcome is necessarily efficient and policies such as rent control necessarily reduce welfare. One argument for such policies and against unfettered gentrification, however, is that poorer households benefit from living in neighborhoods with richer households,[27] while gentrification and segregation may directly lower poor households' welfare because of the disadvantageous mix of households.

We now assume that the endogenous amenity benefits rich and poor symmetrically, so we now assume that the parameter ζ^L, which governs the endogenous amenity effect for the poor, is positive as well. Table B.3 in Appendix B shows the results of the four counterfactuals for different values of ζ^L. As above, in order to find a unique equilibrium ζ^L needs to be sufficiently small. Existing literature does not suggest values for this parameter, and the estimation of the parameter in a reduced form setting is difficult and likely prone to endogeneity issues. We thus present results for $\zeta^L = 0.1$ in addition to our baseline calibration with $\zeta^L = 0$.

As before, in the gentrification counterfactual the highest two income groups experience a welfare gain and the lowest income group experiences a welfare loss. However, the welfare loss of the lowest income group is less pronounced than in the basic calibration without the cross-type externality. In addition, type two and three now experience an average welfare increase. With the externality, lower income households benefit from a greater number of high income households in their ZIP code, which is sparked by gentrification (see Section 5.2). Further, they are more likely to select into areas with richer households. Overall, these effects lead to an increase in the average amenity consumption of the lowest three income groups and ultimately dampen the negative welfare consequences of gentrification.

In the rental cap counterfactual, average welfare changes remain negative across all income groups. However, compared to the basic counterfactual without the segregation externality, the decrease in welfare is less pronounced, particularly for the lowest income groups. With the externality, lower income households are more likely to select into or remain in an area with a greater number of richer households, which dampens the negative welfare effect for these income groups.

The results for the housing subsidy largely remain unchanged. For the supply counterfactual, the positive welfare effects for the lowest two income groups as well as type four are somewhat more pronounced. Conversely, for all remaining income groups the welfare gains are less strong. As shown before increasing the supply of affordable housing reduces

[27] For example see Chetty and Henderson (2018a); Guerrieri et al. (2013).

prices across the city as well segregation (see Section 5.5), as housing becomes more affordable overall. With the externality, this pattern implies a smaller welfare increase for most household types, since the number of high income households is more spread out across the city. Only income type one, two and four experiences a slight increase in welfare with the cross-type externality.

6.5 Absentee Landlords

Lastly, we set all the a^j parameters to zero, which implies that all housing in the city is owned by absentee landlords. Table 11 shows the new results for all four main counterfactuals in relation to the baseline calibration. The effects of gentrification on welfare slightly change with absentee landowners. Welfare now decreases across all income groups, including households of the higher income groups. This in turn suggests that the positive effect found for the highest two income groups in the main specification mainly stems from an increase in rental income of homeowners. Note that, while the lowest income group still suffers the largest percentage welfare loss, the range of welfare changes is compressed relative to our main specification. Therefore, the regressive nature of gentrification seems to be largely due to the distributional implications of homeownership.

Looking at the rental cap counterfactual reveals some interesting differences to our main specification. In particular, while the lowest five income groups still experience welfare losses, the highest two income groups now experience a welfare gain. This is due to the fact that the rich do not suffer from the reduction in rental incomes under absentee ownership. Furthermore, rents are mainly reduced in areas inhabited by mostly affluent households, so the rental cap would be even more regressive if the rich did not own any housing.

Table 11: Robustness Absentee Landowners: Δ in %Welfare

Change in %	**Type 1**	**Type 2**	**Type 3**	**Type 4**	**Type 5**	**Type 6**	**Type 7**
Gentrification	-0.5082	-0.3548	-0.3076	-0.2500	-0.2895	-0.2467	-0.2974
Rental Cap	-2.9192	-0.8448	-0.3829	-0.1612	-0.0417	0.0451	0.0498
Housing Subsidy	2.3668	1.3665	0.9608	-0.7648	-0.5154	-0.2867	-0.1804
Rezoning	0.1416	0.1260	0.1572	0.1173	0.1430	0.1781	0.5521

Source: Own model calculations; values expressed in percentage changes. The above table lists the change in welfare of all counterfactuals in relation to the baseline calibration.

7 Conclusion

This paper uses a quantitative spatial equilibrium model to evaluate the distributional and welfare impacts of gentrification patterns and affordable housing policies in Berlin, Germany. We calibrate the model to key features of Berlin's housing market, in particular the recent gentrification of inner city locations and run a range of counterfactuals simulating affordable housing policies.

Overall, our results document patterns of gentrification in Berlin between the years 2013 and 2019. These patterns suggest distributional consequences: in particular, homeowners at the upper end of the income distribution benefit, while relatively poor renter households lose. According to our simulations, the rental cap does not address these issues. Instead, we find a reduction in housing prices but also a decrease in average housing consumption and rental income across the income distribution, which ultimately reduces welfare across all income groups.

Further, our results suggest that prices in adjacent regions of Berlin increase as a consequence of the rental cap. This effect is driven by an influx of households moving out of Berlin. The inclusion of a segregation externality suggests that the existence of the externality dampens the negative welfare effect of the rental cap on the lower income groups, as the rental cap appears to reduce segregation. However, for the parameter values used, the average welfare effect remains negative. Last, the results suggest that alternative affordable housing policies such as re-zoning policies and housing subsidies are better suited to address the consequences of gentrification. The housing subsidy by construction directly redistributes income from households at the upper end of the income distribution to households at the lower end, which redistributes welfare towards the poor. The re-zoning policies we consider increase housing supply which reduces average housing prices across the city and across income groups, leading to an increase in average housing consumption and ultimately an increase in average welfare across income groups.

Our results are highly topical, not only in a German context. As described in the introduction, rising housing prices and gentrification patterns are hotly debated topics, particularly in urban centres across the developed world. Affordable housing policies are a key topic on ballots in major urban agglomerations in both Europe and the United States. Directly combining the study of gentrification and affordable housing policies, as in our paper, is key for a better understanding of the mechanisms at play and ultimately the distributional and welfare consequences of different affordable housing policies in the context of growing urbanization. In order to study a model with many locations and several household types, our model has made simplifying assumptions along other margins. For instance, we have assumed exogenous housing ownership and exogenous workplace locations. Incorporating these margins could be a fruitful avenue for future research.[28]

[28] Ahlfeldt et al. (2015) is a classic paper with endogenous residential and workplace locations. We follow Couture et al. (2019), however, in assuming workplace locations to be exogenously given. For a dynamic model with endogenous homeownership decisions – which has only two locations – see Favilukis et al. (2019).

Appendix A

Calculation of Hedonic Rent Price Index

For the derivation of the hedonic rent price index we use geo-coded real estate data provided by the RWI. The data is based on online listings from the internet platform ImmobilienScout24 and includes both apartments and houses for sale and for rent (for a more detailed description see Breidenbach and Schaffner (2020)). In our derivation we focus on rental dwellings [29]. For each postal code and for each year between 2007 and 2020 we regress the logarithm of the rental price per square metre on a range of housing and quality characteristics such as the number of rooms, the apartment size, the age of the dwelling, the existence of a balcony, garden or cellar and the type of building the dwelling is situated in. Based on the intercepts we can then calculate a quality-adjusted hedonic rent price index for each ZIP code across Germany. For illustrative purposes Figure A.1 solely focusses on the largest seven cities in Germany. For each city the year 2007 serves as the base year which is normalized to 100.

Calculation of Amenity Index

Table A.1: Principal Component Analysis and Loadings

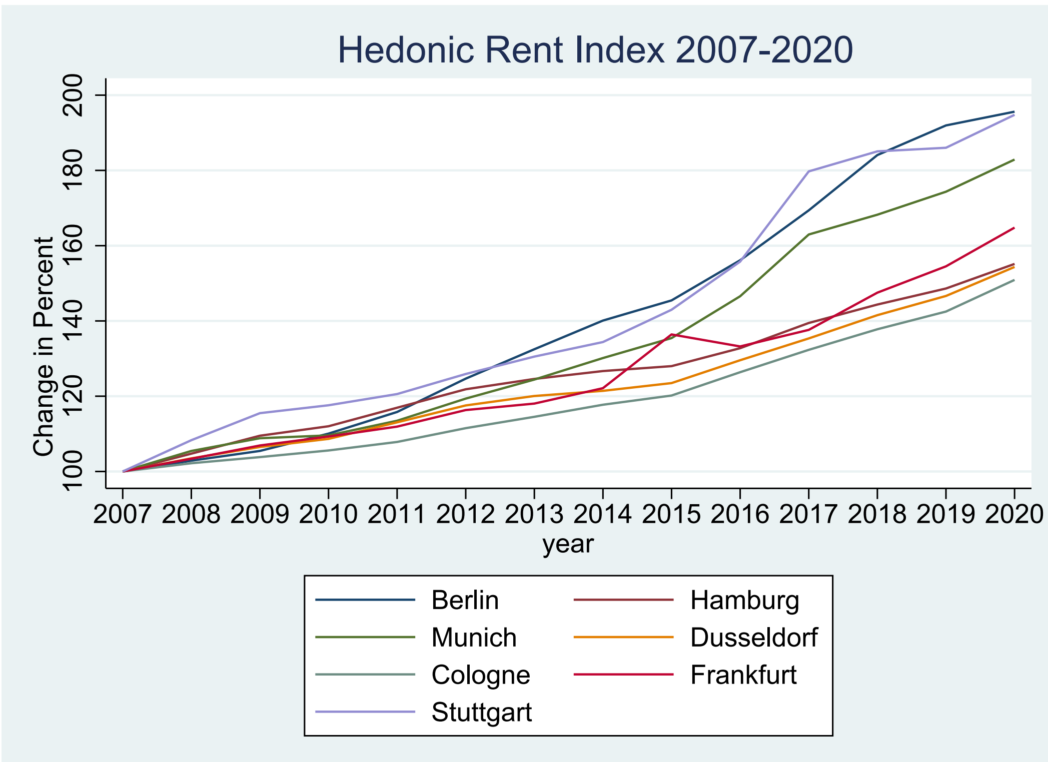
Variable	Loadings
Bar Score	0.3905
Shop Score	0.4119
Station Score	0.1441
Supermarket Score	0.3320
Nightclub Score	0.3395
ATM Score	0.4178
Park Score	0.1849
Restaurant Score	0.4103
Doctor Score	0.2335
Proportion of Variance	0.5219

Source: Open Street Map Data, own calculations.

The data is collected through the open source platform Open Street Map. For each postal code we count the number of a range of amenities within the post code. More precisely, we collect the number of bars, nightclubs, restaurants, shops, supermarkets, ATMs, parks and doctors within each ZIP code. Based on these values we perform a principal component analysis (PCA). PCA allows us to calculate a single measure which can best predict amenities in each ZIP code. The first principle component of these amenities then serves as the basis of the exogenous part in the composite amenity index as depicted in Figure B.2. Table A.1 depicts the corresponding loadings.

[29] The corresponding datasets are Boelmann et al. (2020a,b); Boelmann and Schaffner (2019)

Figure A.1: Development of hedonic transaction price rents



The figure depicts the development of a hedonic, quality–adjusted rent price index for new rental leases in the seven largest cities of Germany. The base year is 2007 for each city. The index uses the RWI RED dataset, which includes all advertised rents on Germany's largest internet platform *Immoscout24*. For a detailed description see of the data and the derivation of the hedonic price index see the Appendix.

Estimation of shape parameters

We now describe the estimation of the income-specific shape parameters, ϵ^j. Rewriting (10), we get

$$\ln \pi_k^j = \ln B_k^j + \epsilon^j \ln\Big((A_k^j)^\beta (w^j + a^j R - p_k q_0)^{1-\beta} p_k^{-\alpha}\Big) + \ln\left(\sum_{\ell=1}^{K} B_\ell^j ((A_\ell^j)^\beta (w^j + a^j R - p_\ell q_0)^{1-\beta} p_\ell^{-\alpha})^{\epsilon^\ell}\right). \tag{A.1}$$

Letting s_k^j be the observed share of type-j households in zip code k, we then estimate

$$\ln s_k^j = \lambda^j + \epsilon^j \ln X_k^j + \mu_k^j, \tag{A.2}$$

where $X_k^j = \ln\Big((A_k^j)^\beta (w^j + a^j R - p_k q_0)^{1-\beta} p_k^{-\alpha}\Big)$ and the constant is

$$\lambda^j = \ln\left(\sum_{\ell=1}^{K} B_\ell^j ((A_\ell^j)^\beta (w^j + a^j R - p_\ell q_0)^{1-\beta} p_\ell^{-\alpha})^{\epsilon^j}\right).$$

Finally, μ_k^j is an error term which captures $\ln\Big(B_k^j\Big)$ together with other unobservables.

Table A.2: Shape Parameter across Income Brackets

Income Bracket	850	1100-1500	1500-2000	2000-2600	2600- 4000	4000-7500	9000
ϵ	4.9141	6.5097	6.0734	5.8911	3.530823	3.4030	4.3654

However, OLS estimates may be biased. For instance, housing prices could be influenced by B_k^j or other ZIP code specific unobservables that attract certain household types. Hence, we estimate equations (A.2) by IV regressions. To this end, we need variables that affect prices but are not correlated with the population shares. The instruments we use include a range of supply shifters which make housing supply in specific areas of the city more expensive through special regulations or physical constraints, but should be exogenous to the share of households living in the region. We now briefly discuss these instruments.

Our first instrument is the number of archeological sites and historical land monuments per hectare in each ZIP code.[30] Second, we compute the average distance from ground water to the surface in each ZIP code. Our third instrument is the share of land in each ZIP code that is part of a so-called preservation zone (*Erhaltungsgebiet*). Fourth, we compute a ZIP code specific developable land index from satellite data. In particular, we construct an indicator variable for each ZIP code which equals one when based on this satellite data there is developable land within the ZIP code.[31]

[30] We standardize the variable by dividing it by its standard deviation. Land monuments for example are ruins of old fortifications, burial mounds or estates.

[31] We use Corine Land Cover 2018 data to identify land that is potentially developable. The Corine Land

All four variables shift the housing supply function. Building is subject to special regulations in the presence of archeological sites or within preservation zones. A small distance to groundwater makes construction more difficult and hence more expensive. Last, the amount of developable land is a physical constraint on the supply of housing.

The exclusion restriction states that the instruments should not affect the type-specific population shares other than through their effect on housing prices. This likely holds for distance to groundwater, which should not affect type-specific population shares directly. It might be problematic if, for instance, landmarks are amenities that particularly attract high-income earners, or if non-developable land consists of parks or other green amenities which attract certain types of households.[32] Since we have several instruments, however, for each type we can choose the set of instruments which are least likely to be endogenous. We do this by presenting Hausman-Wu tests for endogeneity and overidentification tests using Sargan statistics. These are presented at the bottom of Tab. A.3. In addition we present first-stage F-statistics. In summary, the instruments seem to be strong, and pass the overidentification tests.[33]

Our IV estimates of the type-specific shape parameters are shown in Tab. A.3. Overall, the IV coefficients are lower than the OLS estimates except for the highest income type. In the text, we use these parameters for our counterfactuals. For completeness, in Table A.4 we present the welfare effects of our main counterfactuals using the shape parameter estimates obtained via OLS (see Tab.A.2). Qualitatively, the results are similar and quantitatively, the differences are mostly small.

Table A.3: Shape Parameter across Income Types: Instrumental Variable Approach

	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
ϵ	4.793	4.542	3.374	4.654	3.915	2.849	1.753
Instrument	monuments per ha	Monuments per ha, preserv. zone	preserv. zone	land index	preserv. zone per ha	log monuments per ha	monuments per ha, preserv. z., distance groundwater
F-Stat	9.36	16.88	12.652	14.397	49.470	29.814	39.964
Wu-Haus. p-va.	0.9884	0.681	0.6787	0.8465	0.912	0.903	0.685
Sargan p-va.		0.186					0.227

Cover data is based on 100m resolution satellite data that via remote sensing provides the basis for over 37 land cover and land use categories such as *Sports and Leisure Facilities* or *wetlands*.

[32] This is not especially likely for archeological sites, which are underground sites.

[33] The F-statistic for Type 1 is just below 10, which might indicate a weak instrument. However, the usual problem that the first-stage coefficient becomes close to zero, which would inflate the IV coefficient, does not seem to occur here.

Table A.4: Robustness OLS Shape Parameter: Δ in %Welfare

Change in %	**Type 1**	**Type 2**	**Type 3**	**Type 4**	**Type 5**	**Type 6**	**Type 7**
Gentrification	-0.5524	-0.0205	-0.0088	-0.0751	-0.0267	0.0281	0.0243
Rental Cap	-2.5618	-0.8082	-0.5123	-0.2986	-0.2561	-0.1817	-0.2128
Housing Subsidy	2.3096	1.2638	0.8949	-0.7273	-0.4827	-0.2681	-0.1670
Rezoning	0.1398	0.0961	0.0948	0.0938	0.1516	0.1477	0.1926

Source: Own model calculations; values expressed in percentage changes. The above table lists the change in welfare of all counterfactuals in relation to the baseline calibration using the shape parameter estimates obtained via OLS.

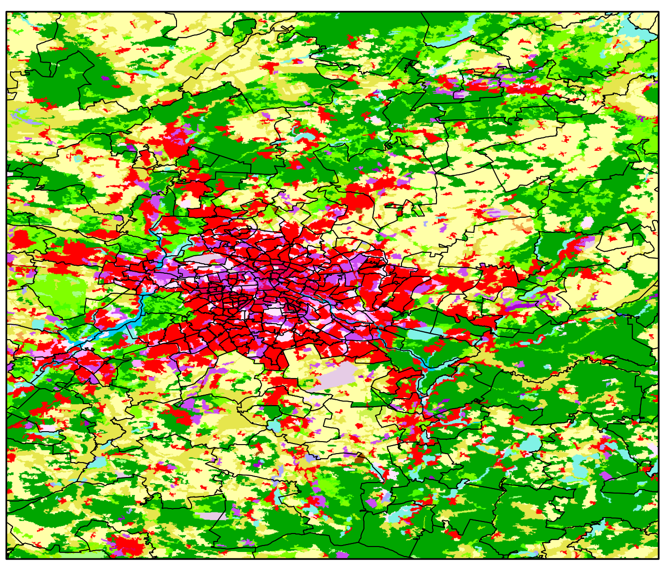


Figure A.2: Landcover Berlin

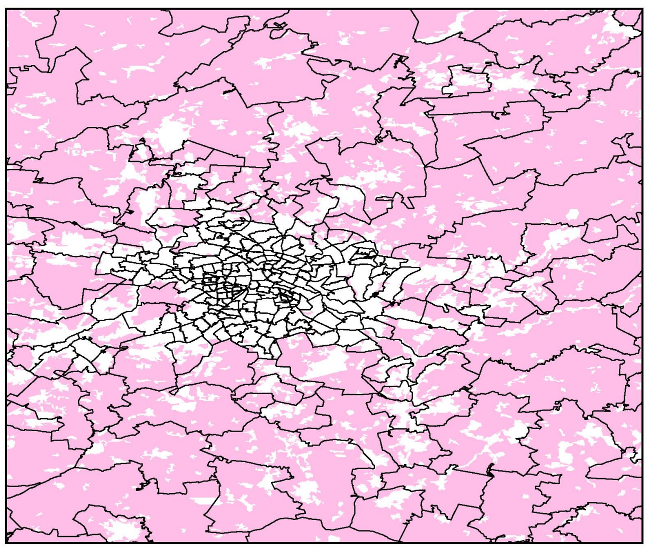


Figure A.3: Developable Land
Note: The figure depicts the share of developable land in each ZIP code in white.

Appendix B

Tables and Figures

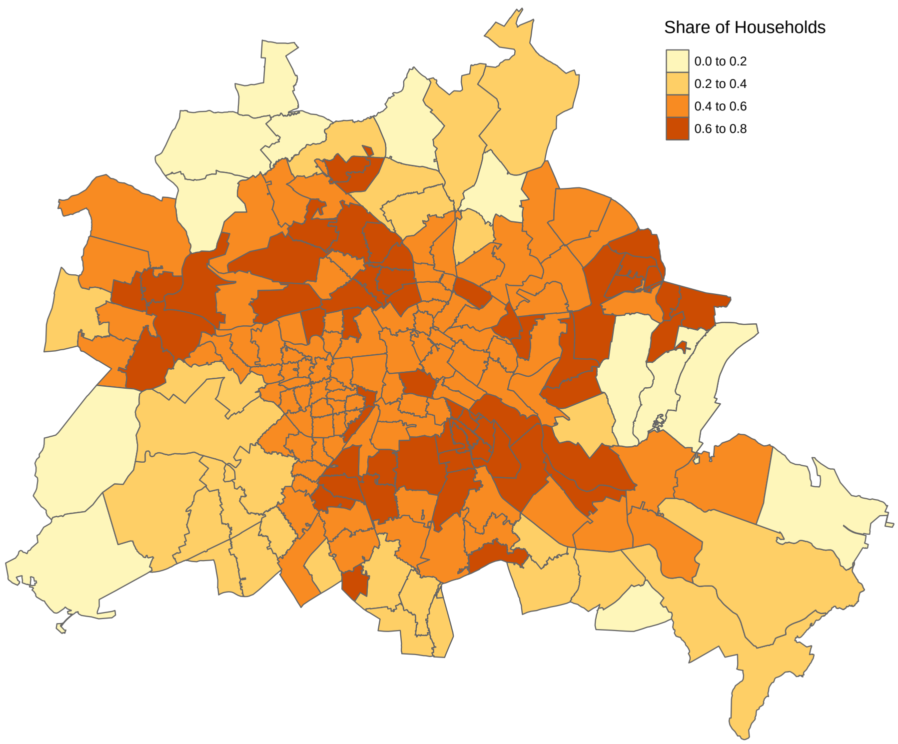


Figure B.1: Share of households of the lower three income brackets

Note: The figure depicts the share of households in the lowest three income brackets in each ZIP Code.

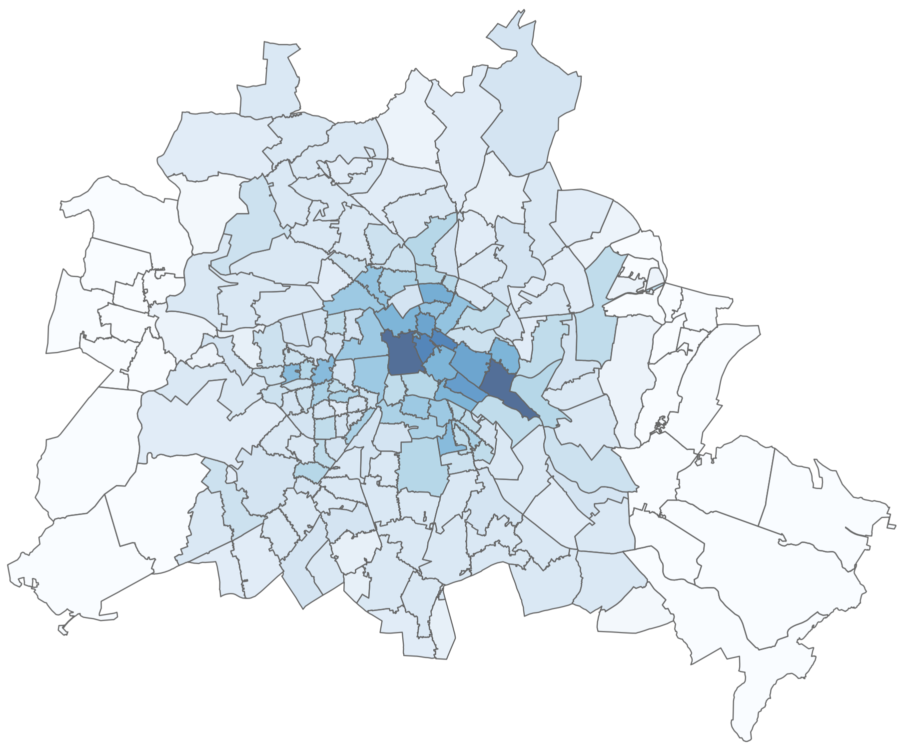


Figure B.2: Amenity score

Note: The range of the amenity index is normalized to 0–100. Dark blue represents values close to 100 and lighter blue values close to 100.

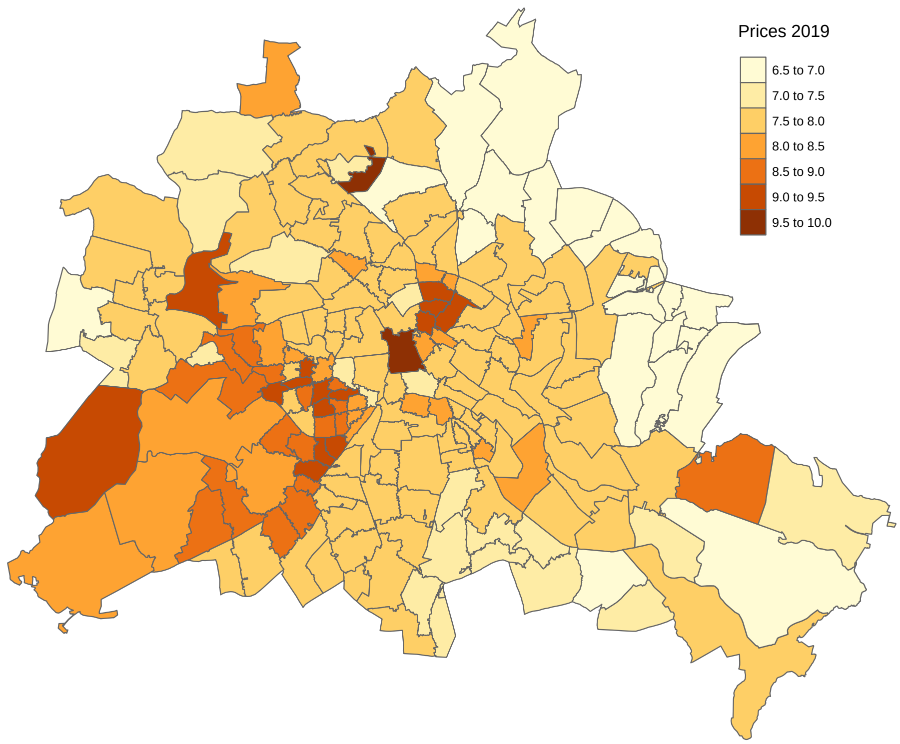


Figure B.3: Rental prices 2019

Note: The figure depicts the average square metre price of rental leases across Berlin ZIP codes. Rents include payments for utilities and bills but exclude heating payments.

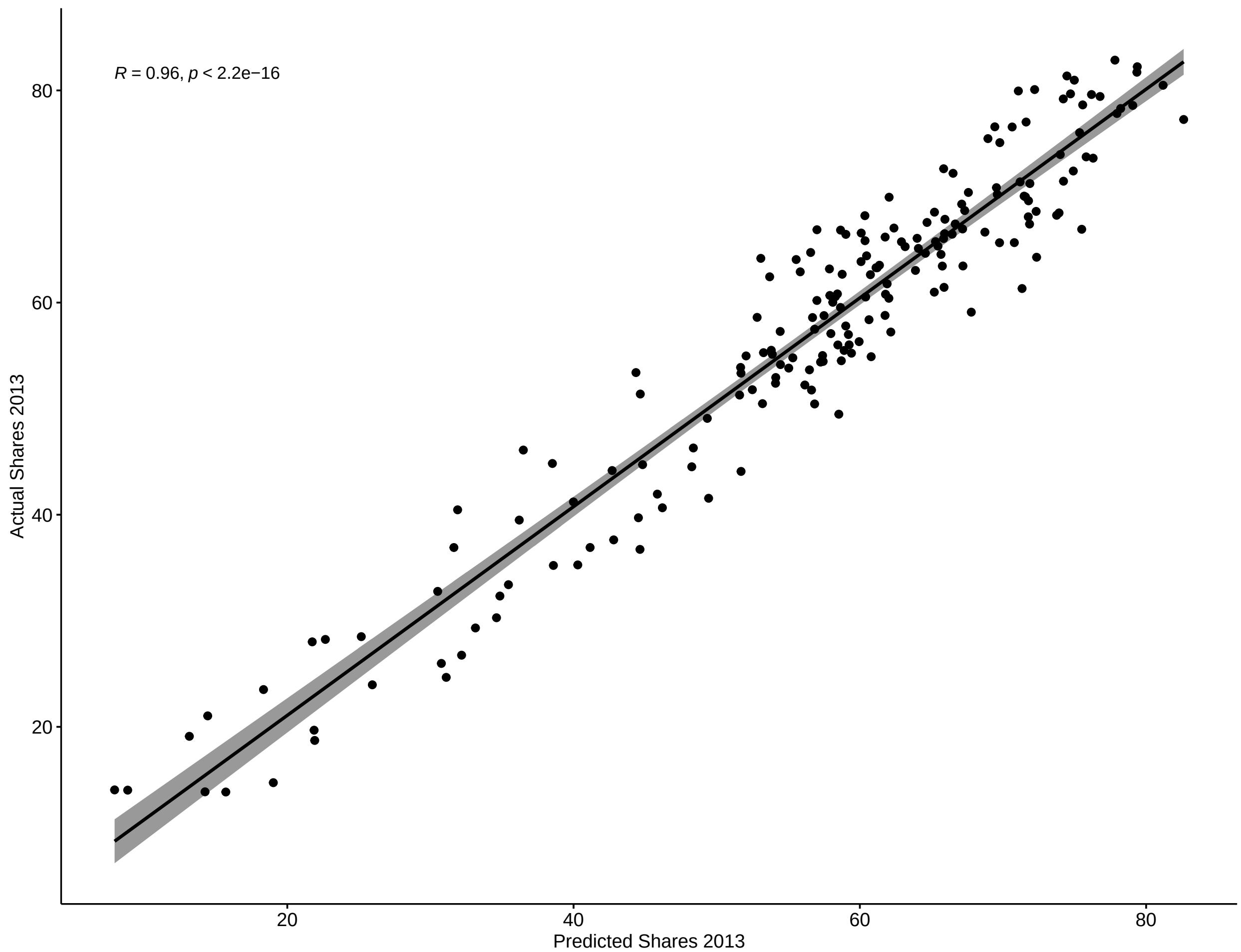


Figure B.4: Correlation actual and predicted shares 2013

Note: The figure plots the actuak share of households of the lowest three income brackets in each ZIP code for the year 2013 against the predicted shares of our model.

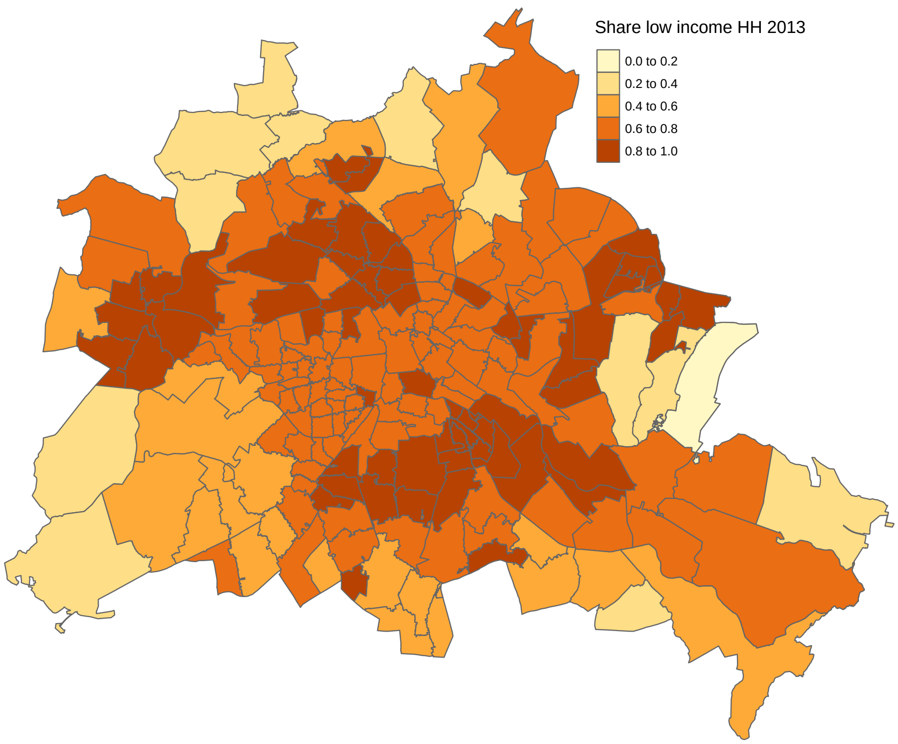


Figure B.5: Share of low income households per ZIP code in 2013

Note: The figure depicts the predicted share of households of the lowest three income brackets in each ZIP code for the year 2013.

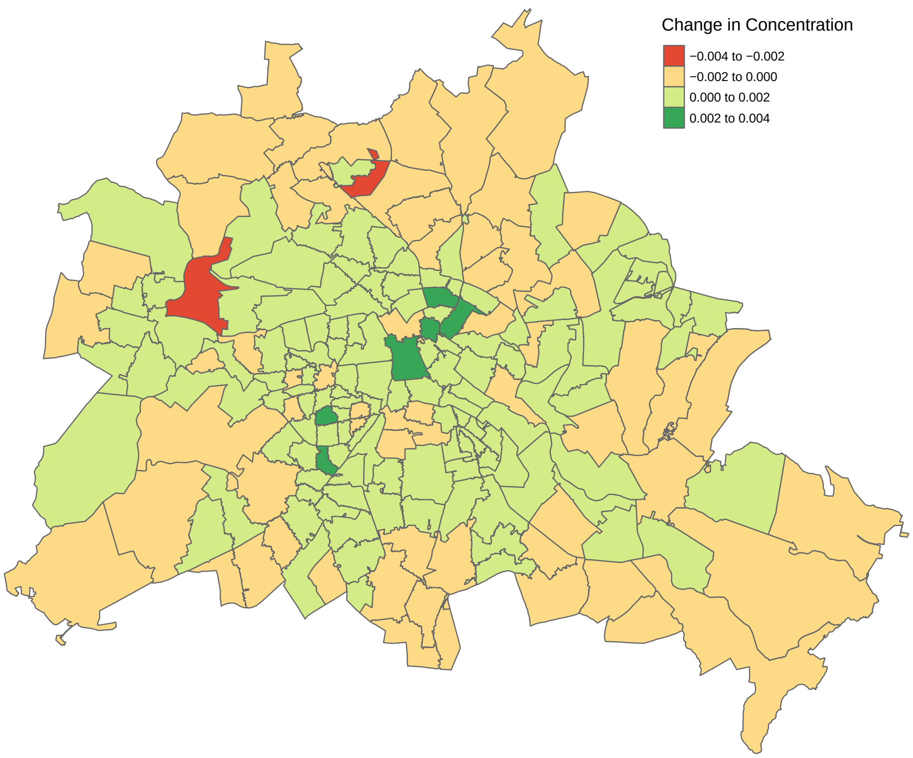


Figure B.6: Change in within ZIP Code Concentration after Rental Cap

Note: The figure depicts the change in the within ZIP code concentration after the rental cap counterfactual.

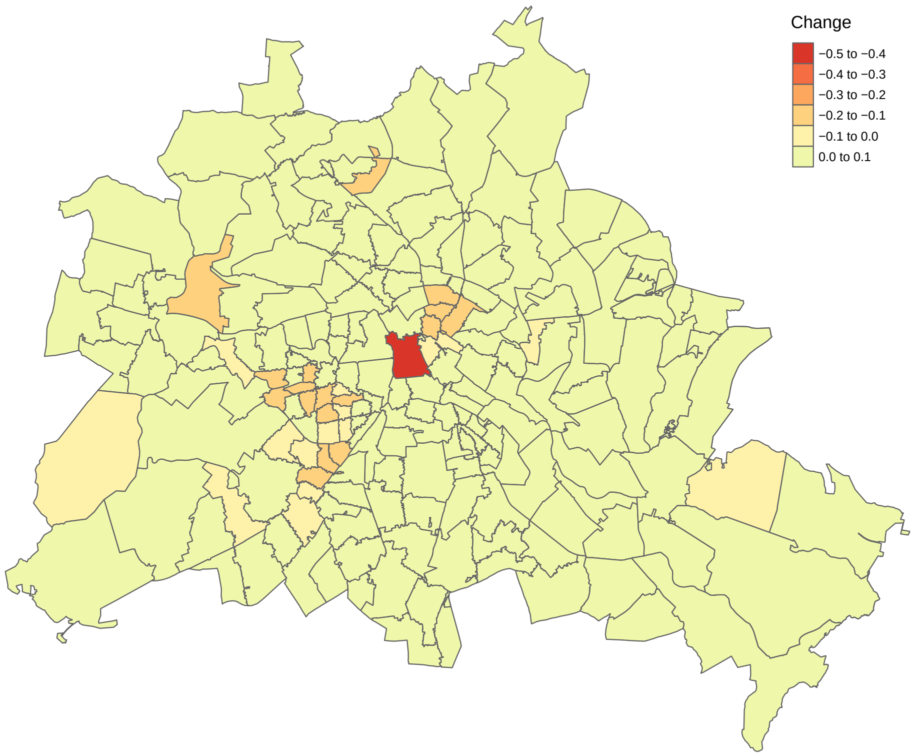


Figure B.7: Change in within ZIP Code Share of Low Income Households after Rental Cap

Note: The figure depicts the change in the within ZIP code share of households of the lowest three income group after the rental cap counterfactual.

Table B.1: Baseline Calibration in Berlin and adjacent Regions

Change in %	**Type 1**	**Type 2**	**Type 3**	**Type 4**	**Type 5**	**Type 6**	**Type 7**
Berlin							
Budget Share	0.40	0.32	0.28	0.26	0.23	0.21	0.20
Sqm Price	7.86	7.85	7.85	7.84	7.86	7.96	7.93
Floor Space	43.92	55.73	66.30	78.26	102.98	161.63	241.90
Amenity Index	21.43	20.21	19.96	29.92	29.78	30.92	29.34
Rental Income	13.37	89.01	113.90	105.57	211.33	392.35	732.98
Brandenburg							
Budget Share	0.36	0.28	0.25	0.24	0.21	0.19	0.18
Sqm Price	6.64	6.68	6.70	6.68	6.71	6.73	6.84
Floor Space	47.48	61.49	74.02	88.21	117.53	187.08	282.28
Amenity Index	15.42	15.34	15.13	25.05	24.49	23.88	23.04
Rental Income	21.23	141.35	180.88	167.65	335.60	623.07	1164.00

Source: Own model calculations.

Table B.2: Different Values of ζ^H

Change in %	ζ^H	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
				Gentrification Counterfactual				
Sqm Price	0.01	1.5252	1.6080	1.7270	1.8641	2.4405	2.5586	3.2510
	0.1	1.5283	1.6102	1.7282	1.8665	2.4405	2.5605	3.2526
Floor Space	0.01	-0.5584	-0.5465	-0.7134	-0.9880	-1.4735	-1.7288	-2.4177
	0.1	-0.5596	-0.5476	-0.7141	-0.9900	-1.4727	-1.7296	-2.4184
Amenity Index	0.01	-0.0567	-0.0265	-0.0135	0.1579	0.1922	0.1913	0.2014
	0.1	-0.0571	-0.0269	-0.0137	1.6183	1.7308	1.7690	1.8521
Welfare	0.01	-0.5451	-0.0155	-0.0053	-0.0734	-0.0289	0.0257	0.0197
	0.1	-0.5466	-0.0163	-0.0057	0.2456	0.3066	0.3682	0.3772
				Rental Cap Counterfactual				
Sqm Price	0.01	-1.9879	-1.5556	-1.5144	-1.5049	-1.7643	-2.4070	-2.5469
	0.1	-1.9898	-1.5547	-1.5146	-1.5067	-1.7629	-2.4054	-2.5413
Floor Space	0.01	-1.0973	-3.5945	-3.8701	-3.9099	-4.3408	-5.4621	-5.3158
	0.1	-1.1049	-3.6071	-3.8994	-3.8541	-4.3422	-5.4565	-5.3082
Amenity Index	0.01	-0.9403	-0.3070	-0.2434	-0.1126	-0.0430	-0.0018	-0.0029
	0.1	-0.9409	-0.3045	-0.2131	-0.1577	-0.0466	-0.0191	-0.0567
Welfare	0.01	-2.6153	-0.8689	-0.5720	-0.3103	-0.2639	-0.1898	-0.2209
	0.1	-2.6199	-0.8646	-0.5557	-0.3017	-0.2614	-0.1886	-0.2238
				Subsidy Counterfactual				
Sqm Price	0.01	-5.4534	-4.4086	-3.7484	-0.0031	-0.0003	0.0017	0.0020
	0.1	-5.4533	-4.4085	-3.7484	-0.0052	-0.0004	0.0014	0.0017
Floor Space	0.01	0.8603	0.6965	0.5924	-0.5445	-0.4199	-0.2715	-0.1840
	0.1	0.8602	0.6963	0.5923	-0.5433	-0.4199	-0.2713	-0.1838
Amenity Index	0.01	0.0135	0.0035	0.0013	-0.0018	-0.0009	-0.0004	-0.0002
	0.1	0.0136	0.0035	0.0014	-0.0027	-0.0009	-0.0009	-0.0007
Welfare	0.01	2.3096	1.2638	0.8949	-0.7273	-0.4827	-0.2680	-0.1669
	0.1	2.3096	1.2638	0.8950	-0.7272	-0.4827	-0.2681	-0.1670
				Rezoning Counterfactual				
Sqm Price	0.01	-0.1064	-0.1068	-0.1073	-0.1068	-0.1091	-0.1153	-0.1176
	0.1	-0.1065	-0.1073	-0.1080	-0.1058	-0.1092	-0.1164	-0.1143
Floor Space	0.01	0.0419	0.0527	0.0604	0.0669	0.0755	0.0897	0.0942
	0.1	0.0420	0.0530	0.0608	0.0660	0.0754	0.0903	0.0907
Amenity Index	0.01	-0.0389	-0.0336	-0.0324	-0.0296	-0.0319	-0.0345	-0.0470
	0.1	-0.0376	-0.0329	-0.0320	-0.0275	-0.0291	-0.0340	-0.0178
Welfare	0.01	0.1422	0.1256	0.1522	0.1132	0.1385	0.1737	0.4590
	0.1	0.1421	0.1255	0.1521	0.0807	0.1498	0.1749	0.3233

Source: Own model calculations.

Table B.3: Different Values of ζ^L

Change in %	ζ^H	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
				Gentrification Counterfactual				
Sqm Price	0	1.5252	1.6080	1.7270	1.8641	2.4405	2.5586	3.2510
	0.1	1.5301	1.6147	1.7272	1.8633	2.4403	2.5598	3.2509
Floor Space	0	-0.5584	-0.5465	-0.7134	-0.9880	-1.4735	-1.7288	-2.4177
	0.1	-0.5602	-0.5495	-0.7135	-0.9871	-1.4731	-1.7294	-2.4173
Amenity Index	0	-0.0567	-0.0265	-0.0135	0.1579	0.1922	0.1913	0.2014
	0.1	1.5434	1.5856	1.6026	0.1574	0.1919	0.1910	0.2013
Welfare	0	-0.5451	-0.0155	-0.0053	-0.0734	-0.0289	0.0257	0.0197
	0.1	-0.1934	0.3340	0.3458	-0.0733	-0.0289	0.0254	0.0196
				Rental Cap Counterfactual				
Sqm Price	0	-1.9879	-1.5556	-1.5144	-1.5049	-1.7643	-2.4070	-2.5469
	0.1	-1.9885	-1.5481	-1.5198	-1.5025	-1.7620	-2.4050	-2.5449
Floor Space	0	-1.0973	-3.5945	-3.8701	-3.9099	-4.3408	-5.4621	-5.3158
	0.1	-1.0926	-3.6290	-3.8163	-3.9106	-4.3386	-5.4560	-5.3095
Amenity Index	0	-0.9403	-0.3070	-0.2434	-0.1126	-0.0430	-0.0018	-0.0029
	0.1	-0.9831	-0.2969	-0.2564	-0.1116	-0.0422	-0.0013	-0.0027
Welfare	0	-2.6153	-0.8689	-0.5720	-0.3103	-0.2639	-0.1898	-0.2209
	0.1	-2.5413	-0.8669	-0.5392	-0.3085	-0.2625	-0.1883	-0.2197
				Subsidy Counterfactual				
Sqm Price	0	-5.4534	-4.4086	-3.7484	-0.0031	-0.0003	0.0017	0.0020
	0.1	-5.4528	-4.4090	-3.7478	-0.0031	-0.0003	0.0018	0.0021
Floor Space	0	0.8603	0.6965	0.5924	-0.5445	-0.4199	-0.2715	-0.1840
	0.1	0.8601	0.6967	0.5921	-0.5445	-0.4199	-0.2715	-0.1840
Amenity Index	0	0.0135	0.0035	0.0013	-0.0018	-0.0009	-0.0004	-0.0002
	0.1	0.0140	0.0032	0.0018	-0.0018	-0.0009	-0.0004	-0.0002
Welfare	0	2.3096	1.2638	0.8949	-0.7273	-0.4827	-0.2680	-0.1669
	0.1	2.3096	1.2639	0.8950	-0.7273	-0.4827	-0.2680	-0.1669
				Rezoning Counterfactual				
Sqm Price	0	-0.1064	-0.1068	-0.1073	-0.1068	-0.1091	-0.1153	-0.1176
	0.1	-0.1070	-0.1076	-0.1078	-0.1079	-0.1089	-0.1152	-0.1135
Floor Space	0	0.0419	0.0527	0.0604	0.0669	0.0755	0.0897	0.0942
	0.1	0.0420	0.0530	0.0606	0.0677	0.0754	0.0895	0.0904
Amenity Index	0	-0.0389	-0.0336	-0.0324	-0.0296	-0.0319	-0.0345	-0.0470
	0.1	-0.0288	-0.0261	-0.0274	-0.0293	-0.0317	-0.0343	-0.0468
Welfare	0	0.1422	0.1256	0.1522	0.1132	0.1385	0.1737	0.4590
	0.1	0.1435	0.1350	0.1190	0.1133	0.1384	0.1735	0.4583

Source: Own model calculations.

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