CLOSING THE RENT INDEX GAP – A QUANTITATIVE APPROACH TO RENTAL-SECTOR GENTRIFICATION

SELIM BANABAK

Urban and Regional Research, TU Wien, Vienna, Austria. E-mail: selim.banabak@tuwien.ac.at (Corresponding author)

Received: July 2023; accepted November 2023

ABSTRACT

This paper advocates for a greater emphasis on supply sided concepts such as the rent gap in the empirical operationalizations of gentrification. It provides a novel framework to identify rental-sector gentrification areas through index construction by drawing on insights from the gentrification, rent gap, price index and hedonic regression literatures. The approach is highly adaptable to a variety of regulatory contexts and other housing market idiosyncrasies through the design of the underlying regression model. Drawing on data from the city of Vienna, local rent changes and their relationship to price-effective transformations of the rental housing supply are quantified. After computing the respective indices, bivariate mapping is utilized to identify potential gentrification areas.

Key words: Gentrification; Rent Gap; Rent Index; Qualitative Transformation; Vienna

INTRODUCTION

Although the literature on gentrification has produced multiple theoretical explanations (Lees *et al.* 2008), Neil Smiths rent gap theory (1979) remains one of the key concepts. After nearly halve a decade, it is still invoked to understand the link between urban transformation and contemporary issues such as the '*buy-fix-sell*' approach of major global investors (Christophers 2022) or the emergence of the sharing economy (Wachsmuth & Weisler 2018). Clark and Pissin (2020) even argue for an application of the concept beyond urban transformation. Nonetheless, empirical gentrification studies which attempt to operationalize rent gaps are scarce (Lees *et al.* 2008, p. 61f). Indeed, rent gaps are a very abstract concept and measuring them remains a challenging task. This issue of course, does neither halt the negative real-world impacts of gentrification nor academic discussion of the phenomenon. However, quantitative studies are thereby severely constrained and as a result often detached from supply-sided gentrification theories.

Due to widespread privatization and promotion of homeownership, tenure conversion has often been seen as the key gentrification mechanism across European cities (e.g., Andersson & Turner 2014; Boterman & Van Gent 2014). However, private rental markets are re gaining importance (Eurofound 2023), often even being actively promoted (Hochstenbach & Ronald 2020). Ironically, private rental markets are one of the still understudied contexts within empirical approaches to the rent gap. Of course, rent gaps are by no means limited to rental markets, despite linguistic proximity. Nonetheless, the most severe consequence of gentrification i.e., direct displacement of residents is most likely for tenants in the private rental sector. Thus, this paper aims

Tijdschrift voor Economische en Sociale Geografie – 2023, DOI:10.1111/tesg.12607, Vol. 0, No. 0, pp. 1–17.

to analyse rent gap induced gentrification where the property is transformed but continues to be supplied on the private rental market. Following Millard-Ball (2000) I will refer to this as 'rental-sector gentrification' as opposed to modes of gentrification which involve tenure changes.

Surprisingly there is a rather small set of quantitative gentrification studies that explicitly include rental market variables (e.g., Freeman *et al.* 2016; Kadi *et al.* 2022b) and they typically do not provide any clear link to rent gap theory. The aim of this paper is thus to propose a framework for quantitative identification of neighbourhoods which are transformed through landlords seeking to close existing rent gaps, but properties remain on the rental market. To do so, I draw on two very different strands of the literature. First, Bernt's (2022) discussion of the 'realization problem' to conceptually link rent gaps, which are very abstract and difficult to quantify, to more tangible transformations in the local rental market. Two key dimensions identified in the context of rental-sector gentrification are price-effective, qualitative transformations of the housing supply and a subsequent increase in the rents charged by landlords. It needs to be emphasized, though, that these are not measurements of the rent gap as such but of the empirical implications associated to a certain type of rent gap closing. Second, the house price index literature which provides the tools to measure these transformations using hedonic regression models and index construction. Finally, bivariate mapping of the proposed indices can be utilized to identify neighbourhoods with high rental-sector gentrification pressure.

The proposed identification strategy is then exemplified, drawing on the case of Vienna after the 2008 Global Financial Crisis (GFC). Although, traditionally rather known for social housing than gentrification, the city of Vienna has several features which make it an ideal case study. It has a large private rental sector which has undergone significant transformations (Kadi 2015), with strong price increases especially in the post-GFC context (Kadi *et al.* 2022a). Thus, the study period 2011–2020 should be able to capture significant dynamics both in terms of qualitative transformations and rising rent levels. Accordingly, there is an ongoing debate on the drivers of gentrification in the city. While, among others, Kadi and Verlič (2019) argue landlords seeking to close existing rent gaps are causing gentrification, Musil *et al.* (2022) focus on housing stock transformation as an indication of closing value gaps. Furthermore, the Viennese rental market is well known for its complex regulations, which should help to exemplify how the approach can easily be adapted to local idiosyncrasies through specification of the underlying regression model. For the case study, this paper draws on an extensive dataset, covering rents and characteristics of over ten thousand apartments listed on the Viennese private rental market.

The remainder of this paper is structured as follows: Section "Gentrification, Rent Gaps and the Measurement Issue" reviews theoretical debates around gentrification and common quantitative approaches. Section "Identifying Rental-Sector Gentrification" presents a novel framework to identify potential gentrification areas. Section "The Unlikely Case of Vienna" introduces the case of Vienna, while Section "Modelling Viennese Housing Rents" reports how the proposed methodology has been implemented in the case study and Section "Results" presents the empirical findings. Section "Discussion and Conclusion" discusses the findings and provides a brief conclusion.

GENTRIFICATION, RENT GAPS AND THE MEASUREMENT ISSUE

The term gentrification was coined by Glass (1964) to describe a rather specific process of middle-class gentrifiers moving into Victorian houses formerly occupied by working-class families in London. However, this paper follows a more general understanding of gentrification as a 'a process involving change in the population of land users such that the new users are of a higher socio-economic status than the previous users, together with an associated change in the built environment through a reinvestment of capital' (Clarke 2005, p. 258).

Another important distinction among theoretical approaches to gentrification is between demand- and supply-side explanation patterns (Lees *et al.* 2008). Demand-side theories typically contend that local changes in the built environment are preceded by social practices. Thus, they are initiated by so-called *Pioneers* entering deprived areas who eventually attract an inflow of capital. However, the remainder of this paper will concentrate on the debate surrounding supply-side theories. These imply that changes in the socio-economic structure of a neighbourhood are caused by capital reinvestment in the built environment.

According to Smith (1979), such reinvestment occurs when the rent gap, or the gap between actual ground rent and potential rent ground rent, has grown sufficiently large. Here it is important to distinguish between the different types of rent mentioned. First, ground rent as understood by Smith (1979, p. 543), is 'a claim made by landowners on users of their land.' Ground rents vary with its competitive advantages associated to different qualities of the land. These can be caused either by natural features of a given plot of land or by improvements to it (Bernt 2022, p. 29). Thus, ground rents change with urban expansion (Smith 1979), provision of public infrastructure (López-Morales *et al.* 2023) or crucially in the context of rental-sector gentrification, investment into the housing stock (Smith 1979). Capitalized ground rent then refers to 'the actual quantity of ground rent that is appropriated by the landowner, given the present land use' Smith (1979, p. 543). Meanwhile, potential ground rent is defined as 'the amount that could be capitalized under the land's "highest and best use."' (Smith 1979, p. 543). Hence, with increasing gaps between actual and potential ground rent, there is an economic incentive to transform a property, which may result in various forms of displacement. If such a transformation successfully takes place, the rent gap is considered as either partially or even fully closed.

Meanwhile, Maloutas (2012) argues that gentrification as a concept is highly dependent on contextual causality and application beyond the Anglo-American metropolis implies an unwelcome shift from causal mechanisms to mere similarities in outcomes. Ghertner (2015) similarly argues that market forces are typically not the key drivers of displacement in the global-south and therefore different explanations are required. Indeed, it self-evident, that local housing market structures, regulations etc. play a crucial role in understanding urban transformations. I further agree that gentrification should not be solely understood by socio-spatial outcomes but by the underlying drivers and the mechanisms through which they are realized. Nonetheless, I follow the notion of rent gaps as indeed global cross-contextual drivers of gentrification (López-Morales 2015; Slater 2015). One of the weaknesses of the original rent gap theory, however, is regarding what Bernt (2022) calls the realization problem of the rent gap. Thus, to question how reinvestment of capital, transformation of the built environment and displacement are conceptually connected. How and if developers can realize potential ground rents is indeed highly dependent on local conditions such as housing market regulations, thus political determination.

Despite being called upon to explain gentrification across the world, rent gaps are considered as extremely hard to measure (Lees *et al.* 2008, p. 61f) and few empirical studies offer explicit operationalizations. Although some early attempts have been made (e.g., Ley 1986; Clark 1988; Badcock 1989; Hammel 1999), they typically rely on proxies of capitalized- and potential ground rent, but so far, no consensus could be established regarding the choice of proxies. A systematic overview of common operationalizations can be found in Liu *et al.* (2018). Bourassa (1990, 1993), an outspoken opponent of the rent gap theory, provides an in-depth criticism of these early operationalizations. He further points out that the rent gap hardly plays a role in Smiths own empirical studies, which should become indicative for a wider trend in empirical gentrification research. Indeed, quantitative gentrification studies frequently have a vague relationship to the rent gap theory when it comes to identifying gentrification areas. This is particularly problematic as empirical findings are known to be quite sensitive to the underlying definitions and their operationalizations (Barton 2016; Finio 2022). A notable

exception to this trend, however, is provided by López-Morales (2011, 2016).

Most gentrification studies, though, do not consider supply-sided theories in their research design. While some studies identify gentrification areas simply based on prior local knowledge (Freeman & Braconi 2004), others do not operationalize the underlying changes to the built environment (Atkinson 2000; Walks & Maaranen 2008; Hedin *et al.* 2012). Another set of studies, employs both real estate and socio-economic indicators but does not distinguish between gentrification's drivers and outcomes (Holm & Schulz 2016; Reades *et al.* 2019; Kadi *et al.* 2022b; Bunten *et al.* 2023). Although these studies allow for valuable insights into the geography of neighbourhood transformation, they presuppose their socio-spatial implications. A key advantage of supply-sided theories, however, is that they allow to disentangle the driver from the outcome. Freeman *et al.* (2016) provide one of the few quasi-experimental gentrification studies, which explicitly feature rental market dynamics. Surprisingly though, the authors treat rising rents as a control variable rather than immanent feature of gentrification. Of course, deprived households do not necessarily oppose improvements to their homes, but they may be unable to afford the resulting increase in housing costs.

Acknowledging that directly measuring rent gaps is quite difficult, the aim of this paper is nonetheless to propose an identification method for gentrification areas which is theoretically grounded and in the spirit of a supply-sided explanation of gentrification. I thus draw on Bernt's (2022) discussion of the realization problem and the varying mechanisms through which rent gaps may or may not translate to displacement, to come up with a quantitative operationalization. While Bernt analyses the 'historically specific nexus between commodification and decommodification in driving gentrification' (Bernt 2022, p. 3), my task is of a more technical nature. However, understanding the mechanisms through which transformations of the built environment are conducted to close existing rent gaps in a way that brings about a change in the status of land-users, is crucial for the empirical identification of gentrification areas. Broadly speaking, these mechanisms include (1) a transformation of the built environment which changes the residential nature of the built structure which thereby displaces all former residents.

Alternatively, (2) the built structure may remain residential but experience a tenure conversion. Since, former residents may not be able to purchase the apartments they previously rented, such a transformation also caused displacement. This mechanism is typically analysed through the value gap framework (Hamnett & Randolph 1984). The value gap refers to a disparity between a properties' difference between tenanted investment and vacant possession value, which, if sufficiently large, incentivises tenure conversion, thereby causing displacement. However, according to Clark (1992) the closing of a value gap entails at least a partial closure of the rent gap. See Musil *et al.* (2022) or Boterman and Van Gent (2014) for empirical applications.

Furthermore, (3) apartments may also remain in rental supply despite qualitative transformations. In such instances, gentrification is initiated by 'landlord developers' who aim to rent to tenants after rehabilitation (Smith 1979, p. 546). Thus, in an open market setting, properties would receive qualitative upgrading to attract more affluent tenants from which higher rents can be commanded. However, frequently rents are kept below market rates by state interventions such as price caps. If applicability of regulations is tied to certain characteristics of the property, transformation of the built structure can be a way to escape those regulations (e.g., Hatz 2021). In both instances, (contract-) rents will be raised after the transformation is conducted. It is important to emphasize, though, that housing (or contract) rent is not the only component of ground rent (Clark 1995) and thus 'quite a different animal from ground rent, but both are forms of rent' (Smith 1996, p. 1200). See Haila (2015) for a good overview of different concepts of rent. However, Smith (1979, p. 543) also points out that 'in the case of rental housing […] the landlord's capitalized ground rent returns mainly in the form of house rent paid by the tenants'. Accordingly, housing rent is not a proper measure of ground rent

and therefore neither of the rent gap, but nonetheless a necessary implication of rent gap closings in the context of rental-sector gentrification. Although rental-sector gentrification has been studied empirically across different cities (e.g., Millard-Ball 2000; Van Criekingen 2010; Bernt 2022), very few contributions feature quantitative operationalizations. However, the current resurgence of private rental markets combined with the fact that they disproportionally house low-income households (Eurofound 2023) leaves tenants particularly vulnerable to this type of gentrification. Thus, the remainder of this paper will focus on rental-sector gentrification and propose a novel approach to identify it based on the previous discussion.

IDENTIFYING RENTAL-SECTOR GENTRIFICATION

Since both forms of rental-sector gentrification imply rising rent levels in the neighbourhood, this will be the first dimension to be quantified. However, rent increases are a necessary but not a sufficient condition for rental-sector gentrification. Given the initially cited definition, declining affordability needs to be an outcome of a change in the built environment, thus a qualitative transformation, not just inflation. Nonetheless, not all qualitative transformations lead to an increase in housing costs, either because rents are not allowed to adjust due to regulations or the conducted changes are simply not attracting increased demand by affluent tenants. Thus, the second dimension to be measured is price-effective qualitative transformation of the supplied rental housing stock in the neighbourhood. Here, price-effectiveness refers to a transformations ability to impact the rents charged. Such transformations can either be qualitative upgrading or, depending on the regulatory context, a transformation which allow the landlord to bypass price caps, or a combination of both.

In principle, price changes, particularly changes in housing rent, can be measured in a variety of ways. Hill (2013) provides a good overviews of the various methods that are commonly used. Accordingly, the most-simple type of housing price index would be a *Mean Index* that tracks the average price over time. Thus let: $P_{st}^{M} = \left(1/H_t \times \sum_{h=1}^{H_t} p_{th}\right) / \left(1/H_s \times \sum_{h=1}^{H_s} p_{sh}\right)$ denote the price index between the initial period s and the current period t where H indexes the set of supplied flats and p *denotes* their respective price. The mean index is simple to calculate and directly reflects the housing cost that tenants must bear. However, this approach has obvious drawbacks, as it is prone to conflating quality with price changes, resulting in a systematic bias. The mean index overestimates the actual price increase because the quality of the underlying dwellings typically improves over time. This fact will be used later to obtain an idea of price-effective transformation. A straightforward approach to the problem of confusing price and quality changes is to examine the same objects repeatedly over time. Bailey *et al.* (1963) proposed a regression-based index construction method known as the *repeated sales method.* Although appealing due to its simplicity, an application for building indices on a local level is difficult because the number of flats reappearing at a given point in time and space may be too small to obtain a reliable estimate.

Another option for creating quality-adjusted price indices is to employ the so-called hedonic regression methods. As the name implies, these are based on regression models in which the price of a product is regressed on a vector of characteristics that do not have individually observed prices. Hill (2013) summarizes three types of hedonic housing price indices. First is the *time-dummy method* that regresses prices onto observed product characteristics and a set of time-dummies to produce a quality-adjusted price index via the time-dummy coefficients. The second approach is called the *imputation method.* It makes use of price index formulas which compare price levels of a fixed product basket, in this case a set of flats, across two periods. Most common are the Laspeyres Index: $P_{st}^{L} = \sum_{h=1}^{H_s} p_{th} / \sum_{h=1}^{H_s} p_{sh}$ tracking the initially supplied set of flats Hs and the Paasche Index: $P_{st}^{P} = \sum_{h=1}^{H_t} p_{th} / \sum_{h=1}^{H_t} p_{sh}$ tracking the current set of flats Ht. While the Laspeyres

Index is prone to overestimating housing price inflation the opposite holds true for the Paasche Index. Thus, the Fisher Index: $P_{st}^{F} = \left(P_{st}^{L} \times P_{st}^{P}\right)^{1/2}$ defined as the geometric mean of the previous two, tries two offset this problem. However, these indices can only be computed if the current price of each good is available across all periods. Because this requirement is typically not met for rental market data, a hedonic pricing model is required to impute prices for all residences at all times. For consistency, the available price observations are typically replaced by their predicted values. The term *double-imputation* method is used in this case. This should also help mitigate the effects of omitted variable biases caused by unobserved characteristics (Hill & Melser 2008).

The *characteristics method* is similar to the *imputation method*, except that it replaces the set of observed apartments with the average unit for all periods used for imputation. Although considering changes in the average unit may be appealing from an interpretation standpoint, it may also introduce a bias, as no such average flat exists in the real world. These standard approaches can be applied to any level of spatial aggregation; however, the literature on local housing price indexes tends to favour more sophisticated statistical modelling. For instance, Goetzmann and Spiegel (1997) estimate a local variant of the repeated sales index, whereas Pace *et al.* (1998) and Clapp (2004) propose autoregressive models for index-surface construction as an advanced version of the time-dummy method.

To obtain an indication of price-effective transformations without exogenously defining good and bad characteristics, one could again draw on the previously summarized literature on price index construction. The concept proposed here is quite simple. If one type of price index is quality-adjusted whereas another is not, the difference must somehow reflect the underlying qualitative changes. If the adjusted index value is greater than the unadjusted index value, one would assume that either upgrading or another price-effective transformation has occurred without having to specify which qualities are considered superior. In this way any systematic qualitative change of the rental housing supply in a neighbourhood can be measured in a single number. The respective impact of the various possible qualitative changes onto the index directly depends on their regression coefficients or theoretically speaking, shadow price functions, which provides an endogenous weighting mechanism. If price dampening regulations are in place, this needs to be properly reflected in the specification of the regression model. Otherwise, both the regression coefficients will be biased and transformations which allow landlords to bypass regulations, cannot be captured.

The Laspeyres index appears to be an obvious choice for the quality-adjusted index. The same holds true for the mean index as the selection for the non-quality-adjusted index, as both refer to the same set of flats H_s. These can be used to compute an *Index Gap*: $G_{st} = P_{st}^{M} - P_{st}^{L}$ Under the condition that $P_{st}^{M} \geq P_{st}^{L}$ the index will return a positive value indicative of price-effective transformation in the housing characteristics. Higher values are associated to higher levels of transformation. If $P_{st}^{M} > P_{st}^{L} > 1$ this transformation goes hand in hand with actual increase in rent levels. However, if $1 > P_{st}^{M} > P_{st}^{L}$ there is a rent deflation despite price-effective transformation. Although this scenario may not be too likely in practice, its possibility highlights the need to include both transformation and rent increases in the subsequent identification scheme. Similarly, any constellation where $P_{st}^{L} > P_{st}^{M}$ returns a negative value suggesting qualitative transformations associated with lower rents. Again, this could be in the context of rent inflation if $P_{st}^{L} > P_{st}^{M} > 1$ or deflation if $1 > P_{st}^{L} > P_{st}^{M}$. Finally, both a Price Index and the Index Gap are utilized to identify potential rental-sector gentrification areas. For this paper the Fisher Index, computed through the double-imputation method is chosen to measure rent increases as it provides the best link to the proposed supply upgrading measurement while being less biased than the characteristics method. Furthermore, the Laspeyres Index and the Mean Index are similarly computed using a double-imputation method before producing the Index Gap.

After computing the respective indices, neighbourhoods that experienced significant

price-effective transformations in housing characteristics and subsequently high rent increases are identified through bivariate mapping. Given a lack of theoretical guidance on what constitutes a high increase, the average development across areas appears to be a reasonable point of reference. Therefore, the terciles of both the Fisher Index and the Index Gap at the end of the observed period are plotted. A subdistrict must be in the top tercile in both dimensions to be considered potentially gentrifying.

THE UNLIKELY CASE OF VIENNA

The case of Vienna will be used to demonstrate the methodological framework outlined in the previous sections. Vienna is traditionally not considered an obvious case for a gentrification study. On the contrary, the city is well-known for its high standard of living and emphasis on social cohesion (Hatz 2008). This is frequently linked to widespread and stable social housing provision which aims to promote social mixing (Premrov & Schnetzer 2023) and a wider price dampening effect (Banabak 2023). Together the communal and the non-profit housing segments provide housing to about half of Viennese residents. However, the social housing segments are not prone to gentrification and thus not subject of the following empirical investigation. Meanwhile, approximately one-third of the population is housed in the private rental market, which has either free market pricing or price controls. The latter is primarily applicable to housing units with a construction permit before 1945.

Nonetheless, the city has undergone significant transformations as well as a significant rise in housing costs over the last decades. After an extended period of population decline, Vienna experienced a renewed period of urban growth in the late 1980s and 1990s, accompanied by geopolitical shifts. The subsequent housing market boom was accompanied by a series of market liberalizations (Kadi & Matznetter 2022), but new construction lagged for a long time. Real estate prices and housing rents have sharply risen, putting Vienna's status as a city capable of providing affordable housing in jeopardy (Kadi *et al.* 2022a). This sparked an increased interest in the relationship between housing market developments and increased socio-spatial inequality, challenging the long-held belief that gentrification has little relevance in Austria's capital (Fassmann & Hatz 2004; Novy 2011).

According to Kadi and Matznetter (2022), new regulations in the price-capped rental market prompted a massive inflow of private capital into the Viennese rental market in an attempt to close the existing rent gap. The primary features of these liberalizations were the introduction of location bonuses and the possibility for time-limited contracts on the condition that the apartment was of the highest equipment standard category. This is said to have resulted in a higher-quality but also higher-priced market. Here both qualitative upgrade and escaping the harsher regulation are appearing intertwined. Meanwhile, Musil *et al.* (2022) argue that historic housing stock transformation is the driver of gentrification in Vienna. The authors contend that property owners seeking to close the value gap push for the legal conversion of old tenement buildings (Zinshäuser) into owner-occupied housing, causing displacement. Such a conversion is required to profit from the recent real estate price boom by selling single apartments. Alternatively, demolition and new construction is a way to fully escape existing price caps, as these are only applicable to the historic housing stock.

Although arguing within different theoretical frameworks, one consensus across these studies is to identify the private rental market as the one housing market segment most vulnerable to gentrification. Yet, Musil *et al.* (2022) strictly limit the claim to the historic housing stock and argue that gentrification processes are highly unlikely in the unregulated segment of the private market because presumably no value gap exists. However, tenure conversion is not the only possible gentrification mechanism. Thus, the Viennese case will be used to demonstrate how the methodological framework outlined in the previous Section allows to identify potential within rental-sector gentrification.

MODELLING VIENNESE HOUSING RENTS

The approach outlined in Section "Identifying Rental-Sector Gentrification" comes with

many benefits, however, it relies on a properly specified hedonic regression model for rent price imputations. To obtain such a model, both general as well as context specific aspects need to be considered. The model's functional form is a good starting point for developing a hedonic pricing model. In most cases, a semi-log model specification is thought to be useful (Malpezzi 2003), but imputations will necessitate a bias correction (Malpezzi *et al.* 1998). However, a log-linear model may still be too restrictive. Thus, Wallace (1996) already suggests explicitly allowing for nonlinearities in shadow price functions. A semiparametric model specification can be used to deal with the issue of potentially nonlinear price responses to changes in continuous characteristics (e.g., Anglin & Gencay 1996) or time trends (Waltl 2016). *Generalized Additive Models*, as summarized by Wood (2017) provide an ideal framework for the estimation of such a semiparametric hedonic model. It allows to model nonlinear shadow price functions as smooth terms through a set of basis-functions. The framework also nests the hierarchical modelling approach, which can be used to introduce random intercepts across different locations. Lee *et al.* (2016) show that a hierarchical approach can help to mitigate the modifiable areal unit problem. However, when random effects are used to introduce varying intercepts between spatial units, their attached distributional and independence assumptions will almost certainly be violated. Thus, Fahrmeir *et al.* (2004) present an alternative approach using Markov-random-fields (*mrf*) to model a spatially structured random effect for discrete spatial data. Instead, of independence, the assumption is that nearby locations are more similar than distant ones.

As indicated by Brunauer *et al.*'s (2010), another important consideration for hedonic modelling is the parameter heterogeneity of flat characteristics across space. For example, having a parking spot included might have a vastly different impact on the total rent in a peripheral location than in a central district. In a hierarchical modelling framework, spatial heterogeneity can also be introduced by interacting a covariate with a random effects term. Following Pedersen *et al.* (2019) global smooths can be combined with group-level smooth terms that allow for local deviations. Thereby, the relationship between the rent and the respective hedonic characteristic in a given place, is allowed to deviate from the city-wide relationship depending on the number of observations available. As previously stated, there is no reason to believe that characteristics shadow prices remain stable over time. Thus, time variation in shadow prices of characteristics should be considered as well. This can be accomplished once more by interacting the coefficients with a smooth time trend. Estimation can be simplified by using fewer basis functions and a stronger penalty on the interaction term compared to the baseline time trend. However, due to the limited number of parameters that can be estimated, the spatial and temporal variations must be treated as additive rather than interactive.

As summarized in Section "The Unlikely Case of Vienna", the private Viennese rental sector can be divided into two segments with distinct pricing mechanisms. While one segment has no price setting restrictions, the regulated segment reflects market developments through complex regulations that include quality-related modifiers and location factors. Thus, the price setting mechanism very much resembles a hedonic model. However, the price effects of different characteristics might vary considerably between segments. Hence, regime heterogeneity in model parameters should be considered. This can be accomplished by using an interaction term between a tenancy law regime indicator and potentially all (non-)linear covariates. Incorporating the regime heterogeneity into the model serves two main purposes. First, if regulations do impact prices considering regime heterogeneity should produce a better prediction quality. Second, it also allows the Index Gap to capture transformations aiming to get rid of existing price caps, such as demolition and new construction, additionally to upgrading through renovation. Furthermore, as Kadi (2015) discusses, location bonuses applicable in the price regulated segment have skyrocketed in some parts of the city since 2010. Thus, location-specific intercepts should not only be allowed to evolve over

time, but they should also be able to grow at different rates while keeping spatial dependencies in mind. This is accomplished by the interaction of the time trend with the subdistrict *mrf*, which results in spatially structured time trends.

The hedonic model is set up based on the previous considerations and estimated using listings data collected and generously made available by the DataScience Service GmbH and TU Wien's Research Unit Urban and Regional Research. These include a total of 107,685 listed apartments available on the private Viennese rental market between 2011 and 2020. The hedonic variables available, their respective model terms and the interactions considered are reported in Table 1. The model is fitted by penalized restricted maximum likelihood estimation and compared against seven nested model versions of lower complexity based on their AIC to avoid overfitting. The best-performing model, however, is also the most complex one, considering both regime and spatial heterogeneity as well as temporal variation. To demonstrate these variations, Figure 1 depicts the area shadow price functions. The upper part of Figure 1 shows the price response function concerning changes in the area of a median flat across the two regulatory regimes and the 23 districts. The lower part of Figure 1 depicts the relationship between area, time, and rent/square metre for both regimes.[1] Although the level of heterogeneity in the shape of the response functions is notable, clear common trends also exist. The overall picture of declining price functions fits findings by Brunauer *et al.*'s (2010). Meanwhile, the lower left graph shows that nearly all sizes

Table 1. *Variables and model terms included in the hedonic regression.*

			Interaction		
Variable	Term	Description	District	Time	Regulated
Rent/sqm (log)	Dependent variable	Gross rent per square metre excl. operating costs			
Area	Smooth	Square metre living space	X	X	X
Age	Smooth	Age of building at time of measurement	X	X	X
Ptind	Smooth	Index measuring public transport time to central places	X	X	X
Time	Smooth	Time difference to first observation in days	X		X
Dist	Random effect	Identifier for each of 23 districs (Bezirke)		X	X
Subdist	Markov random field	Identifier for each of 230 subdistrics (Zählbezirke)		X	X
Rooms	Binary	Identifiers based on the number of rooms within flat	X	X	X
Floor	Binary	Identifiers for five floor level categories	X	X	X
Balcony	Binary	Identifiers for four size categories	X	X	X
Elevator	Binary	Elevator in building	X	X	X
Cellar	Binary	Basement compartment available	X	X	X
Garage	Binary	Garage available	X	X	X
Heating	Binary	Identifiers for district, floor, oven or central heating	X	X	X
Condition	Binary	Identifiers for four condition categories	X	X	X
Sbath	Binary	Second bathroom in flat	X	X	X
Provider	Binary	Identifier for data provider	X	X	X
Regulated	Binary	Full applicability of tenancy law	X	X	

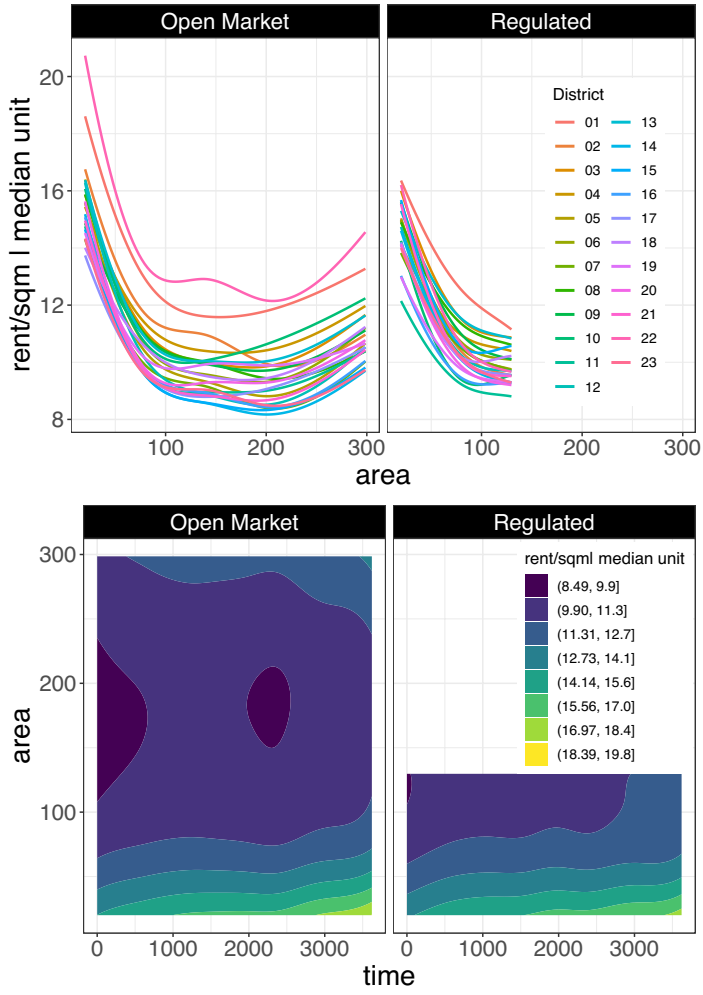

Figure 1. *Area response functions across districts, time and pricing regimes.*

of flats have become more expensive over time. However, smaller units increased more than mid-sized flats and the regulated segment increased earlier, particularly in the 100 m^2 unit range. This highlights the importance of allowing for time variation in the shadow price functions and heterogeneous responses across regulatory regimes.

RESULTS

Finally, the hedonic model is used to impute the rents of a specific subdistrict's housing units repeatedly over time. The Fisher Index and Index Gap are then computed based upon these imputations. If fewer than ten listings are observed within a subdistrict in each period, missing index values are replaced by a simple moving average to produce a continuous time series. The left column of Figure 2 depicts the evolution of the index over time. Each line represents one of the 181 subdistricts considered. Thus 69 of the city's 250 subdistricts were omitted from the analysis, the majority of which are in the city's outskirts with few residents or small private rental shares. The thick black line depicts the median development of subdistricts.

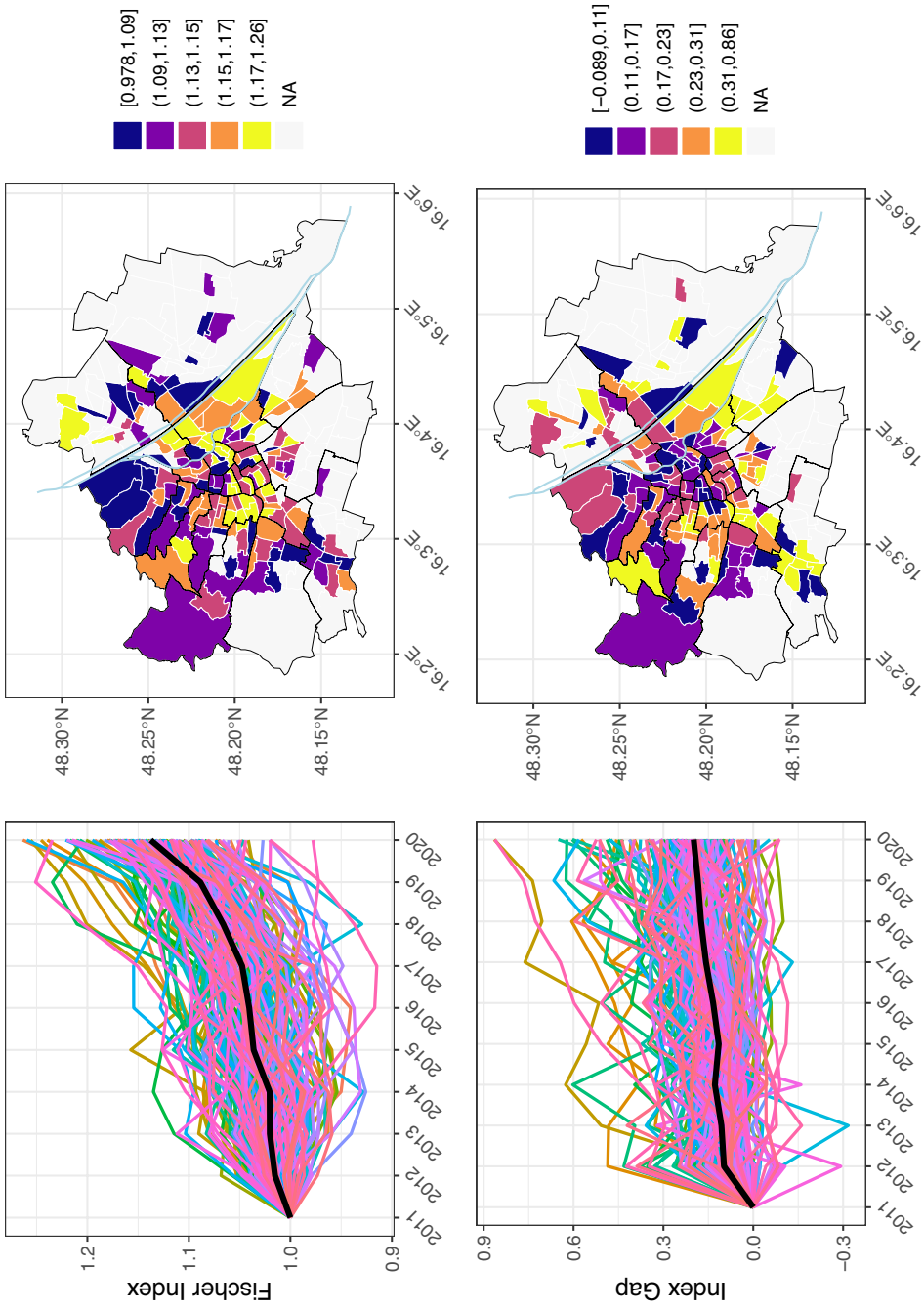

Figure 2. *Fisher Index and Index Gap by subdistrict across time (black line shows median) and space (evaluated in 2020).*

The Fisher Index shows a 14 per cent increase in median, quality-adjusted rent between 2011 and 2020. However, the variation across neighbourhoods is significant, with growth rates ranging from slightly negative to 27 per cent. Following a period of moderate growth, prices begin to rise more rapidly around 2017 in most subdistricts. Meanwhile, the median subdistrict reports an Index Gap of around 20 percentage points. Again, there is substantial variation across subdistricts, ranging from around slightly negative values to 90 percentage points.

After focusing on the indices' temporal development, the right column of Figure 2 depicts the spatial distribution of the index values in 2020. Clusters of subdistricts with hight rent increases can be found all over the city. While one cluster is within the affluent city centre, there also three clusters within typical working-class neighbourhoods. One in the west, one between the 'donaukanal' and the Danube and one in the south-east. Notably, the richer outskirts in the north show rather low rent increases. Meanwhile, the areas east of the Danube are extremely heterogeneous. When the spatial distribution of the Index Gap is examined, an interesting picture emerges. Central areas show rather low transformation levels. However, areas in the west, south-west and south-east indicate high transformation activity. Again, these are traditional working-class neighbourhoods, which contributes significantly to the gentrification narrative. As before, the patterns east of the Danube are less distinct.

Overlaying the information provided by both indices in a bivariate map helps to identify potential gentrification areas. Figure 3 depicts such a bivariate map of rent increase and price-effective transformation. It shows potentially gentrifying neighbourhoods in the south-eastern part of Vienna and along the Danube's western bank. Another cluster is in the southwest. Notably the city centre hardly features any gentrification areas. Similarly, quarters previously studied through qualitative methods such as Karmeliterviertel (Huber 2011) or Gumpendorf (Franz 2011) are not identified as gentrifying, nonetheless exhibit rather high rent increases. However, transformation activities appear to be either low or modest, thus rent gaps might have been closed prior to the study period. The general notion of of outward-moving gentrification dynamics is in line with findings by Musil *et al.*'s (2022).

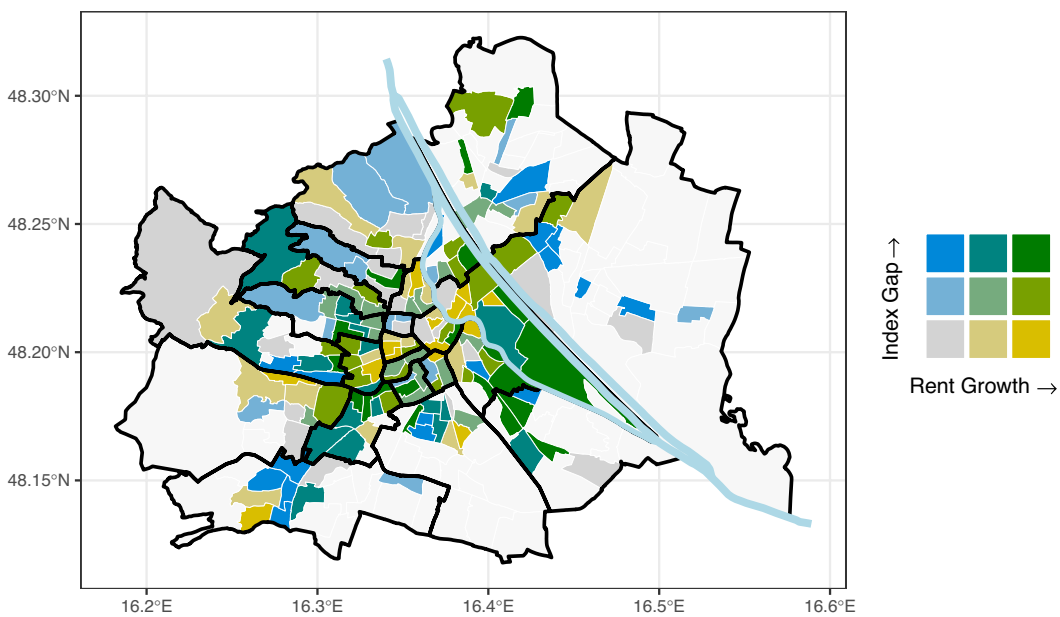

Figure 3. *Bivariate map of Fisher Index and Index Gap; dark green indicates potential gentrification.*

DISCUSSION AND CONCLUSION

This paper advocates for a greater reliance on supply-sided gentrification theories to empirically identify gentrification areas. As outcomes of applied studies are known to be sensitive to the underlying operationalization of gentrification, theoretical justification is particularly important. While rent gaps, as one of the key concepts in gentrification theory, are inherently hard to quantify when the arise, their closing implies measurable outcomes. Thus, I do not follow the likes of López-Morales (2011) in trying to directly measure the rent gap through proxy variables but aim to theoretically link the closing of rent gaps to more tangible outcomes in the local housing market. The proposed rent index approach should therefore not be mistaken for a measurement of ground rent changes which are at the heart of the rent gap theory. Instead, drawing on Bernt's (2022) discussion of the realization problem helps to conceptually relate rent gaps as the theoretical drivers of gentrification to the mechanisms through which gentrification is ultimately realized. Given a certain mode of gentrification, these mechanisms then provide an opportunity to obtain measurable implications of rent gap closings. While this line argumentation is utilized to develop a quantitative approach for identifying rental-sector gentrification; the reasoning is equality applicable to other context but would then necessitate a different set of measurements.

In the case of rental market gentrification, however, these measurable implications are identified as price-effective, qualitative transformations and subsequent rent increases in a neighbourhood. Drawing on the housing price index literature allows to operationalize these dimensions. Based on the well-established hedonic price indices, the paper proposes a novel method for quantifying price-effective, qualitative transformation without relying on subjective judgements of what constitutes a quality upgrade or downgrade. A key strength of the methodology is its ability to both capture gentrification through (luxury-) renovations (Millard-Ball 2000) as well as strategies to circumvent price regulations (Hatz 2021) within a single index, given a properly specified regression model. This is demonstrated for the case of the Viennese private rental market, where both aspects are considered potential drivers of gentrification by the literature (Kadi & Verlič 2019; Hatz 2021). Thereby, this paper provides novel evidence about the geography of rental-sector gentrification in the Viennese post-GFC context.

However, the proposed framework is not solely intended to analyse the Viennese case but also for applications beyond the Austrian capital. Given data availability, any setting where the mechanisms of rental-sector gentrification laid out in Section "Gentrification, Rent Gaps and the Measurement Issue" are at play, could be investigated. This said, many contexts will not meet this criterion. These include among others, gentrification of informal housing which is particularly relevant in the global south (López-Morales 2015), or non-market gentrification through housing allocation mechanisms (Millard-Ball 2000). Since most cities have multiple housing market segments, the framework shall at least be applicable to a certain segment of the housing in most cases.

Another drawback of the methodology is its reliance on proper regression model specification and estimation. Because a one-size-fits-all approach does not exist, modelling decisions were made based on three main factors. These are general recommendations based on the hedonic housing price literature, a review of the literature on the specifics of the Viennese housing market and data-driven model selection. In this case, the hierarchical GAM framework proposed by Pedersen *et al.* (2019) comes in handy because it allows for a lot of potential flexibility, but only if it is properly informed by the data available.

The Viennese case study also features several limitations. First, the data set is rather noisy and does not guarantee that random sampling assumptions. Due to the nature of listing data, it can only measure changes in current market rates. Data covering the entire existing rental housing stock would be preferred but is currently not available. Although estimations based on listing data must be treated with caution, Kolbe *et al.* (2021) show that index construction is indeed their most useful application. Thus, mean indices were compared to data from the Austrian Economic Chamber as a robustness check and found to

be within a similar range. Second, the choice of spatial unit is worth debating. Viennese subdistricts may be too diverse to be considered an ideal unit for measuring neighbourhood transformations. However, the choice of the spatial unit reflects a trade-off between aiming for the smallest scale possible and the number of observations available to produce reliable estimates.

Finally, identifying potential gentrification areas in this paper is rather haphazard. One can argue that the identification should be based on absolute values rather than relative border. However, what constitutes a high level of rent growth or qualitative transformation is always contextual. Regardless, the bivariate mapping approach should serve as a proof of concept. One may even argue for a continuous instead of a dichotomic understanding of gentrification. In this instance, the proposed indices and their spatial patterns can be conveniently interpreted without introducing further delimitations. Furthermore, the taken approach is not able to verify whether gentrification is taking place as it does not measure the implied change in land-users. Nonetheless, focusing on the real estate dimension rather than incorporating the subsequent changes to the socio-economic geography into the identification strategy comes with major advantages. It is, first, closer to the general idea of supply sided gentrification theories, where dynamics arise from and are driven by the real estate sector. It further enables to empirically test the assumed relationship between gentrification drivers and displacement outcomes in a quasi-experimental spirit (e.g., Freeman *et al.* 2016), however, in a more theoretically grounded way. At the same time, it also allows to capture cases where gentrification has negative impacts but does not lead to direct- but other forms of displacement (Marcuse 1986).

ACKNOWLEDGEMENTS

The author would also like to thank Justin Kadi as well as the reviewers for valuable feedback which helped to substantially improve the manuscript. Furthermore, the author wishes to thank the DataScience Service GmbH, as well as Wolfgang Feilmayr for the data provision and the TU Wien Bibliothek for financial support for editing/proofreading and through its Open Access Funding Programme.

Endnote

[1]Note that the price regulated smooths only go up to 130 m^2 corresponding to the applicability of the rent cap.

REFERENCES

Andersson, R. & L.M. Turner (2014), Segregation, Gentrification, and Residualisation: from Public Housing to Market-Driven Housing Allocation in Inner City Stockholm. *International Journal of Housing Policy* 14(1), pp. 3–29.

Anglin, P.M. & R. Gencay (1996), Semiparametric Estimation of a Hedonic Price Function. *Journal of Applied Econometrics* 11(6), pp. 633–648.

Atkinson, R. (2000), Measuring Gentrification and Displacement in Greater London. *Urban Studies* 37(1), pp. 149–165.

Badcock, B. (1989), An Australian View of the Rent Gap Hypothesis. *Annals of the Association of American Geographers* 79(1), pp. 125–145.

Bailey, M.J., R.F. Muth & H.O. Nourse (1963), A Regression Method for Real Estate Price Index Construction. *Journal of the American Statistical Association* 58(304), pp. 933–942.

Banabak, S. (2023), Neighbourhood Rental Market Integration and Private Rent Trajectories – Evidence from the City of Vienna. *International Journal of Urban Sciences* 27(2), pp. 239–259.

Barton, M. (2016), An Exploration of the Importance of the Strategy Used to Identify Gentrification. *Urban Studies* 53(1), pp. 92–111.

Bernt, M. (2022), *The Commodification Gap: Gentrification and Public Policy in London*, Berlin and St. Petersburg: John Wiley & Sons.

Boterman, W.R. & W.P. Van Gent (2014), Housing Liberalisation and Gentrification: The Social Effects of Tenure Conversions in Amsterdam. *Tijdschrift voor Economische en Sociale Geografie* 105(2), pp. 140–160.

Bourassa, S.C. (1990), On "An Australian View of the Rent Gap Hypothesis" by Badcock. *Annals of the Association of American Geographers* 80(3), pp. 458–459.

Bourassa, S.C. (1993), The Rent Gap Debunked. *Urban Studies* 30(10), pp. 1731–1744.

Brunauer, W.A., S. Lang, P. Wechselberger & S. Bienert (2010), Additive Hedonic Regression Models with Spatial Scaling Factors: An Application for Rents in Vienna. *The Journal of Real Estate Finance and Economics* 41(4), pp. 390–411.

Bunten, D.M., B. Preis & S. Aron-Dine (2023), Re-Measuring Gentrification. *Urban Studies*, 00420980231173846.

Christophers, B. (2022), Mind the Rent Gap: Blackstone, Housing Investment and the Reordering of Urban Rent Surfaces. *Urban Studies* 59(4), pp. 698–716.

Clapp, J.M. (2004), A Semiparametric Method for Estimating Local House Price Indices. *Real Estate Economics* 32(1), pp. 127–160.

Clark, E. (1988), The Rent Gap and Transformation of the Built Environment: Case Studies in Malmö 1860–1985. *Geografiska Annaler: Series B, Human Geography* 70(2), pp. 241–254.

Clark, E. (1992), On Gaps in Gentrification Theory. *Housing Studies* 7(1), pp. 16–26.

Clark, E. (1995), The Rent Gap Re-Examined. *Urban Studies* 32(9), pp. 1489–1503.

Clark, E. & A. Pissin (2020), Potential Rents vs. Potential Lives. *Environment and Planning A: Economy and Space* 55(6), pp. 1485–1505.

Clarke, E. (2005), The Order and Simplicity of Gentrification – A Political Challenge. *In*: R. Atkinson & G. Bridge, (eds.), *Gentrification in a Global Context: The New Urban Colonialism*, pp. 256–264. London: Routledge.

Eurofound (2023), *Unaffordable and Inadequate Housing in Europe*, Luxembourg: Publications Office of the European Union.

Fahrmeir, L., T. Kneib & S. Lang (2004), Penalized Structured Additive Regression for Space-Time Data: A Bayesian Perspective. *Statistica Sinica* 14(3), pp. 731–761.

Fassmann, H. & G. Hatz (2004), Fragmentierte stadt? sozialräumliche struktur und wandel in wien, 1991–2001. *Mitteilungen der Österreichischen Geographischen Gesellschaft* 146, pp. 61–92.

Finio, N. (2022), Measurement and Definition of Gentrification in Urban Studies and Planning. *Journal of Planning Literature* 37(2), pp. 249–264.

Franz, Y. (2011), Gentrification in Vienna. *In*: V. Szirmai, ed., *Urban Sprawl in Europe*, pp. 189–208. Budapest: Aula Kiadó.

Freeman, L. & F. Braconi (2004), Gentrification and Displacement New York City in the 1990s. *Journal of the American Planning Association* 70(1), pp. 39–52.

Freeman, L., A. Cassola & T. Cai (2016), Displacement and Gentrification in England and Wales: A Quasi-Experimental Approach. *Urban Studies* 53(13), pp. 2797–2814.

Ghertner, D.A. (2015), Why Gentrification Theory Fails in 'Much Of The World'. *City* 19(4), pp. 552–563.

Glass, R. (1964), Aspects of Change. *In*: J. Brown-Saracino, ed., *The Gentrification Debates: A Reader*, pp. 19–30. New York: Routledge.

Goetzmann, W.N. & M. Spiegel (1997), A Spatial Model of Housing Returns and Neighborhood Substitutability. *The Journal of Real Estate Finance and Economics* 14(1), pp. 11–31.

Haila, A. (2015), *Urban Land Rent*, 1st edition. Chichester: Wiley. https://doi.org/10.1002/9781118827611.

Hammel, D.J. (1999), Gentrification and Land Rent: A Historical View of the Rent Gap in Minneapolis. *Urban Geography* 20(2), pp. 116–145.

Hamnett, C. & W. Randolph (1984), The Role of Landlord Disinvestment in Housing Market Transformation: An Analysis of the Flat Break-Up Market in Central London. *Transactions of the Institute of British Geographers* 9(3), pp. 259–279.

Hatz, G. (2008), Vienna. *Cities* 25(5), pp. 310–322.

Hatz, G. (2021), Can Public Subsidized Urban Renewal Solve the Gentrification Issue? Dissecting the Viennese Example. *Cities* 115, 103218.

Hedin, K., E. Clark, E. Lundholm & G. Malmberg (2012), Neoliberalization of Housing in Sweden: Gentrification, Filtering, and Social Polarization. *Annals of the Association of American Geographers* 102(2), pp. 443–463.

Hill, R.J. (2013), Hedonic Price Indexes for Residential Housing: A Survey, Evaluation and Taxonomy. *Journal of Economic Surveys* 27(5), pp. 879–914.

Hill, R.J. & D. Melser (2008), Hedonic Imputation and the Price Index Problem: An Application to Housing. *Economic Inquiry* 46(4), pp. 593–609.

Hochstenbach, C. & R. Ronald (2020), The Unlikely Revival of Private Renting in Amsterdam: Re-Regulating a Regulated Housing Market. *Environment and Planning A: Economy and Space* 52(8), pp. 1622–1642.

Holm, A. & G. Schulz (2016), Gentrimap: Ein messmodell für gentrification und verdrängung. *In*: I. Helbrecht, ed., *Gentrifizierung in Berlin. Verdrängungsprozesse und Bleibestrategien*, pp. 287–318. Bielefeld: Transcript Verlag.

Huber, F.J. (2011), Sensitive Urban Renewal or Gentrification? The Case of the Karmeliterviertel in Vienna. *In*: *Everyday Life in the Segmented City*, Vol. 11, pp. 223–239. Leeds: Emerald Group Publishing Limited.

Kadi, J. (2015), Recommodifying Housing in Formerly "Red" Vienna? *Housing, Theory and Society* 32(3), pp. 247–265.

Kadi, J., S. Banabak & A. Schneider (2022a), Widening Gaps? Socio-Spatial Inequality in the "Very" European City of Vienna since the Financial Crisis. *Cities* 131, 103887.

Kadi, J., S. Banabak & A. Schneider (2022b), Eine indikatorbasierte identifizierungvon gentrifizierungsgebieten in wien. *Wirtschaft und Gesellschaft* 48(1), pp. 23–57.

Kadi, J. & W. Matznetter (2022), The Long History of Gentrification in Vienna, 1890–2020. *City* 26(2–3), pp. 450–472.

Kadi, J. & M. Verlič (2019), Gentrifizierung am privaten wiener mietwohnungsmarkt. *In*: J. Kadi & M. Verlič, (eds.), *Gentrifizierung in Wien: Perspektiven aus Wissenschaft, Praxis und Politik*, pp. 35–50. Vienna: Arbeiterkammer Wien.

Kolbe, J., R. Schulz, M. Wersing & A. Werwatz (2021), Real Estate Listings and their Usefulness for Hedonic Regressions. *Empirical Economics* 61(6), pp. 3239–3269.

Lee, G., D. Cho & K. Kim (2016), The Modifiable Areal Unit Problem in Hedonic House-Price Models. *Urban Geography* 37(2), pp. 223–245.

Lees, L., T. Slater & E. Wyly (2008), *Gentrification*, New York: Routledge.

Ley, D. (1986), Alternative Explanations for Inner-City Gentrification: A Canadian Assessment. *Annals of the Association of American Geographers* 76(4), pp. 521–535.

Liu, C., D. O'Sullivan & G.L.W. Perry (2018), The Rent Gap Revisited: Gentrification in Point Chevalier, Auckland. *Urban Geography* 39(9), pp. 1300–1325.

López-Morales, E. (2011), Gentrification by Ground Rent Dispossession: The Shadows Cast by Large-Scale Urban Renewal in Santiago de Chile. *International Journal of Urban and Regional Research* 35(2), pp. 330–357.

López-Morales, E. (2015), Gentrification in the Global South. *City* 19(4), pp. 564–573.

López-Morales, E. (2016), Assessing Exclusionary Displacement through Rent Gap Analysis in the High-Rise Redevelopment of Santiago, Chile. *Housing Studies* 31(5), pp. 540–559.

López-Morales, E., C. Sanhueza, N. Herrera, S. Espinoza & V. Mosso (2023), Land and Housing Price Increases Due to Metro Effect: An Empirical Analysis of Santiago, Chile, 2008–2019. *Land Use Policy* 132, 106793.

Maloutas, T. (2012), Contextual Diversity in Gentrification Research. *Critical Sociology* 38(1), pp. 33–48.

Malpezzi, S. (2003), Hedonic Pricing Models: A Selective and Applied Review. *Housing Economics and Public Policy* 1, pp. 67–89.

Malpezzi, S., G.H. Chun & R.K. Green (1998), New Place-to-Place Housing Price Indexes for US Metropolitan Areas, and their Determinants. *Real Estate Economics* 26(2), pp. 235–274.

Marcuse, P. (1986), Abandonment, Gentrification and Displacement: The Linkages in New York City. *In*: N. Smith & P. Williams, (eds.), *Gentrification of the City*, pp. 153–177. Boston, MA: Allen and Unwin.

Millard-Ball, A. (2000), Moving Beyond the Gentrification Gaps: Social Change, Tenure Change and Gap Theories in Stockholm. *Urban Studies* 37(9), pp. 1673–1693.

Musil, R., F. Brand, H. Huemer & M. Wonaschütz (2022), The Zinshaus Market and Gentrification Dynamics: The Transformation of the Historic Housing Stock in Vienna, 2007–2019. *Urban Studies* 59(5), pp. 974–994.

Novy, A. (2011), Unequal Diversity – On the Political Economy of Social Cohesion in Vienna. *European Urban and Regional Studies* 18(3), pp. 239–253.

Pace, R.K., R. Barry, J.M. Clapp & M. Rodriquez (1998), Spatiotemporal Autoregressive Models of Neighborhood Effects. *The Journal of Real Estate Finance and Economics* 17, pp. 15–33.

Pedersen, E.J., D.L. Miller, G.L. Simpson & N. Ross (2019), Hierarchical Generalized Additive Models in Ecology: An Introduction with MGCV. *PeerJ* 7, e6876.

Premrov, T. & M. Schnetzer (2023), Social Mix and the City: Council Housing and Neighbourhood Income Inequality in Vienna. *Urban Studies* 60(4), pp. 752–769.

Reades, J., J. De Souza & P. Hubbard (2019), Understanding Urban Gentrification through Machine Learning. *Urban Studies* 56(5), pp. 922–942.

Slater, T. (2015), Planetary Rent Gaps. *Antipode* 49, pp. 114–137. https://doi.org/10.1111/anti.12185.

Smith, N. (1979), Toward a Theory of Gentrification a Back to the City Movement by Capital, Not

People. *Journal of the American Planning Association* 45(4), pp. 538–548.

Smith, N. (1996), Of Rent Gaps and Radical Idealism: A Reply to Steven Bourassa. *Urban Studies* 33(7), pp. 1199–1203.

Van Criekingen, M. (2010), 'Gentrifying the Re-Urbanisation Debate', Not Vice Versa: The Uneven Socio-Spatial Implications of Changing Transitions to Adulthood in Brussels. *Population, Space and Place* 16(5), pp. 381–394.

Wachsmuth, D. & A. Weisler (2018), Airbnb and the Rent Gap: Gentrification through the Sharing Economy. *Environment and Planning A: Economy and Space* 50(6), pp. 1147–1170.

Walks, R.A. & R. Maaranen (2008), Gentrification, Social Mix, and Social Polarization: Testing the Linkages in Large Canadian Cities. *Urban Geography* 29(4), pp. 293–326.

Wallace, N.E. (1996), Hedonic-Based Price Indexes for Housing: Theory, Estimation, and Index Construction. *Economic Review-Federal Reserve Bank of San Francisco* 3, pp. 34–48.

Waltl, S.R. (2016), A Hedonic House Price Index in Continuous Time. *International Journal of Housing Markets and Analysis* 9(4), pp. 648–670.

Wood, S.N. (2017), *Generalized Additive Models: An Introduction with R*, Boca Raton: CRC Press.