The impact of COVID-19 on real estate markets in Germany

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Abstract

The COVID-19 pandemic has disrupted established urban patterns. The literature on the impact of the pandemic on the US housing market has shown a significant increase in the demand for suburban housing, resulting in a considerable increase in suburban prices compared to those in the city center (termed the "donut effect"). However, the German housing market did not experience such drastic changes. To examine price and rent adjustments during the pandemic, we analyze detailed housing data and find little evidence supporting the donut effect seen in the US. Apartment rents increase in suburban areas, while house prices do not change significantly. Examining the role of amenities, we find no explanation for price and rent differences between the central business district (CBD) and suburbs. The differences between the two markets may be attributed to cultural and structural distinctions. Our analysis, which includes data on population patterns and migration behavior, reveals that residents in Germany exhibit a slower-moving trend. Our findings remain robust across different settings and subsets of cities.

JEL codes: R23, R31
Keywords: House prices, Rent gradient, COVID-19, Donut effect, Urban amenities

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1 Introduction

The key prediction of the Alonso (1964), Mills (1967), Muth (1969) (AMM) model is the rent gradient, which establishes a negative relationship between house prices or rents and distance from the city center. Lower commuting costs, higher amenities, and other agglomeration benefits justify higher prices in city centers than in the suburbs (Brueckner, 1987). However, following the outbreak of the COVID-19 pandemic, commuting costs have fallen or been eliminated because of the possibility of working from home (WFH), and urban consumption amenities were largely inaccessible because of strict lockdown measures. This may have reduced the demand for housing in city centers and dense neighborhoods within cities. Furthermore, there is strong evidence that the pandemic has caused significant population movements away from these areas to suburbs and low-density neighborhoods. However, much of the existing literature exclusively studies the US housing market (see, for example, Gupta et al., 2022; Liu and Su, 2021; Ramani and Bloom, 2021; and Duranton and Handbury, 2023). In this paper, we study how the COVID-19 pandemic and urban amenities affected real estate markets within and across German cities. In addition to adding the German experience to the current literature, our contribution is emphasizing the role of amenities. In the US literature, the WFH channel is championed as a potential explanation for changes in the housing market during the pandemic. The discussion of amenities is less detailed, although it is considered as a potential mechanism. We focus on house prices and apartment rents comparing them before and after the pandemic to document changes in the housing market.

We develop a simple spatial equilibrium model to analyze the impact of the COVID-19 pandemic on housing demand in densely-populated central locations versus low-density suburban areas within cities. Our model builds upon previous research by Liu and Su (2021), Ramani and Bloom (2021), and Duranton and Handbury (2023), which primarily focuses on commuting costs and remote work's impact on housing demand in high-density central locations. However, the literature is limited on how the pandemic may have affected people's preferences for local amenities and its subsequent impact on housing demand. This paper aims to highlight the pandemic's impact on housing demand through the revaluation of amenities between consumption and environmental amenities. The model shows how commuting costs and amenities determine the spatial distribution of housing prices in an equilibrium setting. It predicts that housing demand will shift from the CBD to the suburbs due to the increased value of suburban amenities, decreased value of consumption amenities, and the fall of commuting costs due to the rise of remote work arrangements during the pandemic. The shift in the importance of amenities is expected to lead to a decline in CBD prices and an increase in suburban prices.

Our empirical strategy follows these predictions of housing demand reallocations. To test these predictions, we utilize data on house prices and apartment rents from the German housing market and amenities data from OpenStreetMap (OSM).

We find that, from March 2020 to March 2021, the slopes of the gradients have changed by 0.005 and 0.010 for prices and rents, respectively. Although the positive changes in the slopes show a flattening of the gradients, the magnitudes are small to suggest that the pandemic has caused the same clear and strong flattening of gradients in Germany as observed in the US. For comparison, Gupta et al. (2022) found the change in slope for price 0.012, and the slope change for rents 0.032, from December 2019 to December 2020, for the US. Put differently, while for the US the decrease in the slopes of the price and rent gradients are 11.65% and 100.00%, for Germany, they are 9.38% and 22.40%. Thus, it is not evident that the pandemic has caused the same strong flattening of gradients in Germany as observed in the US. There appear to be only minor adjustments to the slopes of the gradients.

Overall, our results show little evidence of the flattening of the bid-rent curve in the German housing market. This result is robust to spatial subdivision into large, medium, or small cities. Amenities, our main mechanism, do not explain the donut effect. Based on our data, we do not observe a significant shift in the importance of consumption amenities towards environmental amenities, especially at the monthly level. We also find that residents in Germany did not move more than before the pandemic. We did not observe population movements within and between cities during the pandemic. Overall, according to our results, the German housing market has not been as disrupted as in the US by the COVID-19 pandemic. The differences may be attributed to institutional and cultural differences. The German housing market has proven to be fairly stable and resistant to disruption, as detailed in the Appendix.

The remainder of the paper is structured as follows. Section 2 provides a summary of the literature on the impact of the pandemic on housing markets and highlights key findings. Section 3 presents a simple theoretical model that guides our empirical strategy. Section 4 discusses the data sources and presents stylized facts. Section 5 presents our main findings, and Section 6 concludes the paper.

2 Literature Review

Our work expands on the increasing volume of research exploring the intersection of the COVID-19 pandemic, remote work practices, amenities, and real estate markets. Several studies demonstrate that the pandemic has induced a redistribution of housing demand, population, and economic activities within cities, shifting from city centers and densely populated areas to suburban and less dense regions (Gupta et al., 2022; Liu and Su, 2021; Ramani and Bloom, 2021). Duranton and Handbury (2023) complement these studies by providing a comprehensive review of the effects of the pandemic and the rise of work from home (WFH) in cities, employing a version of the monocentric city model. The authors highlight the "commuting dividend" and "home office tax" effects of WFH, noting short-term downtown housing price drops, subsequent rebounds, and continued suburban price rises. They connect the pandemic and WFH trends to changes in housing prices and commuting patterns and discuss potential challenges for maintaining vibrant downtown economies due to the loss of daytime workers and the potential impact on agglomeration benefits.

These studies collectively show how the pandemic flattened the bid rent curve in US metropolitan areas, causing house prices and rents in city centers to decrease while increasing in the suburbs. This led to a population shift from central urban areas to suburban locales. These changes in housing demand and population are most noticeable in metropolitan regions characterized by a high proportion of remote workers, strict lockdown measures, and inelastic housing supply (Gupta et al., 2022). The decrease in demand in densely populated and central urban neighborhoods is attributed to the diminished need for proximity to jobs that can be done remotely and the reduction in the appeal of urban amenities (Liu and Su, 2021; Ramani and Bloom, 2021).

This urban-to-suburban shift, dubbed the "donut effect" by Ramani and Bloom (2021), is not observed in smaller cities or movements across cities. The intercity relocations from larger, denser cities to smaller or less populated ones are also less substantial, attributed in part to the emergence of hybrid work patterns in the post-pandemic period (Liu and Su, 2021; Ramani and Bloom, 2021).

The literature strongly supports a positive relationship between population density and the potential for WFH and the movement of workers with high WFH potential away from the CBD during the pandemic in the US Althoff et al. (2022). Therefore, the question is how significant is WFH in the German context. Overall, the COVID-19 pandemic had a greater impact on the labor markets of major German cities compared to other regions, which experienced a faster recovery(Hamann et al., 2023). Thus, similar to the US, the effects seem to be present in large cities in Germany. Furthermore, Alipour et al. (2023) shows that about 56% of jobs in Germany can be performed (at least partially) from home, although there is great heterogeneity across occupational groups. The increase in WFH has also led to a shift in consumption patterns away from the CBDs to the suburbs, where people now also work from (Alipour et al., 2022). However, WFH is a much less valued job attribute than other job benefits. German workers report that they are willing to give up about 5% of their income for the opportunity to work from home two days a week. The effects for other job benefits, such as additional paid days off, are two to three times greater (Nagler et al., 2022).

The other channel discussed for explaining the changes in real estate markets during the pandemic, albeit to a lesser extent, is the change in the valuation of (urban) amenities. The literature generally documents a positive impact of amenities on rents and prices (see, for example, Cho et al., 2006; Conway et al., 2010; Schäfer and Hirsch, 2017; Kolbe and Wüstemann, 2015). This applies to both environmental amenities, such as green spaces and water bodies, and consumption amenities, like fancy restaurants, cafes, and tourist attractions. However, these studies also show that the effect of amenities on house prices is typically smaller than the effect of structural variables such as the unit's size or the building's age. The key question for our study is whether the valuation of amenities changed with the pandemic. However, the literature is rather limited on this specific question. van Vuuren (2023) finds that house prices in amenity-rich areas decreased during the pandemic (compared to less amenity-rich areas) and that there is a reduction in willingness to pay for such amenities. Cheung and Fernandez (2021) examines the impact of amenities on house prices in Auckland (New Zealand) and finds that the premium paid for the enjoyment of amenities is reduced or even negative after the pandemic. They attribute this finding to changes in perceptions of open space, which may signal some risk following the experience of COVID-19. Another study by Batalha et al. (2022) shows that prices and rents in Lisbon and Porto, Portugal, decrease in tourist areas. However, tourist attractions may be a special type of amenity, as they are also typically associated with business activities. Overall, the evidence so far, however limited, points to a negative change in amenities due to the pandemic.

To the best of our knowledge, no study explicitly addresses the potential changes in the valuation of amenities during the pandemic in Germany. Therefore, this study emphasizes this second channel to explain changes in the housing market during the pandemic. An open question with respect to both WFH and amenities is whether developments during the pandemic caused population movements that led to structural changes in the German housing market. We investigate this question by analyzing post-pandemic population levels using county-level migration statistics.

3 Methodology

This section presents a simple spatial equilibrium model that guides our expectations of the impact of the COVID-19 pandemic on housing demand in densely populated central locations versus low-density remote locations. Our model closely follows prior work by Liu and Su (2021), Ramani and Bloom (2021), and Duranton and Handbury (2023). While the literature focuses on the mediating role of commuting costs and the prevalence of WFH on demand for housing in high-density central locations, there is a lack of understanding regarding how the pandemic may have changed people's preferences for local amenities and its subsequent impact on housing demand.

We aim to contribute to the literature by emphasizing the impact of the pandemic on housing demand through the channel of amenity revaluation. We study this with two components of amenities: environmental amenities, such as green spaces and water bodies, and consumption amenities, such as cafes, bars, museums, etc. (see Section 4.3 for the details). This paper investigates the impact of changes in the accessibility of local amenities caused by the pandemic on house prices and rents. The theoretical model supports our empirical approach by providing predictions on housing demand reallocation, which we verify using house price data from the German housing market and amenities data from OpenStreetMap (OSM).

3.1 Model

Following Duranton and Handbury (2023), we consider a city that produces its consumption good in its downtown, often called the central business district (CBD), where all jobs are concentrated. Residents derive utility from the consumption good, denoted q, sold at a fixed price of one, and housing, denoted h. Every location in the city is indexed by d, representing the distance to the CBD. Housing is supplied competitively across the city from the CBD (where $d = 0$) to the urban fringe (where $d = \bar{d}$). We take the housing supply and its distribution across the city as given.

Residents' preferences are represented by a utility function $u(h, q, A(d))$, where A represents local amenities, which is a function of d. We assume that utility is increasing in all three arguments and is strictly quasi-concave.

A resident living at a distance d from the CBD incurs a commuting cost of td^{τ}, where $\tau < 1$. This implies that commuting costs increase disproportionately with distance.[1] Let $r(d)$ denote the rental price of floorspace per unit of housing at a distance d from the CBD. The resident's budget constraint can be expressed as

[1]Following Duranton and Handbury (2023), we adopt the assumption that commuting costs increase non-linearly with distance to the CBD d. This specification aligns with the real-world commuting data, which indicates that households' distance to work and total vehicle-kilometers driven increase less than proportionately with the distance to the CBD.

$w - td^\tau = r(d)h + q$, where w represents income.

We assume a Cobb-Douglas form for the utility function:

$$u(h, q, A) = h^\alpha q^{1-\alpha} A(d), \tag{1}$$

where α reflects the importance of housing in utility, with $\alpha \in (0, 1)$.

Solving the utility maximization problem subject to the budget constraint yields the demand functions for housing and the consumption good:

$$h^* = \alpha \frac{w - td^\tau}{r(d)}, \quad q^* = (1 - \alpha)(w - td^\tau) \tag{2}$$

Note that these solutions do not include the effect of amenities A directly. In this simplified model, amenities affect utility but do not directly affect the budget constraint. Thus, they do not appear in the optimal choice of consuming h and q. However, they affect the location choice of the resident and thus the price of housing $r(d)$, which indirectly affects housing and consumption choices.

3.1.1 Spatial equilibrium

Assuming that all residents in the city are homogeneous in incomes and preferences and are freely mobile within the city, the concept of "spatial equilibrium" states that they should attain the same level of utility, represented by $\bar{u}$, throughout the city. Quantitatively, this can be expressed as:

$$u(h, q, A(d)) = h^\alpha q^{1-\alpha} A(d) = \bar{u} \tag{3}$$

That means, residents that live in the CBD $d = 0$ and in the suburb $d = \bar{d}$, enjoy the same level of utility:

$$u_{\text{cbd}} = u_{\text{suburb}} \tag{4}$$

The spatial equilibrium condition implies that residents have no utility gains by moving from one location to another within the city. Therefore, the total derivative of utility with respect to distance must be zero.

We obtain the equilibrium price difference between the CBD and the suburb by inserting the respective distances and using the optimal choice values in Equation 2.

$$
\begin{aligned}
h_{\text{cbd}}^{\alpha} \cdot q_{\text{cbd}}^{1-\alpha} \cdot A(0) = h_{\text{suburb}}^{\alpha} \cdot q_{\text{suburb}}^{1-\alpha} \cdot A(\bar{d}) \\
\frac{h_{\text{cbd}}^{\alpha}}{h_{\text{suburb}}^{\alpha}} \frac{q_{\text{cbd}}^{1-\alpha}}{q_{\text{suburb}}^{1-\alpha}} &= \frac{A(\bar{d})}{A(0)} \\
\left(\frac{w}{w - t\bar{d}^{\tau}} \frac{r(\bar{d})}{r(0)}\right)^{\alpha} \left(\frac{w}{w - t\bar{d}^{\tau}}\right)^{1-\alpha} &= \frac{A(\bar{d})}{A(0)} \\
\left(\frac{r(\bar{d})}{r(0)}\right)^{\alpha} &= \frac{w - t\bar{d}^{\tau}}{w} \frac{A(\bar{d})}{A(0)} \\
\implies \frac{r(\bar{d})}{r(0)} &= \left(\frac{w - t\bar{d}^{\tau}}{w} \frac{A(\bar{d})}{A(0)}\right)^{\frac{1}{\alpha}}
\end{aligned}
$$

Taking the logarithm yields the equilibrium percentage difference between the CBD and the suburb prices:

$$
\ln\left(\frac{r(0)}{r(\bar{d})}\right) = \frac{1}{\alpha} \ln\left(\frac{w}{w - t\bar{d}^{\tau}}\right) + \frac{1}{\alpha} \ln\left(\frac{A(0)}{A(\bar{d})}\right) \tag{5}
$$

This equation shows that the relative commute cost and amenity levels determine the price difference. Higher amenities or lower commuting costs for the suburb (due to lower t) increase the price in the suburb relative to the CBD, and the price difference decreases, all else being equal.

3.1.2 Introducing amenity shock

The COVID-19 pandemic has caused a WFH shock and a potential revaluation of amenities. Since the beginning of the pandemic, access to consumption amenities has been largely restricted due to strict lockdown and social distancing measures. Moreover, the virus has been spreading rapidly, resulting in higher infection and death rates in high-density central locations within cities. It is crucial to capture these local shocks to amenities to understand the effects of the pandemic on housing demand.

We build upon the above part by providing more specific information about amenities to introduce an amenity shock. In the pre-pandemic time, amenity enters the utility of a representative resident as $U(h, q, A(d)) = h^{a} \cdot q^{1-\alpha} \cdot (\kappa A_c + \varepsilon A_e)$ where A_c and A_e denote consumption and environmental amenities. The parameters κ and ε are weights that represent the relative importance placed by the resident on each type of amenity, respectively. During the pandemic, the relative importance of consumption and environmental amenities may change due to factors such as the closure of establishments in the CBD or the increased preference for open spaces in the suburb. We consider this shift by modifying the utility function during the pandemic to U', which now has $\kappa' A_C + \varepsilon' A_E$ in the amenity component, where $\kappa' < \kappa$ represents the decreased weight of consumption amenities in the CBD due to closures and restrictions, and $\varepsilon' > \varepsilon$ represents the increased weight of environmental amenities in the suburb due to greater emphasis on open space and nature during lockdowns or WFH periods. The utility maximization problem now involves comparisons between altered utilities of living in or close to the CBD and further away. Residents reevaluate their preferences based on these changes in amenities and other considerations such as moving and commuting costs. As a result, we may observe a shift in housing demand from the CBD towards the suburb during the pandemic period.

Furthermore, it is important to highlight that consumption amenities, such as access to fancy restaurants, shops, and entertainment venues, are highly concentrated in the CBD, and their availability is limited in the suburbs. In contrast, environmental amenities, such as open space, clean air, and quieter neighborhoods, are scarce in the CBD but more abundant in the suburbs. The amenity function, as defined below, captures this heterogeneity:

$$A(d) = A_c(d) + A_e(d) = a_c \cdot e^{-bd} + a_e \cdot e^{\phi d}, \tag{6}$$

where a_c and a_e represent the maximum (minimum) consumption (environmental) amenity levels in the city at the CBD, and the parameters b and ϕ determine how fast each amenity type changes with distance from the CBD.

For simplicity, suppose $A_c(0) \equiv A_e(\bar{d}) = a_e e^{\phi \bar{d}}$. That means that the highest level of consumption amenities is equivalent to the highest level of environmental amenities. Plugging the amenity function into Equation 5, we get

$$\begin{aligned} \ln \frac{r(0)}{r(\bar{d})} &= \frac{1}{\alpha}\left(\ln \frac{w}{w - t\bar{d}^{\tau}} + \ln \frac{\kappa \cdot a_c + \varepsilon \cdot a_e}{\kappa \cdot a_c \cdot e^{-b\bar{d}} + \varepsilon \cdot a_e \cdot e^{\phi \bar{d}}} \right) \\ &= \frac{1}{\alpha}\left(\ln \frac{w}{w - t\bar{d}^{\tau}} + \ln \frac{\kappa \cdot e^{\phi \bar{d}} + \varepsilon}{e^{\phi \bar{d}}(\kappa \cdot e^{-b\bar{d}} + \varepsilon)} \right). \end{aligned} \tag{7}$$

Equation 7 indicates that the price difference is a function of the weights residents give to amenities. Specifically, the price difference is smaller when residents place greater importance on environmental amenities. In addition, as residents move farther from the CBD, the availability of consumption amenities decreases while the availability of environmental amenities increases.

Taking derivatives of the left-hand side of the equation with respect to κ and ε provides the change in the price differential as a function of a change in the weights assigned to consumption and environmental amenities, respectively.

Specifically, we have:

$$\begin{aligned}\partial \ln \frac{r(0)}{r(\bar{d})} &= \frac{1}{\alpha}\left(\frac{e^{\phi\bar{d}}}{\kappa \cdot e^{\phi\bar{d}} + \varepsilon} - \frac{e^{-b\bar{d}}}{\kappa \cdot e^{-b\bar{d}} + \varepsilon \cdot e^{\phi\bar{d}}}\right) \cdot \partial\kappa \\ &= \frac{1}{\alpha}\left(\frac{1}{\kappa + \varepsilon} - \frac{e^{\phi\bar{d}}}{\kappa \cdot e^{-b\bar{d}} + \varepsilon \cdot e^{\phi\bar{d}}}\right) \cdot \partial\varepsilon\end{aligned}$$

These equations describe how a small change in the relative importance of consumption or environmental amenities affects the log price/rent differential between the CBD and the suburb. If $\kappa' < \kappa$ (i.e., the relative importance of consumption amenities decreases), then $\partial \ln(r(0)/r(\bar{d}))/(\partial\kappa) < 0$, indicating that the price/rent differential will decrease. On the other hand, if $\varepsilon' > \varepsilon$ (i.e., the relative importance of environmental amenities increases), then $\partial \ln(r(0)/r(\bar{d}))/(\partial\varepsilon) < 0$, similarly indicating that the price/rent differential will decrease. Thus, these results suggest that a pandemic-induced decrease in the relative importance of consumption amenities (along with a simultaneous increase in the relative importance of environmental amenities) will decrease the price/rent differential between the CBD and the suburb. This supports the intuitive concept of the "donut effect", where housing demand may shift from the CBD to the suburbs during a pandemic as people prioritize environmental amenities more.

This simple model demonstrates how commuting costs and amenities determine residential choices and the spatial distribution of housing prices in an equilibrium setting. It predicts that housing demand will shift from the CBD to the suburbs due to the increased value of suburban amenities, decreased value of consumption amenities, and the rise of remote work arrangements during the pandemic. This shift is expected to cause a decline in CBD prices and an increase in suburban prices. Before the pandemic, when remote work was not prevalent, commuting costs were high, and there was a strong preference for consumption amenities, CBD house prices and rents were higher. However, during the pandemic, with widespread remote work and a greater preference for suburban amenities, the price and rent differences between CBD and suburbs become smaller, resulting in declining CBD prices and rents and increasing suburban prices and rents.

3.2 Empirical Strategy

The model's theoretical prediction in Section 3.1 suggests that changes in commuting costs, central location attractiveness, and suburban amenities value lead to a reallocation of housing demand. There is a high concentration of consumption amenities near the CBD, while suburbs offer abundant environmental amenities. Due to the rapid spread of the COVID-19 virus in high-density areas during the pandemic, strict lockdown policies were enforced, limiting access to consumption amenities. Consequently, people may have started valuing consumption amenities less since they are inaccessible and placing more importance on suburban amenities, causing high demand for suburban housing. This study aims to empirically examine if this holds true for the German housing market.

We test these predictions by analyzing changes in price and rent gradients following the pandemic. In line with the "flattening the curve" literature for the US, we expect house prices and rents to fall in central locations and rise in suburbs during the pandemic in Germany, at least in big cities. To do so, we estimate the slope of the price and rent gradients for each month from 2017 to 2021.

To identify the impact of the pandemic on property prices in the CBD versus suburbs, like Gupta et al. (2022), we specify the following regression equation:

$$\ln p_{it} = \mathbf{x}_i'\beta + \delta_t(t \times \ln dist_i) + \alpha_t + \alpha_i + e_{it}, \tag{8}$$

where $\ln p_{it}$ is the logarithm of average hedonic price or rent (described in Section 4.1) in zip code i, at time (i.e., month-year) t, $\ln dist_i$ is the logarithm of the (Euclidean) distance between the centroid of the zip code i and its CBD.[2] We control for zip code level cross-sectional characteristics $\mathbf{x}_i$.[3] Finally, time and LMR fixed effects α_t and α_i are included to capture time trends and unobserved regional characteristics.

δ_t, the coefficient of the interaction term between time t and distance, estimates the slope of the gradient for each month. We anticipate the estimates for this coefficient to be negative, as the AMM model predicts, and the magnitude to decrease in absolute terms during the pandemic, indicating a flattening of the

[2] We define the CBD as the geographical center in the labor market region, as defined by Kosfeld and Werner (2012), weighted by the number of inhabitants. For more details, refer to Section 4.2.

[3] The zip code controls are the logarithm of the total purchasing power, average household size, the share of households with German background, and the share of households aged 18-45 years old. These controls represent pre-pandemic levels in 2019, based on data from RWI and Microm (2022). They remain constant throughout our estimations and do not vary over time.

gradient. The cutoff period for the pandemic is March 2020, corresponding to the time when the first lockdown was imposed in Germany.

Alternatively, to analyze the growth of house prices and rents over time, we divided the zip codes into CBD and suburb groups and estimated the following regression equation:

$$\ln p_{it} = \mathbf{x}_i'\beta + \alpha_t + \alpha_i + e_{it}. \tag{9}$$

In this equation, our coefficients of interest are the time fixed effects α_t, which capture the growth of the hedonic values over time. The controls and individual fixed effects remain the same as before. We run this regression analysis separately for each group of zip codes.

Lastly, we specify the following regression equation to investigate the role of amenities, our main explanation channel for the donut effect.

$$\ln p_{it} = \mathbf{x}_i'\beta + \beta_a AI_i + \delta_t(t \times AI_i) + \alpha_t + \alpha_i + e_{it}, \tag{10}$$

where AI_i represents an index of consumption or environmental amenities, all other elements remain the same as before. The coefficient of interest is δ_t, the interaction between time and amenity indices. This interaction captures the effect of changes in the valuation of consumption or environmental amenities on house prices and rents following the pandemic. We expect the coefficient to be negative for consumption amenities and positive for environmental amenities, as predicted in Section 3.1.2.

4 Data

We use real estate data from RWI-GEO-Real Estate Data (RWI-GEO-RED) of the FDZ Ruhr at RWI (RWI and ImmobilienScout24 (2022b) and RWI and ImmobilienScout24 (2022a)), and amenity data from OpenStreetMap (OSM).

4.1 Rents and house prices

We construct house price and rental indices using a comprehensive and detailed dataset on housing RWI-GEO-RED (RWI and ImmobilienScout24, 2022b,a). The dataset includes a wide range of property characteristics, enabling us to calculate hedonic indices.

To create a quality-adjusted index, we employ panel hedonic regression as follows:

$$\ln p_{hijt} = \mathbf{x}'_{hijt}\beta + \alpha_{ijt} + e_{hijt}, \tag{11}$$

where h,i,j, and t index properties, zip codes, municipalities, and times (i.e., month-year), respectively. The variable p denotes rent or price in euros per m^2, α_{ijt} denotes zip code-municipality-time fixed effects, and $\mathbf{x}'_{hijt}$ includes a set of property characteristics.[4] Our zip code-level quality-adjusted prices (or rents) are the estimates of the fixed effects in Equation 11: $\hat{\alpha}_{ijt} = \widehat{\ln p}_{hijt} - \mathbf{x}'_{hijt}\hat{\beta}$.

4.2 Zip Codes, Labor Market Regions (LMRs), and Central Business Districts (CBDs)

Our zip code data come from the Postleitzahlen Deutschland and covers all zip codes in Germany. The data contains information on zip code boundaries and associated towns and cities.

Kosfeld and Werner (2012) define 141 labor market regions (LMRs) in Germany, based on commuting flows. The delineation of these regions is based on combining one or more administrative regions at the county level to create self-contained labor markets. The boundaries of local labor markets are defined so that commuting flows within labor market regions are relatively large compared to commuting between regions, with an upper limit of 45-60 minutes for commuting time.

We use these LMRs to define the CBDs as the geographical center of each LMR, weighted by the number of inhabitants at the 1x1 km grid-cell level.[5] The information on the number of inhabitants comes from RWI and Microm (2022). Figure 1 shows the constructed CBD locations and the respective distance between the CBD and the center of each zip code.

For a categorical classification of CBD and suburb, we rely on a data-driven definition of groups by using percentiles of the distance to the CBD. Locations within the 10$^{\text{th}}$ percentile are considered to belong to the CBD area ($P_{10\%} \approx 6.1km$). We classify locations above this threshold but below the median distance as suburban areas. For a more detailed analysis, we split the suburban areas into two rings:

[4] The hedonic regressions include the following property characteristics: floorspace, number of rooms, floors, bedrooms, and bathrooms; house or apartment dummy; home type; apartment type; type of heating; years of construction and renovation; condition and facilities of the property; whether the property has a basement; whether it has a guest washroom; whether it is in or is a protected building; and whether the property is usable as a holiday house.

[5] Other weighting variables, such as the number of residential buildings and households, are also used to determine the central points in the LMRs. However, the results remain unchanged. We also used the unweighted centers of the LMRs, and the most populous municipality in the county as the CBD location (see Figure A.1 for the comparison).

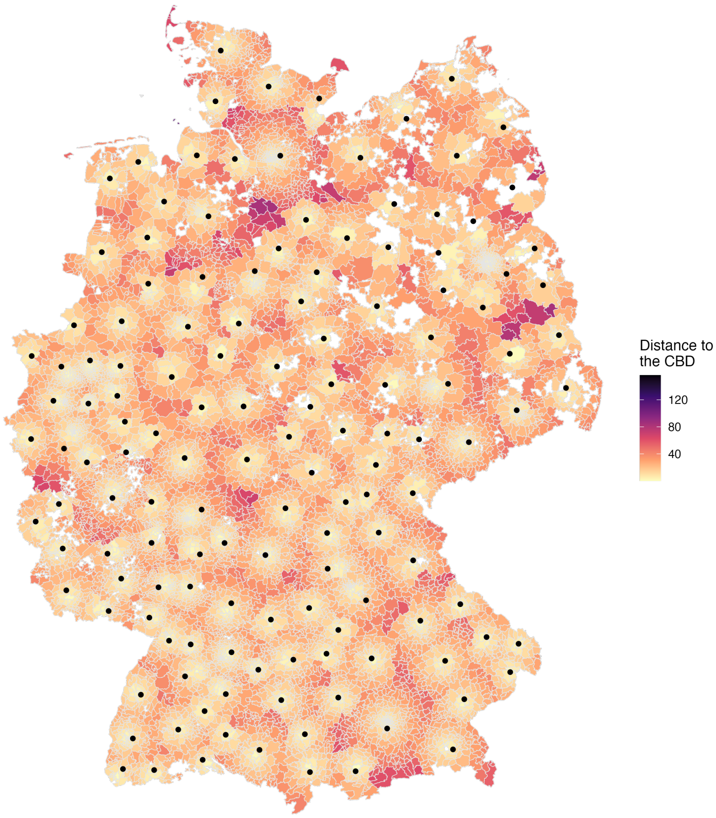


Figure 1: CBD locations and distance to the CBD.
Notes: The distance is calculated as the Euclidean distance between the geographical center of the zip code and the CBD based on the LMR definition.

ring 1 with distances up $P_{30\%} \approx 12.4km$; ring 2 with distances up $P_{50\%} \approx 18.3km$. Zip codes with larger distances to the CBD lay outside the core area and are not further considered in this classification.

4.3 Amenities

We distinguish between two types of amenities — consumption amenities and environmental amenities. To model the presence of amenities in urban areas accurately, we rely on OpenStreetMap (OSM) data, which we extract for the period 2017 to 2021.[6] Consumption amenities combine places to eat, places for education, and places for entertainment. We categorize green spaces and water bodies as environmental amenities.[7]

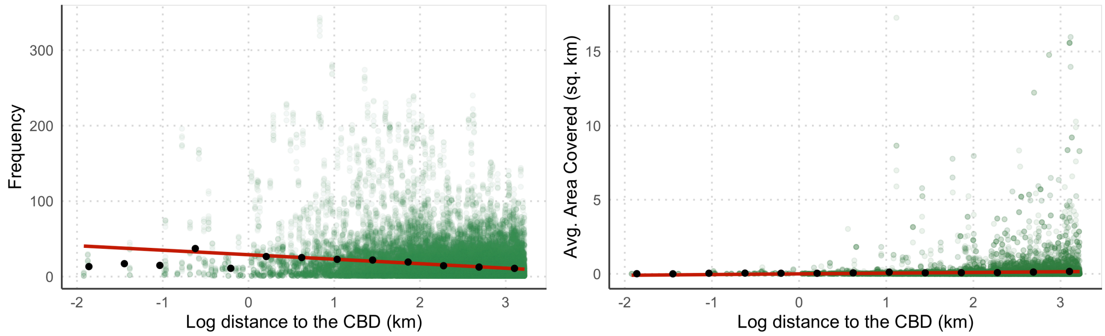
The consumption amenities data are collected as point data. It is possible that we list multiple buildings belonging to an amenity. For example, even though a city may have only one university, its buildings may be scattered throughout the city, resulting in multiple data points in our sample. The environmental amenities data are collected as polygon data.

Figure 2 shows the distribution of consumption amenities (left panel) and environmental amenities (right panel) relative to the distance to the CBD for all zip codes. We report consumption amenities based on frequency, as these are represented by points in space. Environmental amenities are reported in terms of the area covered relative to the size of the zip code, as these are represented as polygons. The figure shows that consumption amenities have a higher frequency closer to the CBD, as indicated by the decreasing slope of the trend line. The pattern is less clear for environmental amenities. Here, the slope of the trend line is close to zero, indicating evenly distributed amenities. However, the stylized facts below (Section 4.4) show locations further away from the CBD benefit, on average, from larger environmental areas. The trade-off between consumption and environmental amenities may influence households' decisions on where to live. Those prioritizing consumption amenities may reside closer to the CBD, while those who value environmental amenities may prefer suburban locations.

We transform the raw data into a zip code dataset to make consumption and environmental amenities usable in the analysis. We use the frequency of consumption amenities and the area covered by environmental amenities, which are normalized

[6] We use a snapshot of OSM at the end of each year.

[7] For consumption amenities, we classify restaurants, bars, cafes, pubs, and ice cream stores as food locations, cinemas, and theaters as places of entertainment, and colleges, universities, kindergartens, schools, and libraries as education opportunities. For environmental amenities, we combine lakes, rivers, streams, canals, parks, gardens, and nature reserves.



(a) Consumption amenities

(b) Environmental amenities

Figure 2: The gradient of amenities (raw values) as a function of the distance to the CBD.
Notes: Both panels illustrate the relationship between amenities and their distance to the CBD, with data points coded green representing zip code values and darker points representing averages within a 2 km distance bins.

into an index using z-score normalization.[8] Following this strategy has the advantage that the resulting indices have a mean of zero and a standard deviation of one, making them comparable despite having different units.[9]

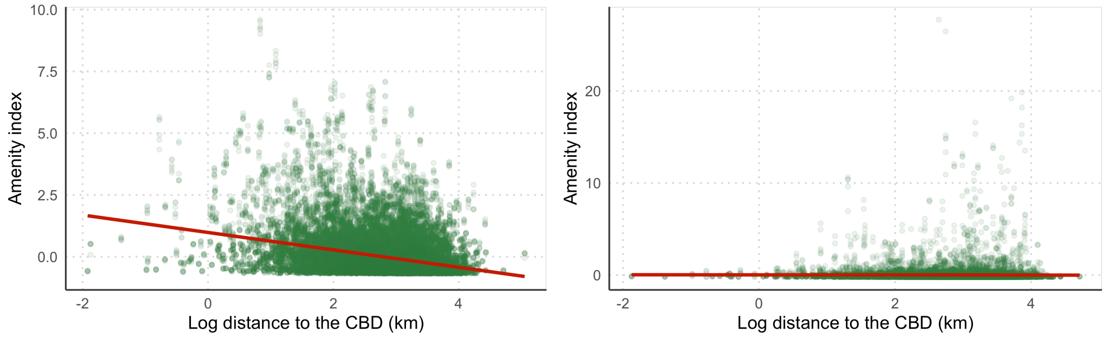
Figure 3 shows the distribution of the constructed index for consumption amenities (left panel) and environmental amenities (right panel). The plot looks almost identical to the raw data plot (Figure 2), which is intended as we only normalize the scales but keep the underlying patterns. It again shows a high frequency of consumption amenities in the CBD and an evenly distributed presence of environmental amenities across space.

4.4 Stylized Facts

Stylized Fact 1: Consumption amenities are more prevalent in the CBD, while environmental amenities cover larger areas in the suburbs. Table 1 shows the average number of amenities and the area covered by environmental amenities, based on our definition of CBD and suburbs. The number of consumption amenities decreases with distance to the CBD. On average, the CBD (within a distance of 6.1 km from the center location) has approximately 22 consumption amenities (such as restaurants, schools, etc.). In the suburban ring 1 (6.1 – 12.4 km), there are only about 16 such facilities, and in the suburban ring 2 (12.4 – 18.3 km), there

[8] z-score normalization follows the formula: $\frac{x-mean(x)}{SD(x)}$

[9] The resulting indices have negative values for low counts of consumption amenities and small areas covered for environmental amenities.



(a) Consumption amenities (b) Environmental amenities

Figure 3: The gradient of amenities (indices) as a function of the distance to the CBD.

are about 13 facilities. For environmental amenities, on average, the area covered by these amenities increases from the CBD to the suburbs, ranging from 0.07 to 0.14 square kilometers.

Table 1: Descriptive statistics on amenities

	Consumption amenities		Environmental amenities	
Ring	N	SD	Covered area (km^2)	SD
CBD	21.86	31.78	0.07	0.49
Suburb Ring 1	15.76	20.46	0.09	0.32
Suburb Ring 2	12.63	16.55	0.14	0.81
Outside	10.21	14.17	0.19	0.84

Notes: The table shows the average number of consumption and the average area covered by environmental amenities for the CBD and the suburban locations. Source: Authors' table.

Overall, this indicates that urban dwellers can avail themselves of consumption facilities more frequently, but they must also share a narrower range of environmental resources with their neighbors. Conversely, suburban residents have access to larger expanses of greenery and aquatic features, although they may have to undertake longer journeys to access consumption amenities.

Stylized Fact 2: While consumption amenities are negatively associated with the distance to the CBD, environmental amenities are positively associated.

Equation 6 demonstrates that the consumption amenities parameter b exhibits a negative sign while the environmental amenities parameter ϕ exhibits a positive one. Empirical evidence supporting this theoretical relationship can be ascertained through regression of the constructed amenity indices against the distance from the CBD.

The results in Table 2 indicate a significant negative effect of distance to the CBD on consumption amenities. The coefficient for environmental amenities (measured as the area covered) is significant and positive, but it is not significant for the index.

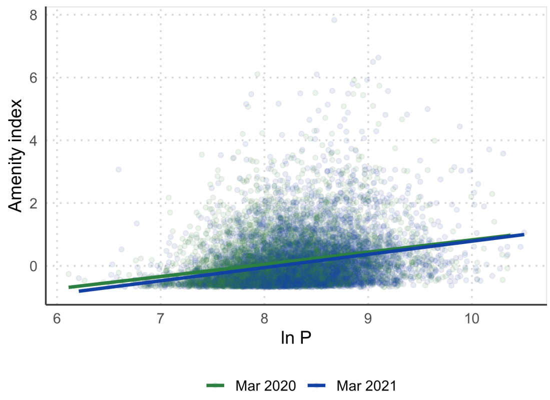
Table 2: Estimates for the parameters b and ϕ

Type	**Consumption amenities**		**Environmental amenities**	
	ln count	index	ln area km^2	index
	(1)	(2)	(3)	(4)
Constant	4.323***	0.9777***	-6.538***	0.0169
	(0.0117)	(0.0508)	(0.0320)	(0.0485)
ln dist	-0.2468***	-0.3508***	0.1669***	-0.0063
	(0.0050)	(0.0166)	(0.0132)	(0.0183)
Observations	65,830	8,478	65,830	3,800
R^2	0.03564	0.08925	0.00231	3.13×10^{-5}

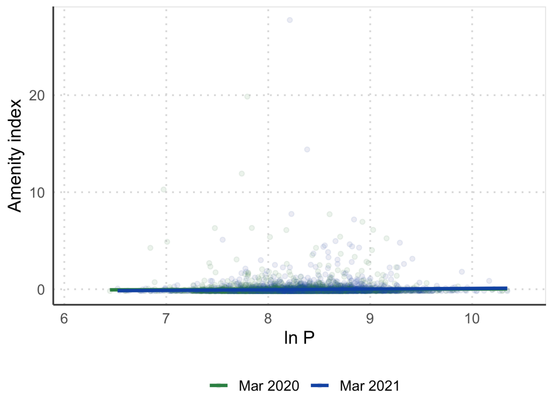
Notes: The table shows the estimates for the parameters b and ϕ from Equation (6), which represent the relationship between amenities and the distance to the CBD. The estimation uses amenity data for 2019. The number of observations for the indices represents zip codes. In the raw data, the number of observations counts the amenity object.

Stylized Fact 3: The valuation of consumption and environmental amenities remains relatively constant in Germany during and after the pandemic.

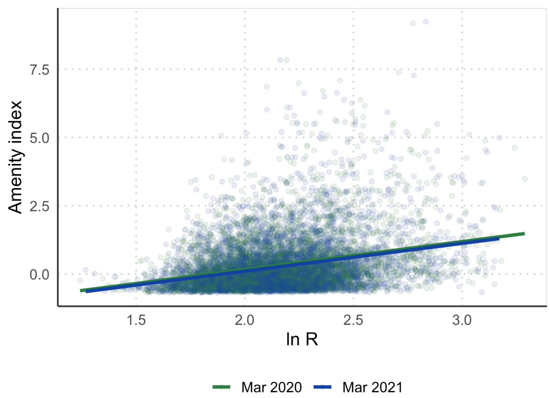
Figure 4 shows the relationship between hedonic prices (rents) and the amenity indices in the top (bottom) panels. The relationship between hedonic values and amenities appears almost identical for both prices and rents. While the price trend for environmental amenities is flat in 2020 and 2021, the slope of the 2021 line for consumption amenities is slightly steeper than in 2020 (compare panels (a) and (b)). This implies that the valuation of consumption amenities with regard to house prices has increased in 2021. This minor change may be attributed to the pandemic and the closure of amenities such as high-end restaurants and cafes due to lockdown and social distancing measures. The (partial) reopening of these establishments and improved pandemic coping strategies may have enhanced the appreciation of local amenities. In contrast, the assessment of both facilities in relation to rental rates shows minimal variation between the onset of the pandemic in March 2020 and March 2021.



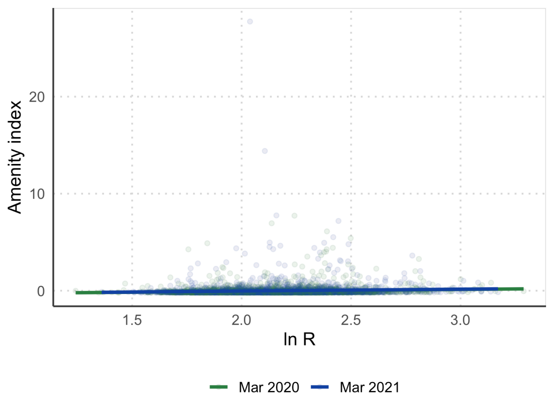
(a) Prices: Consumption amenities



(b) Prices: Environmental amenities



(c) Rents: Consumption amenities



(d) Rents: Environmental amenities

Figure 4: Correlation between prices/rents and amenities in March 2020 and 2021.

5 Results

While the pandemic appears to be affecting the trend of apartment rents in Germany, average house prices have remained unaffected, as shown in Figure 5. In Germany, average rents started decreasing at the beginning of 2020, coinciding with the onset of the pandemic. Rents recovered to the pre-pandemic (late 2019) levels in late 2020. However, the trend repeats starting in January 2021, with rents falling throughout 2021, albeit at a lower rate, paralleling the second wave of the pandemic. Since increasing rents by landlords is highly unlikely due to rental controls in Germany, the downturn in rents may have been triggered by the decline in demand, especially in major German cities and high-density areas.

With respect to house prices, no clear downturn is visible in the trend. House prices remained relatively stable throughout 2020 and 2021. This may be due to several factors. House prices are forward-looking, and home buyers likely anticipate a recovery from the pandemic by 2021. In addition, low interest rates may have supported demand for houses, and housing supply constraints on new construction may have limited the availability of homes for purchase.

Overall, the trends suggest that while the pandemic directly impacted apartment rents, house prices were more resilient, likely due to a combination of demand, supply, and financial factors. The divergence in trends for rents versus prices warrants further research to better understand the dynamics at play.

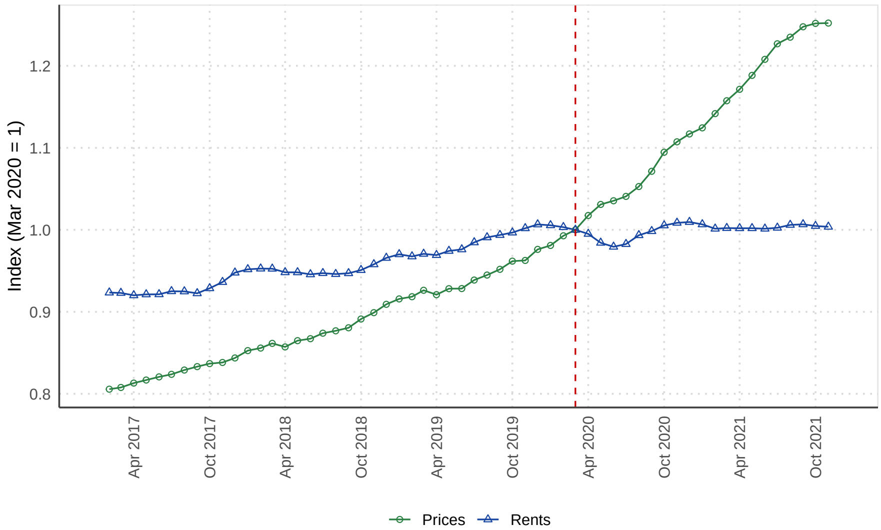
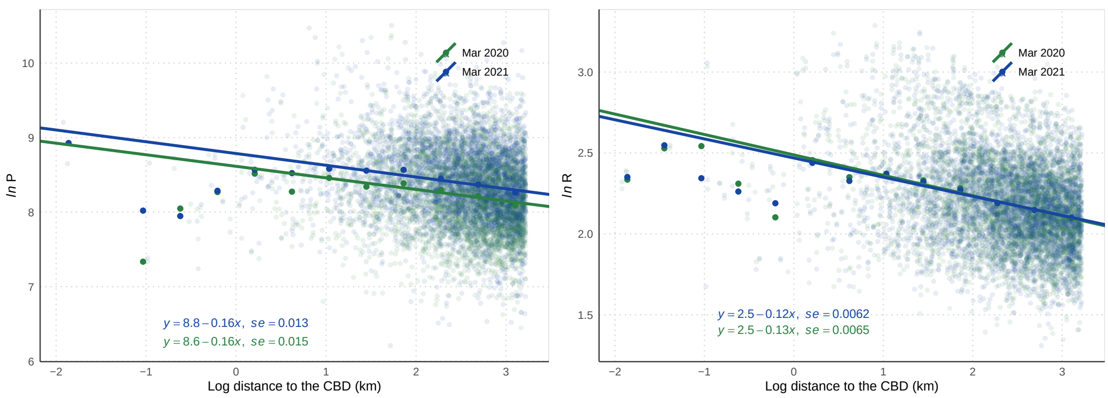


Figure 5: Trends of house prices and rents relative to March 2020.
Notes: Note that the data is smoothed using a 3-month moving average.

A key finding in the literature is that suburban housing prices and rents increased while those in the CBD locations decreased during the pandemic in the US (see, for example, Gupta et al. (2022)). However, according to our results, this pattern is not strongly observed in the German housing market. Figure 6 shows the relationship between hedonic prices (left panel) and hedonic rents (right panel) and the distance to the CBD for March 2020 and March 2021. Both price and rent gradients have a negative slope, consistent with the key prediction of the AMM model that prices or rents decrease with the distance to the CBD.

However, we do not observe any effects of the pandemic leveling the bid-rent curves, at least not in terms of prices. The price curves appear equally parallel in March 2020 and March 2021 (Figure 6 left panel). The slope is slightly flatter for the rent gradient in March 2021 than in March 2020, although the difference is marginal. We also provide additional evidence that strengthens this finding in the Appendix by plotting the change in house prices and rents against the distance to the CBD and comparing the pandemic levels with pre-pandemic values (see Figure A.2 and Figure A.3). We expect suburban areas to experience positive growth in both prices and rents as suburban housing or rental demand increases due to the pandemic. However, there is no clear evidence that this is the case for the German housing market.



(a) Prices (b) Rents

Figure 6: The price and rent gradients for March 2020 and 2021.
Notes: The figure illustrates the relationship between the distance to the CBD, house prices, and apartment rents, comparing the pre-pandemic (March 2020) and pandemic (March 2021) periods. As expected, in both periods, the gradients are negatively sloping, indicating that prices and rents decrease as the distance from the CBD increases. Lighter points represent zip code values, whereas darker points represent averages within a 2 km distance bins.

The story remains the same when comparing prices before and during the pandemic. Those areas where prices or rents were high pre-pandemic (mostly central and high-density zip codes) should experience less growth during the pandemic than those where prices or rents were lower (mostly the suburban areas), as Gupta et al. (2022) found for the US. As the downward-sloping curves in Figure A.3 indicate, expensive zip codes before the pandemic have shown lower or negative growth, while less expensive zip codes have experienced positive growth in both rents and prices, albeit the patterns are not as strong.

Figure 8 displays the estimates of the slopes of the gradients specified in Equation 8 for each month. The slope of the price gradient shows greater fluctuations in the point estimates but maintains a similar trend as the pre-pandemic time. In contrast, the slope of the rent gradient exhibits a smoother gradual increase over time, starting in late 2019, suggesting that the rent gradient has become flatter during the pandemic.

Quantitatively, our estimation results show that the estimated slopes of the gradients are: $(\hat{\delta}_t, \hat{\delta}_{t+1}) = [(-0.052, -0.047); (-0.044, -0.034)]$, where $t =$ March 2020, $t+1 =$ March 2021, for prices and rents, respectively. See Table A.1 for the full set of estimates.

That means, from March 2020 to March 2021, the slopes of the gradients have changed by: $\Delta\hat{\delta} = \hat{\delta}_{t+1} - \hat{\delta}_t = (0.005, 0.010)$ for prices and rents, respectively. The positive changes in the slopes show the flattening of the gradients. However, these values are economically insignificant to suggest that the pandemic has caused the same clear flattening of gradients in Germany as observed in the US. For the US, Gupta et al. (2022) found the change in slope for price ($\hat{\delta} = .012$), and the slope change for rents ($\hat{\delta} = 0.032$), from December 2019 to December 2020.[10]

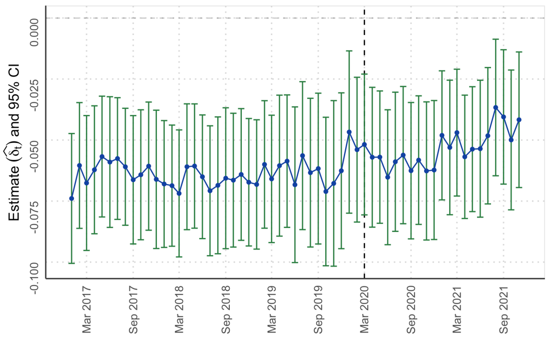
Overall, the changes in slope estimates during the pandemic appear small: the decreases in the gradients' slopes are 9.38% and 22.40% for house prices and rents, respectively. This might suggest that the pandemic has led to a flattening of gradients in Germany, but not as clearly and strongly as observed in the US.

Another approach, as used by Ramani and Bloom (2021), for identifying the donut effect involves dividing the data into CBD and suburban regions and examining the growth of house prices and rents, as specified in Equation 9. Figure 10 shows the evolution of prices for the CBD (in red) and the two suburban rings (in green/blue) estimated for the full sample. The plot shows that the evolution of rents breaks with the onset of the pandemic (right panel Figure 10). While rents increased before March 2020, they stagnated shortly after the start of the pandemic. Rents increased again in the summer of 2020 but then decreased for all three groups. At the beginning of 2021, rents in CBDs appear to fall more sharply than in locations further away from the city center. This suggests a delayed donut effect, at least partially and less strongly than in the US.

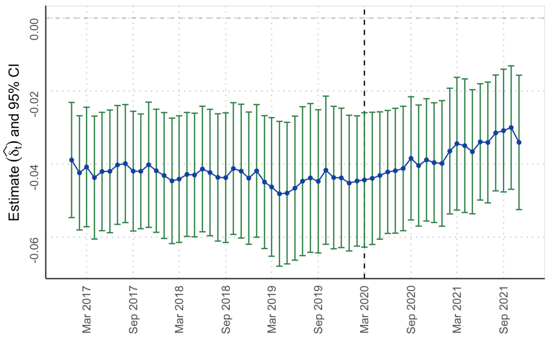
The evolution for prices is even less pronounced (left panel Figure 10). Here, all three groups move in the same direction and show a continuous increase over time.

The donut literature observes that the effect is most prominent in big cities. We

[10] Gupta et al. (2022) for the US found that the elasticity of house prices to distance decreased from -0.103 in December 2019 to -0.090 in December 2020, with a slope change of ($\hat{\delta} = 0.012$), resulting in a 37.5% decrease in the steepness of the gradient. Similarly, the elasticity of rents to distance decreased from -0.032 in December 2019 to -0.0001 in December 2020, with a slope change of ($\hat{\delta} = 0.032$), leading to a 100% decrease in the steepness of the gradient.



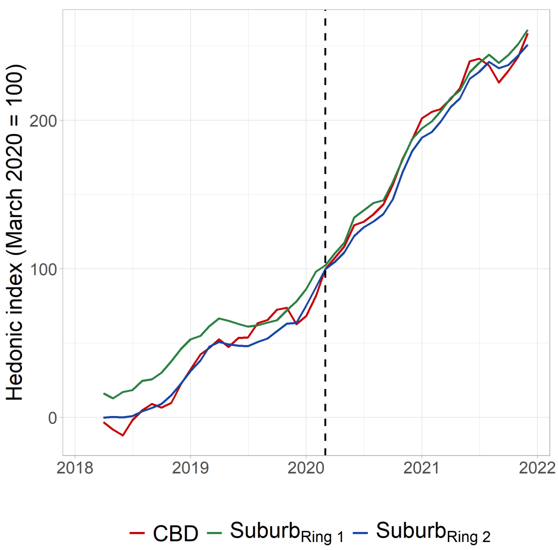
(a) Prices



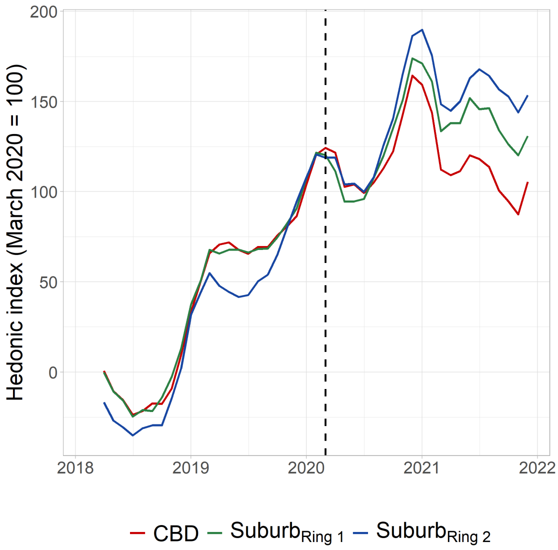
(a) Rents

Figure 8: Estimates for the price and rent gradients.

Notes: This figure shows the estimated slopes of the price and rent gradients, which were obtained from the regression in Equation 8. $\ln P$ and $\ln R$ are regressed on $\ln \text{dist} \times \text{time}$, with time and LMR fixed effects. The zip code controls include the logarithm of purchasing power, the share of males aged 18-45, and the share of individuals with a German background.



(a) Prices

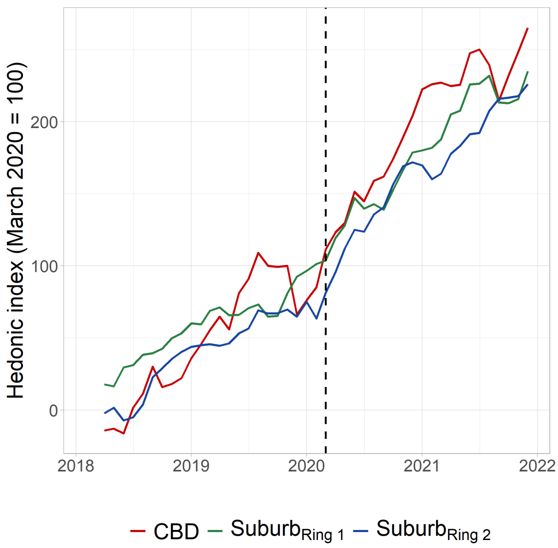


(a) Rents

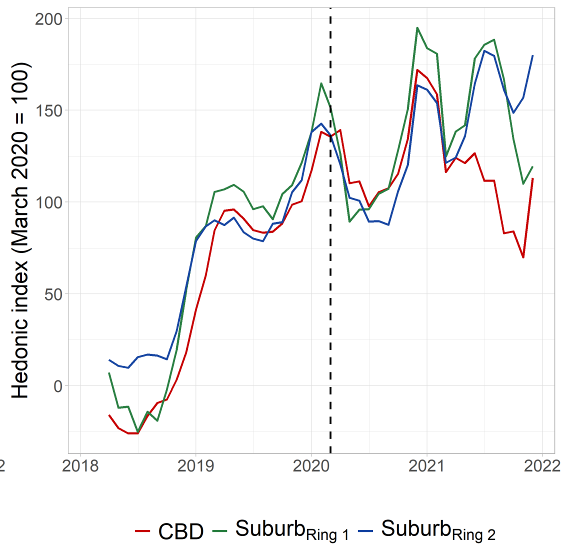
Figure 10: The donut effect for the full sample.

Notes: The vertical dotted line indicates March 2020, the start of the pandemic.

test this prediction by re-estimating Equation 9 only for the 15 largest German cities with approximately 500,000 residents or more. Figure 12 shows that all lines are more volatile for both rents (right panel) and prices (left panel) across all areas. The partial donut effect for rents from the full sample also disappears. Thus, we cannot confirm that the donut effect is strongest in the largest cities in Germany. The indicated donut effect in the full sample comes from medium-sized cities with a population of at least 100,000 but less than 500,000, as shown in Figure A.9 in the Appendix. We also do the same exercise for small cities (below 100,000 in population) and find no evidence of the donut effect (see Figure A.11 in the Appendix).



(a) Prices



(a) Rents

Figure 12: Donut effect for the 15 largest cities.

Notes: The vertical dotted line indicates March 2020, the start of the pandemic.

The disparities in the pandemic's donut effects on the US and German housing markets can be attributed to institutional and cultural differences between the two markets. The German housing market is characterized by a high degree of stability, a low frequency of home resales, and a high proportion of renters. We discuss these peculiarities in more detail in the Appendix (see Section A.1), but overall, the German housing market is quite stable and robust, making rapid and potentially short-term changes during the pandemic unlikely.

In addition, there is no dramatic change in population levels in either the CBD or the suburbs. We analyzed the population information offered by RWI and Microm

(2023), and observed minimal population changes compared to the pre-pandemic levels in 2019 (see Figure A.7 in the Appendix). We also used information on migration across city boundaries provided by Federal Statistical Office (2023). The data shows a very stable pattern of movement into or out of German cities for the years 2017 to 2021 (see Table A.2 in the Appendix). While this data considers movement across cities rather than within cities, which is our focus here, it provides suggestive evidence that residents in Germany do not tend to move frequently and probably less so in uncertain times.

5.1 The role of amenities

The literature identifies WFH and amenities as potential channels to explain the housing market results. Due to data limitations and since WFH seems to be weakly valued in Germany (see, for example, Nagler et al. (2022)), we focus on the second channel — the change in the valuation of (urban) amenities.

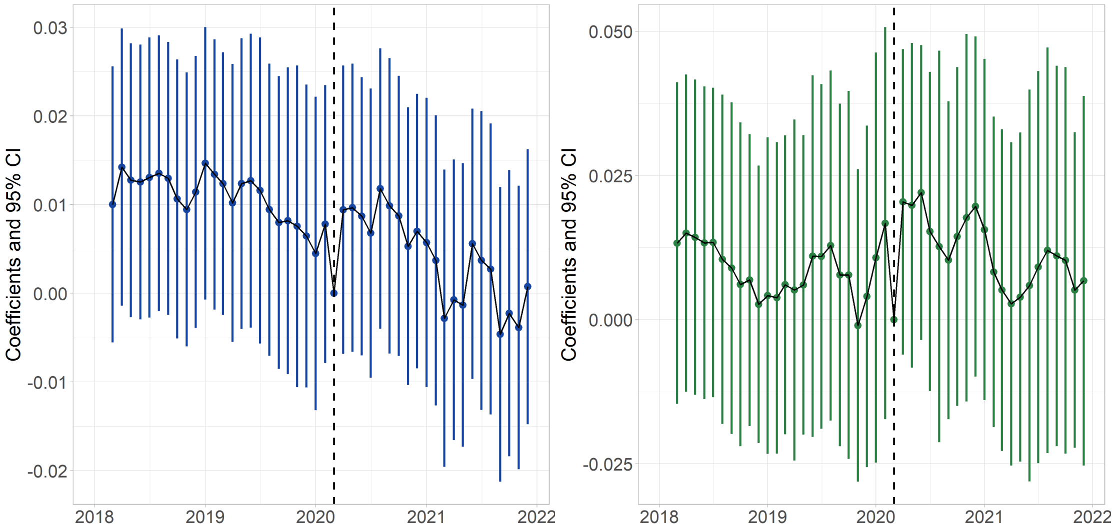
To assess the valuation of amenities, particularly the potential change during the pandemic, we run Equation 10, which includes a continuous time measure with effects relative to March 2020. Figure 14 shows the plotted interaction effects for each month for prices and Figure 16 shows the effects for rents without spatially restricting the sample. Regardless of the type of dwelling and the amenity considered, there seems to be a slight decreasing trend in the value of amenities after the pandemic, but almost all interactions are insignificant. There is little to no evidence that the value of amenities changed during the pandemic. We have also tested the same analysis for CBD and suburbs in the Appendix, with the same result.

Overall, the results suggest that bid-rent curves in Germany have not flattened, except for rents, where there is only slight evidence. This conclusion is reasonable because WFH is not seen as a compelling job attribute in Germany, the value of amenities remains unchanged, and there is little population movement during the pandemic.

6 Conclusion

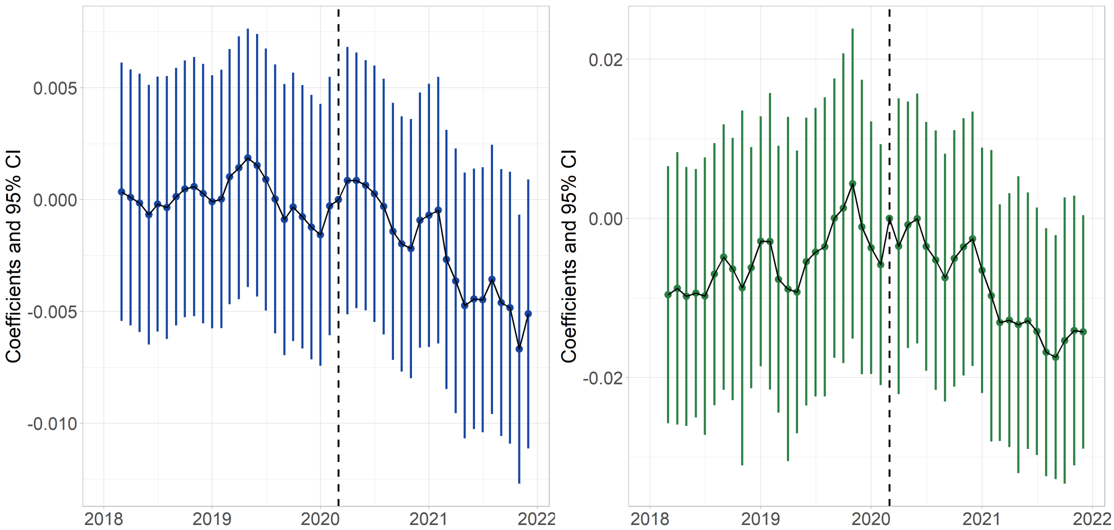
The COVID-19 pandemic has weakened a fundamental tenet of urban economics: the inverse relationship between proximity to the city center and housing prices. However, this conclusion appears to apply mostly to the US housing market and less so to the German housing market, as indicated by the findings of this study.

We used comprehensive zip code-level data on housing prices and rents to examine temporal changes, comparing pre- and post-pandemic periods. We found no strong



(a) Consumption amenities (a) Environmental amenities

Figure 14: Amenities' values vs prices over time - Full sample.
Notes: The vertical dotted line indicates March 2020, the start of the pandemic.



(a) Consumption amenities (a) Environmental amenities

Figure 16: Amenities' values over time with respect to rents - Full sample.
Notes: The vertical dotted line indicates March 2020, the start of the pandemic.

evidence for the flattening of the bid-rent curve. The absence of the donut effect on prices, consistent with the existing literature, is connected to its forward-looking nature. However, we discovered that during the pandemic, rents in suburbs and low-density zip codes have slightly increased compared to those in the CBD and high-density zip codes.

We analyzed urban amenities to explain the impact of the pandemic on rents, but we did not find any significant effect. Our amenity data, constructed from OSM, shows that the valuation of consumption and environmental amenities remains relatively stable. All findings are consistent across various city center definitions and regional subsets, such as big cities versus small cities.

This leads us to conclude that institutional and structural differences between Germany and the US may contribute to the stability of the German housing market. The German housing market is characterized by extensive governmental support, a large renter population, tax legislation restricting speculative behavior, and low interest rates. Our analysis of population and migration data suggests that residents in Germany are less responsive to location changes related to the pandemic.

Therefore, while the COVID-19 pandemic has undeniably posed challenges globally, its impact on the German housing market, as explored in this study, seems to be less disruptive compared to other countries such as the US. This resilience underlines the effectiveness of the existing structures and policies in Germany's housing market. Further research may be beneficial to fully understand the long-term implications of the pandemic on real estate markets.

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Appendix

A.1 The German housing market

The German housing market has a unique structure in Europe. It is characterized by high governmental support, which relies on tools like housing benefits (“Wohngeld”) or the construction of social housing (“sozialer Wohungsbau”). Housing benefits already implemented in 1965 apply to tenants and property owners who use their property themselves. These benefits aim to guarantee a stable living arrangement by lowering the burden of living costs, especially for low-income households. Around 1.5 percent of German households received housing benefits in 2020 (see Federal Ministry for Housing, Urban Development and Building (BMWSB) (2023a), Federal Ministry of Justice (FMJ) (2008)). The government supports the construction of social housing by offering credits with low interest rates. Low-income households can then rent the newly built living space. The government plans to spend one billion Euros annually between 2020 and 2024 for this program (see Federal Ministry for Housing, Urban Development and Building (BMWSB) (2023b)).

The German housing market is characterized by a large rental market, with a high percentage of renters. Over 50 percent of the population rents their living space, the highest value within the European Union (see Federal Statistical Office) (2022)).

In addition, as required by law, sellers of homes who have owned the home for less than ten years must take a significant tax cut on their profit when reselling the home (Federal Ministry of Justice (FMJ), 2023). The legislation aims to prevent speculative behavior that would drive up housing prices even more. It also contributes to a low frequency of change of ownership in the housing market.

The German housing market is remarkably stable, with increasing prices over the last decades. The reasons for this development include the fact that the supply and demand of housing are detached from each other, and the interest rates for mortgages are rather low (see Voigtländer (2022), Deutsche Bank) (2022)).

A.2 Additional figures and tables

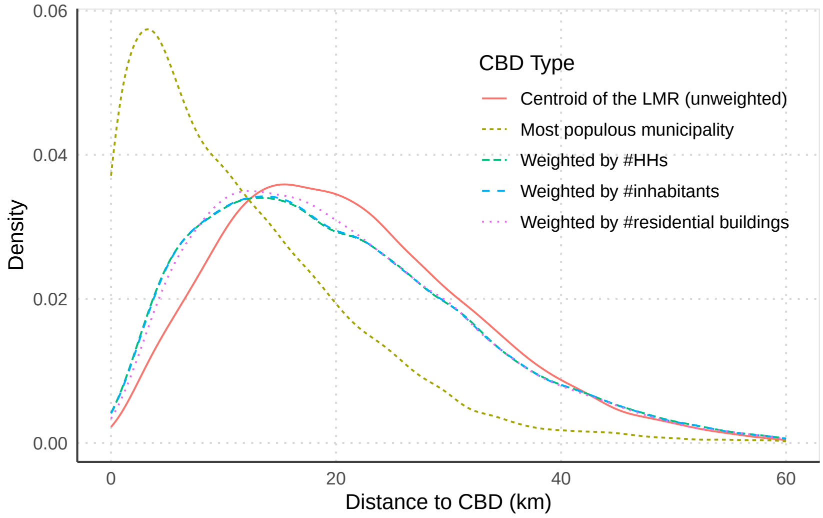


Figure A.1: Density of distance to the CBD by CBD types.
Notes: The figure illustrates the density of distances to the CBD by different types of CBDs. The CBDs are defined based on the geocentroid of the LMR (unweighted), weighted by the number of inhabitants, the number of residential buildings, and the number of households. The fourth type is based on the most populous municipality's centroid in the county, similar to Ahlfeldt et al. (2020).

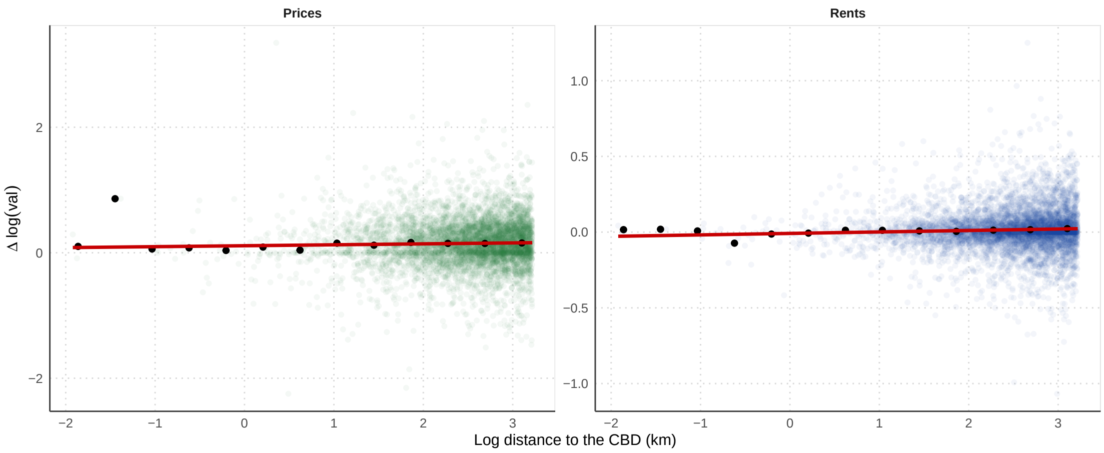


Figure A.2: Changes in prices/rents against distance to the CBD.
Notes: The figure illustrates the relationship between the distance to the CBD and changes in log house prices and apartment rents from the pre-pandemic (March 2020) to the pandemic (March 2021) periods. The expected pattern is upward-sloping curves, indicating that prices and rents tend to increase as the distance from the CBD increases. However, this pattern cannot be observed here, as the curves appear to be almost horizontal. Lighter points represent zip code values, whereas darker points represent averages within a 2 km distance bins.

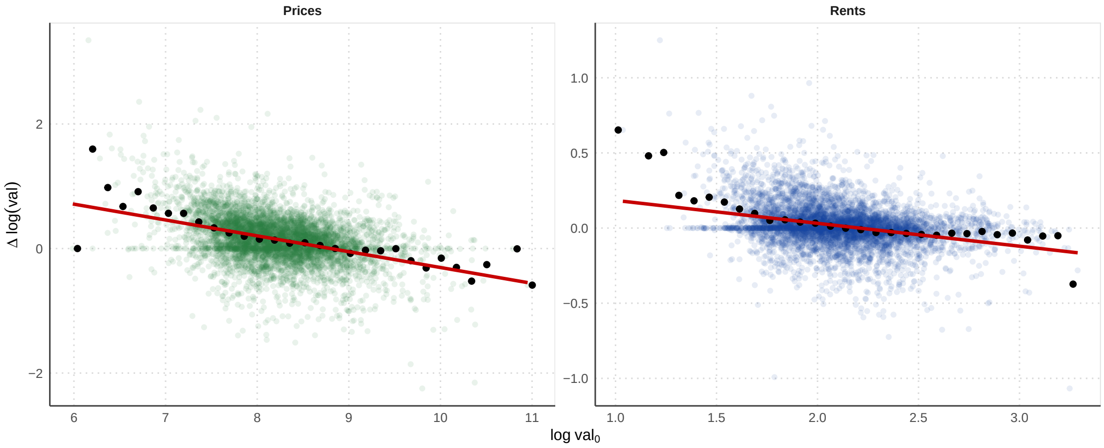
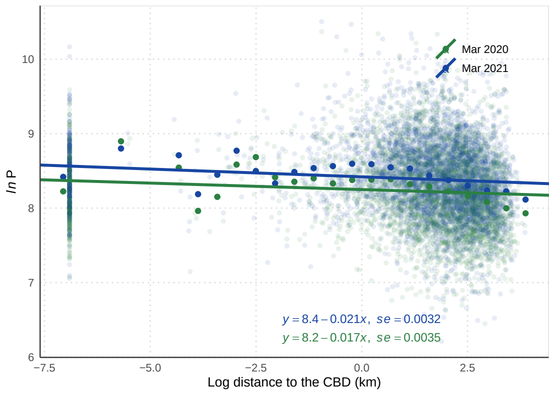
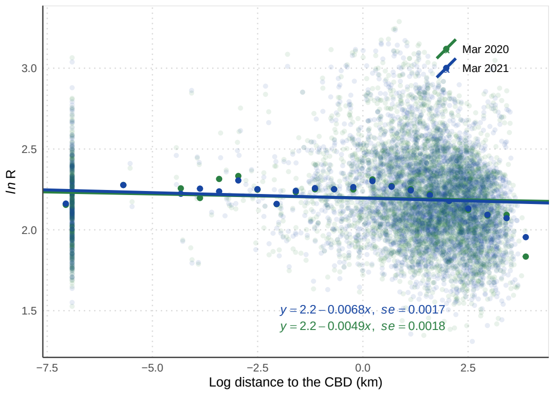


Figure A.3: Changes in prices/rents against the pre-pandemic levels.
Notes: The figure illustrates the relationship between pre-pandemic levels and changes in log house prices and apartment rents from the pre-pandemic period (March 2020) to the pandemic period (March 2021). The expected trend is a downward slope, indicating that zip codes with high prices and rents before the pandemic would experience lower or negative changes. This pattern is evident in the graph, with fitted lines sloping downwards for both prices and rents. Lighter points represent zip code values, whereas darker points represent averages within a 2 km distance bins.



(a) Prices



(b) Rents

Figure A.4: The price and rent gradients for March 2020 and 2021.
Notes: The figure illustrates the relationship between the distance to the CBD, house prices, and apartment rents, comparing the pre-pandemic (March 2020) and pandemic (March 2021) periods. The CBD is the most populous municipality in the county. As expected, in both periods, the gradients are negatively sloping, indicating that prices and rents decrease as the distance from the CBD increases. Lighter points represent zip code values, whereas darker points represent averages within a 2 km distance bins.

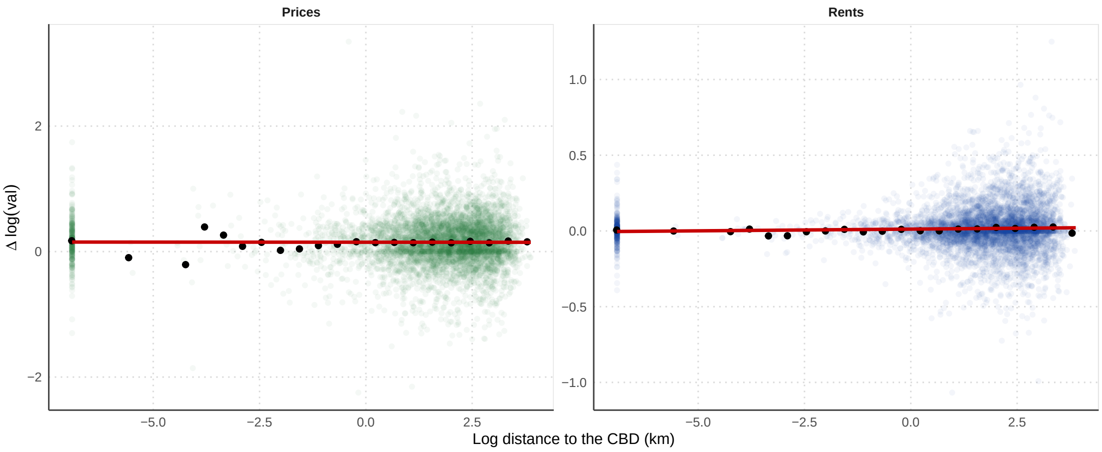


Figure A.5: Changes in prices/rents against distance to the CBD.
Notes: The figure illustrates the relationship between the distance to the CBD and changes in log house prices and apartment rents from the pre-pandemic (March 2020) to the pandemic (March 2021) periods. The CBD is the most populous municipality in the county. The expected pattern is upward-sloping curves, indicating that prices and rents tend to increase as the distance from the CBD increases. However, this pattern cannot be observed here, as the curves appear to be almost horizontal. Lighter points represent zip code values, whereas darker points represent averages within a 2 km distance bins.

Table A.1: Slope estimates of the housing price and rent gradients.

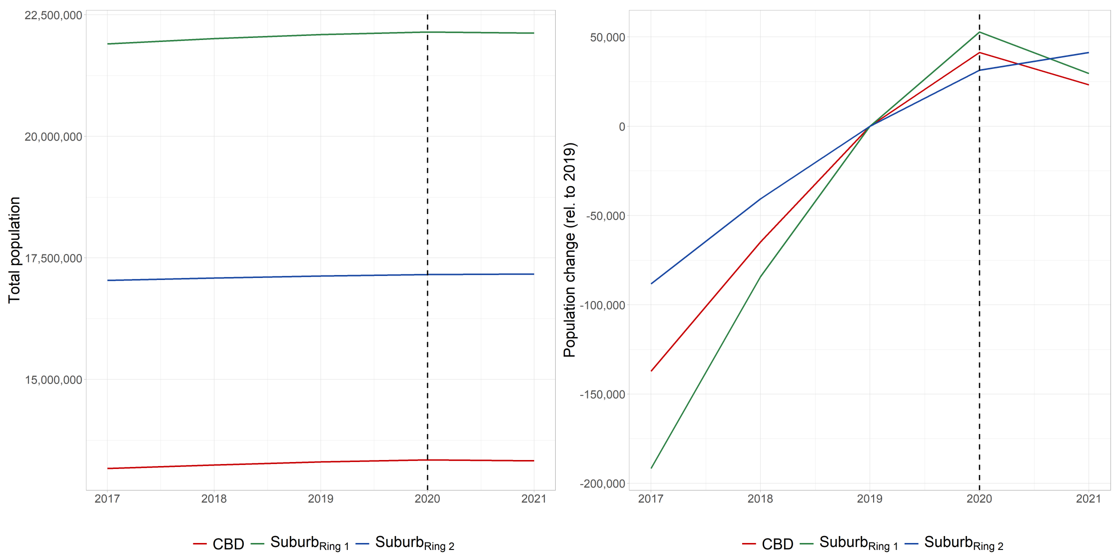
	$\ln P$ (1)	$\ln R$ (2)
Jan2019 × ln dist	-0.0682*** (0.0134)	-0.0418*** (0.0092)
Feb2019 × ln dist	-0.0600*** (0.0132)	-0.0449*** (0.0092)
Mar2019 × ln dist	-0.0659*** (0.0132)	-0.0462*** (0.0096)
May2019 × ln dist	-0.0586*** (0.0137)	-0.0479*** (0.0098)
Jul2019 × ln dist	-0.0564*** (0.0153)	-0.0447*** (0.0103)
Aug2019 × ln dist	-0.0634*** (0.0154)	-0.0438*** (0.0103)
Sep2019 × ln dist	-0.0617*** (0.0156)	-0.0447*** (0.0099)
Nov2019 × ln dist	-0.0678*** (0.0172)	-0.0437*** (0.0099)
Feb2020 × ln dist	-0.0539*** (0.0150)	-0.0446*** (0.0090)
Apr2020 × ln dist	-0.0570*** (0.0145)	-0.0439*** (0.0092)
May2020 × ln dist	-0.0570*** (0.0137)	-0.0431*** (0.0088)
Jul2020 × ln dist	-0.0589*** (0.0144)	-0.0418*** (0.0086)
Aug2020 × ln dist	-0.0562*** (0.0142)	-0.0412*** (0.0086)
Sep2020 × ln dist	-0.0625*** (0.0141)	-0.0384*** (0.0085)
Oct2020 × ln dist	-0.0582*** (0.0133)	-0.0404*** (0.0084)
Nov2020 × ln dist	-0.0626*** (0.0143)	-0.0388*** (0.0085)
Dec2020 × ln dist	-0.0623*** (0.0144)	-0.0396*** (0.0083)
Jan2021 × ln dist	-0.0481*** (0.0134)	-0.0398*** (0.0087)
Apr2019 × ln dist	-0.0605*** (0.0146)	-0.0481*** (0.0100)
Jun2019 × ln dist	-0.0683*** (0.0161)	-0.0466*** (0.0100)
Oct2019 × ln dist	-0.0711*** (0.0154)	-0.0416*** (0.0103)
Dec2019 × ln dist	-0.0626*** (0.0162)	-0.0438*** (0.0097)
Jan2020 × ln dist	-0.0467*** (0.0168)	-0.0452*** (0.0094)
Mar2020 × ln dist	-0.0518*** (0.0146)	-0.0443*** (0.0093)
Jun2020 × ln dist	-0.0652*** (0.0140)	-0.0421*** (0.0085)
Feb2021 × ln dist	-0.0530*** (0.0139)	-0.0364*** (0.0087)
Mar2021 × ln dist	-0.0469*** (0.0131)	-0.0344*** (0.0092)
Apr2021 × ln dist	-0.0569*** (0.0128)	-0.0349*** (0.0092)
May2021 × ln dist	-0.0537*** (0.0129)	-0.0366*** (0.0086)
Jun2021 × ln dist	-0.0535*** (0.0142)	-0.0339*** (0.0081)
Jul2021 × ln dist	-0.0482*** (0.0141)	-0.0341*** (0.0084)
Aug2021 × ln dist	-0.0367** (0.0141)	-0.0315*** (0.0080)
Sep2021 × ln dist	-0.0405*** (0.0139)	-0.0308*** (0.0085)
Oct2021 × ln dist	-0.0500*** (0.0145)	-0.0300*** (0.0085)
Nov2021 × ln dist	-0.0417*** (0.0140)	-0.0340*** (0.0093)
Observations	253,828	235,270
R^2	0.76713	0.80604
Within R^2	0.21043	0.32698
LMR fixed effects	✓	✓
Time fixed effects	✓	✓

Notes: We control for the share of males aged 18-45, the share of German background, and the logarithm of total purchasing power at the zip code level. The estimates for 2017 and 2018 are not shown to fit the table. The standard errors are clustered at the level of the LMR.

Table A.2: Average moving statistics across German cities

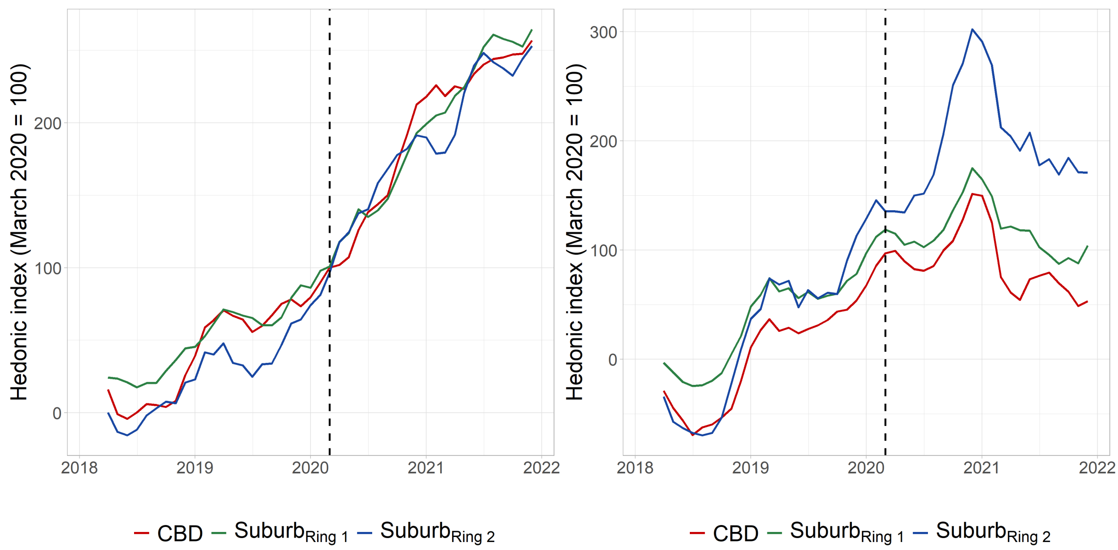
Year	Move-in	Move-out	Net migration
2017	494.72	460.90	33.83
2018	496.25	462.55	33.70
2019	501.92	473.17	28.75
2020	455.52	434.12	21.39
2021	469.87	439.44	30.43

Notes: The table shows the average number of move-in and move-out statistics for German cities from 2017 to 2021. The difference between both columns is listed as net migration in the last column.



(a) Total population (a) Population change

Figure A.7: Population levels across CBD and suburban areas.
Notes: The figure shows the total population for the CBD and suburban locations from 2017 to 2021 (left panel) and the population change relative to 2019 (right panel).

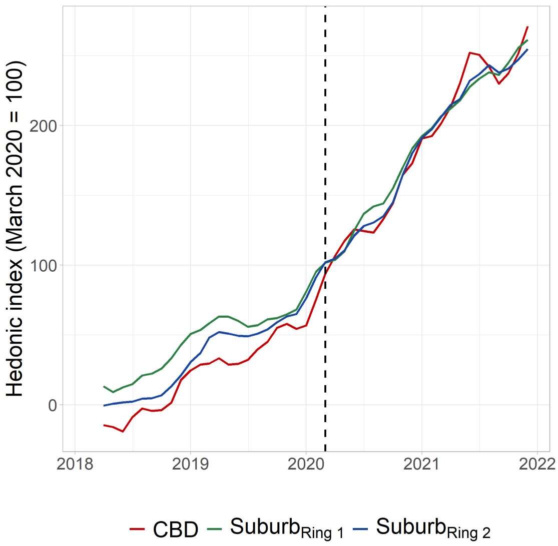


(a) Prices

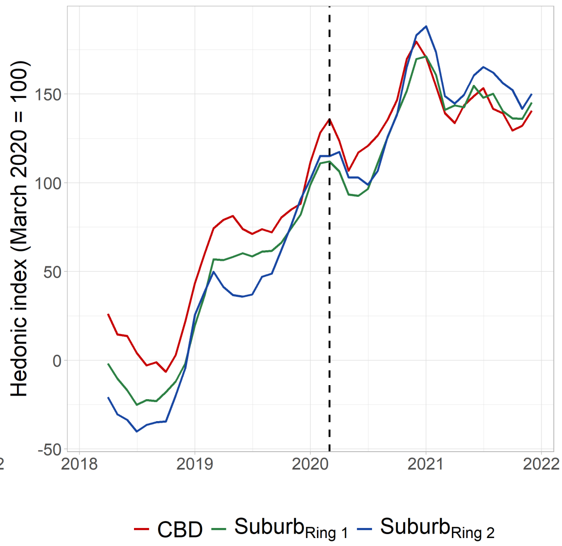
(a) Rents

Figure A.9: The donut effect for medium-sized cities.

Notes: Medium-sized cities are classified as having a population between 100,000 and 500,000. The vertical dotted line indicates March 2020, the start of the pandemic.

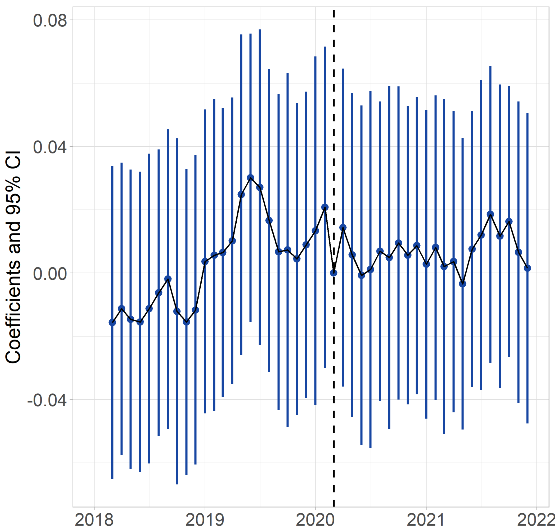


(a) Prices

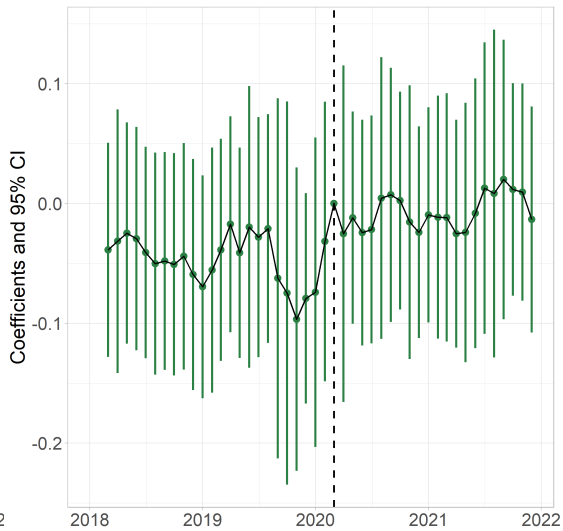


(a) Rents

Figure A.11: The donut effect for small cities.
Notes: Small cities have a population of 100,000 or less. The vertical dotted line indicates March 2020, the start of the pandemic.

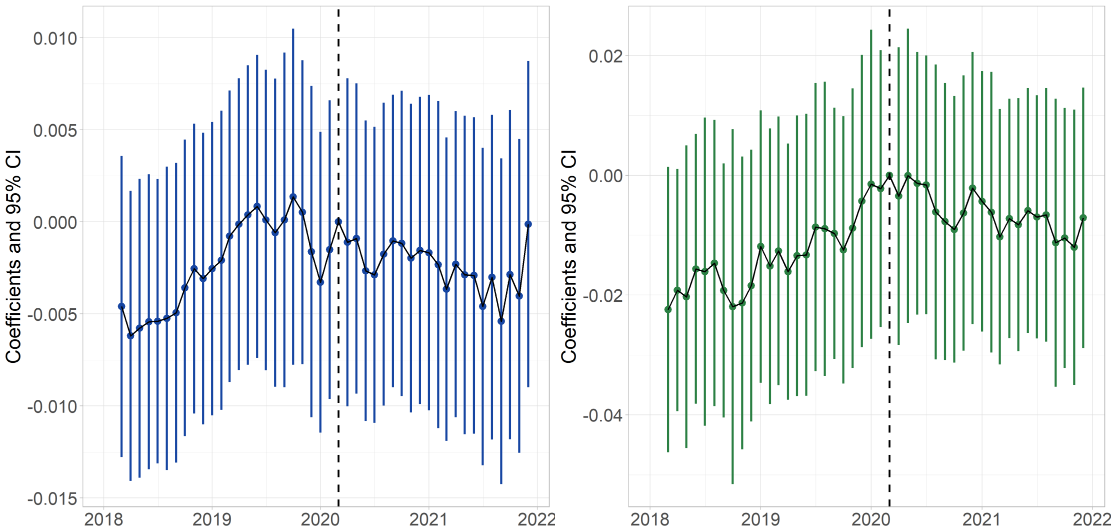


(a) Consumption amenities



(a) Environmental amenities

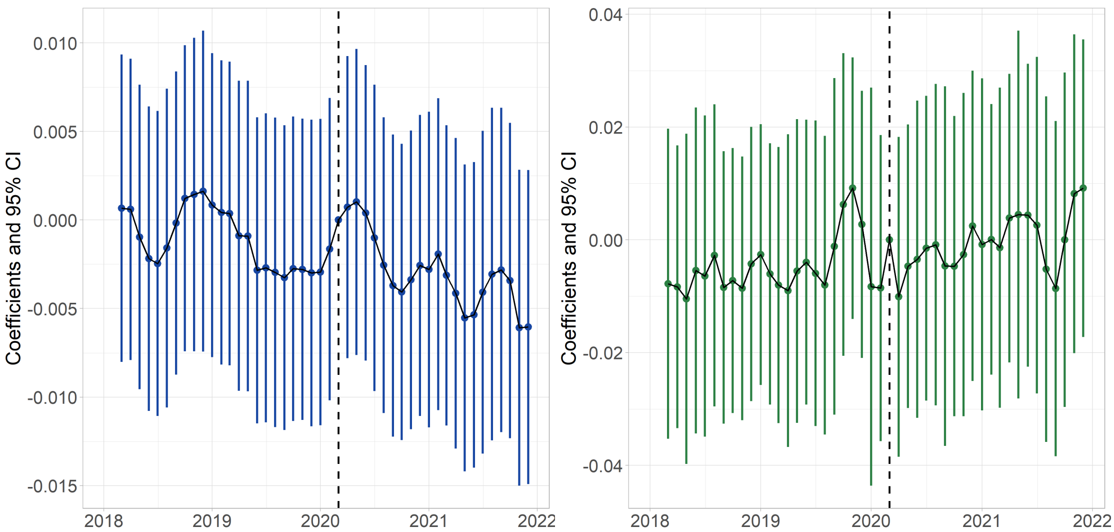
Figure A.13: Amenities' values vs prices over time - CBD locations.
Notes: The vertical dotted line indicates March 2020, the start of the pandemic.



(a) Consumption amenities

(a) Environmental amenities

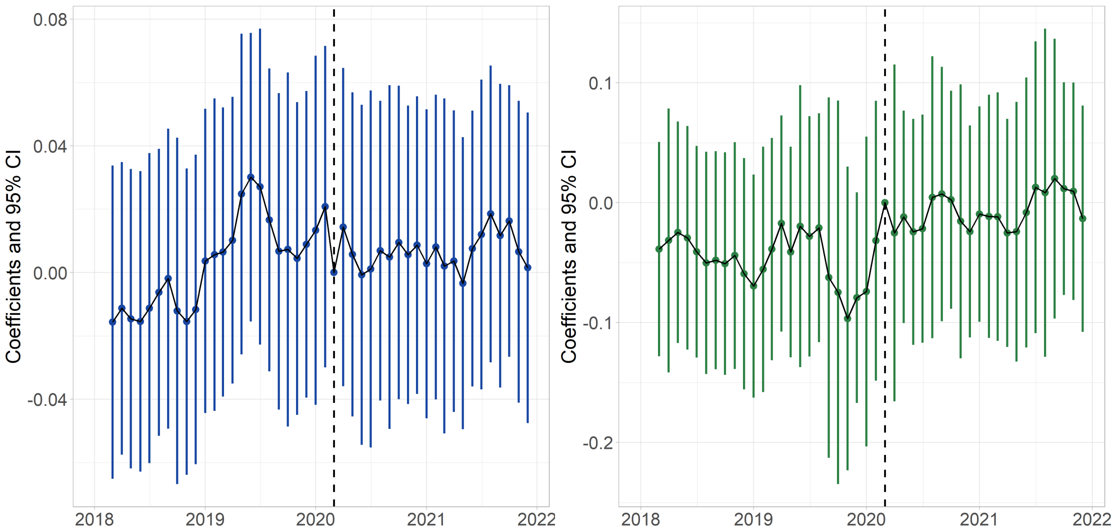
Figure A.15: Amenities' values over time with respect to rents - CBD locations.
Notes: The vertical dotted line indicates March 2020, the start of the pandemic.



(a) Consumption amenities

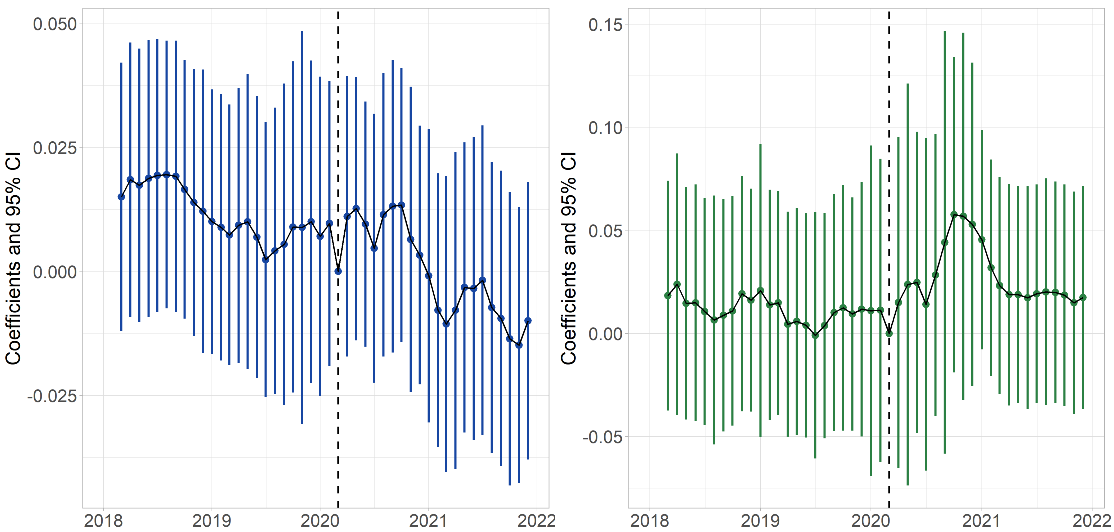
(a) Environmental amenities

Figure A.17: Amenities' values over time with respect to rents - Suburban Ring 1.
Notes: The vertical dotted line indicates March 2020, the start of the pandemic.



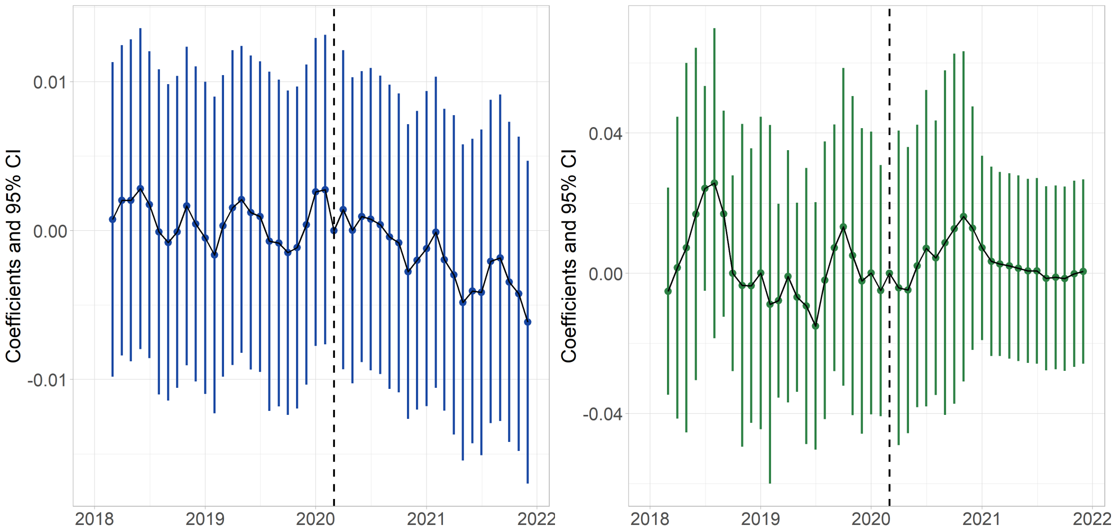
(a) Consumption amenities (a) Environmental amenities

Figure A.19: Amenities' values vs prices over time - CBD locations.
Notes: The vertical dotted line indicates March 2020, the start of the pandemic.



(a) Consumption amenities (a) Environmental amenities

Figure A.21: Amenities' values vs prices over time - Suburban Ring 2.
Notes: The vertical dotted line indicates March 2020, the start of the pandemic.



(a) Consumption amenities (a) Environmental amenities

Figure A.23: Amenities' values over time with respect to rents - Suburban Ring 2.
Notes: The vertical dotted line indicates March 2020, the start of the pandemic.