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ARTICLE

The premium of the old neighborhood upgrading projects in China: evidence from Hefei

Huang Yongbin[1] · **Hong Hai**[2]

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Abstract
Numerous studies have investigated the impact of larger-scale urban demolitions or reconstructions on housing markets, yet few researches on the housing premium of small scale state-led urban renovation. One such policy is the old neighborhood upgrading projects, which aim to enhance neighborhood services without involving house ownership change, building demolition, or resident resettlement. Taking these projects as quasi-natural experiments, we employ a staggered Difference-in-Differences (DID) method to examine its' premium effects in Hefei, China. Our findings reveal that surrounding neighborhoods within a 500-meter radius of the upgrading areas experienced a significant increase in prices by 6.01% compared to neighborhoods located beyond this range. Moreover, the premium effect demonstrates temporal-spatial dynamics, showing that the premium effect diminishes as time passes or distance increases. The mechanism analysis shows the old neighborhood upgrading projects revitalize community vitality, thereby increasing housing prices of surrounding neighborhoods.

Keywords Old neighborhood upgrading projects · Urban renovation · Housing premium · China

1 Introduction

Urban renewal is believed to be the most effective solution to tackle obsolete residential neighborhoods that fail to satisfy minimum conditions of security, habitability, and comfort for residents around the world (Serrano-Jimenez et al., 2019). Many governments launched the national-level urban renewal programs (Nachmany & Hananel, 2022), such as the Choice Neighborhoods and Opportunity Zones in the Unites States, the New Deal for Communi-

✉ Huang Yongbin
huangyb@ahu.edu.cn

[1] School of Economics, Anhui University, Hefei, Anhui 230601, China

[2] School of Public Affairs, Zhejiang University, Hangzhou, Zhejiang 310058, China

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ties (NDC) in the United Kingdom, the Clearance and Construction (CaC) and TAMA 38 in Israel, and Old Neighborhood Upgrading Projects (ONUP for short, hereafter) in China.

It is estimated that the capital demand of ONUP will exceed 6 trillion yuan, yet governments have little budgets in raising funds. The municipal governments in China, who relied on land finance which has resulted in tremendous housing supply, were responsible for financing the urban renewal policy, now tend to cut public financial investment and provide various incentives and in-kind benefits to leverage private capital (Shen et al., 2021; Li et al., 2023). Thus, ONUP facilities exploratory approaches to maximize benefits with lower cost, such as the introduction of new functions to old spaces, integrating shared spaces and facilities, promoting resident-oriented neighborhood transformation, micro-scale or sensitive renewal interventions (Li et al., 2020; Wang et al., 2022; Li et al., 2023). Previous studies have primarily focused on the capitalization effects of urban renewal from the perspective of demolitions, reconversion and reconstructions (Chau, 2014; Ahlfeldt et al., 2017; Liu & Chen, 2021;Zhang et al.,2021; Liu et al., 2022; Peng & Tian, 2022; Gonzalez-Pampillon, 2022; Zhang et al.,2023; Dube et al., 2023), and most studies found a positive primum. However, the literature on the capitalization effects of small-scale state-led urban renewal policy, ONUP, for example, is sparse and lacks consensus.

We take the old residential neighborhood upgrading projects in Hefei city from 2016 to 2021 as quasi-natural experiments and use the staggered DID method to evaluate the premium effect of urban ONUP on housing markets. The ONUP causes an average increase of 6.01% in housing prices within a 500-meter radius. This positive spillover effect demonstrates both temporal persistence and distance decay trends. After the projects, housing prices in the surrounding areas increase by an average of 1.88% per year. Additionally, for every 100-meter increase in distance from the upgrading neighborhoods, the average premium effect decreases by 2.87%. After conducting a series of tests, including adjustments to the distance range and employing Propensity Score Matching (PSM) with Difference-in-Differences (DID), the results consistently remain robust.

Heterogeneity analysis indicates that the premium effect of ONUP does not vary significantly based on administrative districts or community types. However, heterogeneity is observed based on the upgrading types. The improvement-oriented or upgrading-oriented types exhibit a significant increase in housing prices in the surrounding areas, whereas the premium effect is weaker for the basic-oriented type. Mechanism analysis indicates that the ONUP enhances the vitality of the neighborhoods, thereby increasing housing prices in the surrounding areas.

Our paper contributes in two dimensions. Firstly, we add a new evidence on the positive externality of urban renewal form the perspective of small-scale and state-led renovation policy. On the first hand, the renovator in previous studies of urban renovation is mostly homeowners (Mamre & Sommervoll, 2022; Ruming et al., 2024), and less attention is paid to state-led urban renovation. On the second hand, previous studies have primarily focused on the capitalization effect of larger scale residential reconversion, urban wholesale redevelopment or urban village transformations (Chau, 2014; Ahlfeldt et al., 2017; Liu & Chen, 2021;Zhang et al., 2021; Liu et al., 2022; Peng & Tian, 2022; Gonzalez-Pampillon, 2022; Zhang et al., 2023; Dube et al., 2023), yet less attention is paid to capitalization effect of small-scale urban renovation policy. Our findings echo with Lee et al. (2017) in Taiwan and Mamre and Sommervoll (2022) in Norwegian that a significant positive renovation premium exists. The most relevant study is Yu et al. (2023), yet they found that the ONUP

did not contribute to increased property values. Their study case, Hangzhou where the renovated neighborhoods will not undergo redevelopment for at least the next 5–10 years, is a rare setting. In contrast, our study focuses on Hefei, a city representative of most Chinese cities, where no specific time interval for projects is mandated. We believe that our research provides a better case study of the premium effect of small-scale state-led urban renovation.

Secondly, our study demonstrates that urban ONUP enhances housing prices in the surrounding neighborhoods by fostering community vitality. This finding echoes with the perspective of commercial gentrification, which suggests the increased displacement of commercial activities (Immergluck, 2009; Bantman-Masum, 2020; Huang & Gu, 2023). In our study, we use POI data and provide empirical evidence that the implementation of the ONUP in Chinese cities promotes urban renewal by fostering community vitality.

The outline of this paper is as follows. Section 2 reviews the literature on urban renovation and renovation primum, and Sect. 3 describes the background of ONUP in china. Section 4 introduces the identification strategies and data. Section 5 provides the empirical results, robustness checks and heterogeneity analysis and investigates the potential explanations of the premium effect on urban ONUP. The last section concludes the paper.

2 Literature review

ONUP in China align closely with the concept of urban renovation, emphasizing the revitalization or refurbishment of buildings or neighborhoods without reconstruction or household resettlement. However, they vary in decision-making levels and funding sources. Firstly, in Europe and America, urban renewal at the neighborhood level is the culmination of redevelopment decisions made at the property-level (Ruming et al., 2024; Munneka & Womack, 2015), and urban renovation is the culmination of the property level decisions to partially redevelop the existing improvements (Dube et al., 2023); While, ONUP in china is implemented at the neighborhood level[1], which is independent from property-level decisions. Secondly, in Europe and America, urban renovation is typically funded solely by private investors. Absence of public guidance would lead to gentrification, impacting tenants' daily lives and long-term housing conditions (Hatz, 2021; Bengtsson & Bohman, 2021; Mangold et al., 2023). In contrast, ONUP represents a state-led and publicly funded renovation strategy in China.

Prior research focused on renovations, primarily examining decision-making processes (Munneke & Womack, 2015; Irwin, 2019) or projects selection (Chen et al., 2023; Xu et al., 2024). These studies revealed that renovation initiatives tend to attract new residents seeking updated and higher-quality housing, subsequently stimulating additional investments and new businesses. However, this revitalization process may adversely affect the original residents, who may price out of the market as rents from renovated housing stock increase (Baeten et al., 2017; Hatz, 2021).

However, the literature on urban renovation and its' impact on the housing prices is sparse and lacks consensus. These may be related to externalities or positive spillover effects (Wilson & Kashem, 2017). In the case of Taiwanese market, Lee et al. (2017) estimate the

[1] We followed the definition of the neighborhood as a comparatively independent space consisting of a group of residential buildings with shared public space and services. The property owners are empowered to select their own property management and owners' committee (Shen et al., 2021).

renovation premium per capita unit to 10.0% with the DID method. Mamre and Sommervoll (2022) estimated a significant positive renovation premium of 5–7% for renovated dwellings with a hedonic method. Contrarily, Yu et al. (2023) exploit the DID method and found neighborhood renovation does not raise values of all aged properties in Hangzhou. Liu found renovation may have a negative impact on environment, at least in the short run (Liu et al., 2020). Taken together, the impact of neighborhood renovation on housing prices vary across cases.

From the perspective of welfare economics, the ONUP has the potential to generate positive externalities. These projects improve the living environment and enhance community vitality (Noh, 2019), leading to overall benefits for the residents and the surrounding area. On the one hand, the ONUP contributes to an enhancement in urban living conditions. This includes an increase in the availability of public facilities and public spaces designed to accommodate a variety of activities. In China, the ONUP involves the conversion of existing housing, such as public housing and community office buildings, into public facilities and spaces for public services. Furthermore, vacant lots, underutilized lands, and non-residential low-value areas within the neighborhood can be traded through land transfer or allocation methods. This allows for the repurposing of these spaces to better serve the community's needs. This organized spatial planning improves urban living conditions, thereby increasing residents' willingness to pay for a better urban living environment (Shi et al., 2021).

On the other hand, the ONUP contributes to the enhancement of community vitality. The improved living conditions and amenities make the upgraded neighborhoods attractive to higher-income individuals (Arntz et al., 2021). These individuals typically have higher purchasing power, which can drive the development of local retail and service industries, subsequently creating new employment opportunities in the area. Moreover, the ONUP not only provides necessary public goods and services but also enhances commercial vitality, leading to increased housing rentals and commercial turnover (Immergluck, 2009; Bantman-Masum, 2020). Furthermore, the ONUP expands the diversity of consumption spaces, which stimulates the rapid development of surrounding tourism and cultural creative industries. Consequently, the influx of high-income individuals creates competition for housing in the vicinity, thereby driving up housing prices in the surrounding areas.

3 Background

Neighborhood renewal is very important in china nowadays. According to the 7th National Population Census of China, by the end of 2020, around 219,000 urban neighborhoods in china were over 20 years, which housed for more than 61 million people. Residents in these decayed neighborhoods have suffering from poor living conditions. Despite widespread dissatisfaction among residents, a minimal number of property owners in China actively engage in neighborhood renewal initiatives. Instead, it is predominantly the government that spearheads and funds the majority of these renewal projects (Shen et al., 2021).

There are two solutions for the renewal of old neighborhoods. The first option is to demolish and redevelop the entire old neighborhoods, and the other option is dynamic upgrading and renovation of old neighborhoods, such as ONUP. Different from the demolition and reconstruction approach, ONUP doesn't entail changing land ownership or displacing original residents (Ministry of Housing and Urban-Rural Development of People's Republic of

China, 2023). Instead, it prioritizes the enhancement of neighborhood services' functionality and quality. This approach typically presents fewer challenges and incurs lower costs compared with large-scale demolitions and reconstructions.

In March 2017, the Housing and Urban-Rural Development Bureau of Anhui Province implemented an upgrading projects plan for urban old residential neighborhoods throughout the entire province. This plan included 359 neighborhoods earmarked for upgrading, with 8 neighborhoods located in Hefei City. Over the next four years, Anhui Province continued to release upgrading plans for old neighborhoods. These plans encompassed 229 upgrading neighborhoods within the jurisdictional district of Hefei City.

This plan was officially announced in February each year, and the provincial bureau made detailed information of each project publicly available, including the address, street name, number of households, community types, and upgrading types. The ONUP can be classified into three types: basic-oriented, improvement-oriented, and upgrading-oriented (Department of Housing and Urban-rural Development of Anhui Province, 2017). Basic-oriented type is basic rehabilitation includes maintenance and repair of existing infrastructures and shared properties that impact residents' lives and security, such as utility supply, road repairs, and exterior wall refurbishing. Improvement-oriented type aims to provide residents with increased convenience and quality of life by installing elevators, building retrofitting, and improving energy efficiency. These projects include improvements to accessibility, neighborhood green spaces, lighting, aged-friendly facilities, parking lots, and recreational or fitness facilities. Upgrading-oriented type aims to enhance public services and improve the overall environment of the neighborhood. This includes the addition of convenient facilities such as elderly care, childcare, medical, and convenience stores to meet the diverse needs of residents (Zhu & Ye, 2024).

The municipal government will provide monthly reports to the provincial government regarding the initiation and progress of the project. These reports will encompass the project's commencement and completion rates. Hefei, being the capital city of Anhui province, benefits from a comparatively ample public finance budget. All ONUPs in Hefei are scheduled to commence between March and April, aiming for completion and acceptance by the provincial government in November and December.

4 Identification strategies and data

4.1 Identification strategies

ONUP is the project at the neighborhood level, and we examine the impacts of the neighborhood-level renovation on the surrounding neighborhoods. And we exploit the staggered roll out of upgrading projects in different neighborhoods and employ difference-in-differences (DID) method to construct the econometric model as follows:

$$lnprice_{ijt} = \alpha + \beta \mathrm{treat}_{ij} + \gamma renewal_{ijt} + X_{it} + \varphi_d + \eta_j + \lambda_t + \varepsilon_{ijt} \quad (1)$$

Where $lnprice_{ijt}$ denotes the logarithm of the price of neighborhood i in period t. $treat_{ij}$ denotes whether the neighborhood i is located within the influence radius of the upgrading neighborhood j. If it falls within the influence radius of the upgrading neighborhoods, the

variable equals 1; otherwise, it is 0. We therefore define neighborhood *i* is treated if the old neighbor *j* begins to undergo the renovation in year *t*. Such design is identical to a standard staggered difference-in-difference design, where the treatment timing varies due to different upgrading projects targeting old neighborhoods *j*. Moreover, there may be cases such that a neighborhood falls within the influence radius of the neighborhood who undergone renovations. In such cases, we assign the neighborhood *i* to its nearest neighborhood *j* that undergoing renovation. X_{it} is a series of control variables, including both the characteristics of the residential neighborhoods, such as the built year, green space ratio, plot ratio, property fee price, and location-specific variables, such as the distance to the nearest subway station, tertiary hospital, park, and the city center. λ_t is time fixed effect, which is used to control for all time varying common factors, for example, exogeneous shocks to local housing market that affect housing prices. φ_d is district fixed effect, which is used to account for potential differences in policy implementation across different districts. η_j is the matched fixed effect. We define a matched group as all neighborhoods that surrounding to the same old neighbor that is exposed to ONUP. That is, we pool all treatment and control groups surrounding the same old neighbor to form the matched group. Once the matched group is defined, we are able to control for the matched fixed effects, which absorb all time-invariant confounders within the same matched group, which ensures a more transparent comparison between the treatment and control groups. ε_{ijt} is error term.

While the staggered DID design is intuitive and easy to interpret the estimated results, the negative weighting issues highlighted in recent econometric literature may threat our identification. Specifically, the econometric literature points out that the standard DID estimator by two-way fixed effects (TWFE) model may fail to recover a convex combination of the average treatment effects when there are variations in treatment timing and when treatment effects are heterogeneous across different treatment groups (Borusyak et al., 2023). What's worse, the presence of heterogeneous treatment effects (HTE) may even contaminate the estimates of leads and lags in the canonical event study model (Sun & Abraham, 2021). To prevent such contamination, we also use recently developed HTE-robust estimators (Borusyak et al., 2023; Callaway & Sant'Anna, 2021; Sun & Abraham, 2021) that avoid the involvement of negative weights in both DID and event study designs.

We are interested in the estimated coefficient of $renewal_{ijt}$, which reflects the premium effect of urban ONUP. It means the average treatment effect of the ONUP on surrounding neighborhoods which is the treatment group. We set 500 m as the influence radius in the baseline regression, which may neglect the spatial distance decay characteristics. The closer a neighborhood is to the neighborhoods that undergone renovations, the greater may the premium effect. To capture this spatial heterogeneous effect, we add the distance variable $dist_{ij}$ into the model as follows:

$$\begin{aligned} lnprice_{ijt} = \alpha + \beta treat_{ij} + \gamma renewal_{ijt} + \delta renewal_{ijt} * dist_{ij} \\ + X_{it} + \varphi_d + \eta_j + \lambda_t + \varepsilon_{ijt} \end{aligned} \tag{2}$$

$dist_{ij}$ is the distance from neighborhood *i* and neighborhoods *j* that undergone renovations, and other variables remain the same definition as Eq. (1). In addition, to examine the dynamic effects of the renovated neighborhoods on surrounding housing prices, we add time trends $trend_{tj}$ and the specific upgrading time for each old community s_j. Essentially, $trend_{tj}$ represents the specific time trend for each matched group (i.e., observations surrounding the

same old neighborhood). Although we have added several control variables and time fixed effect, the prices may change over time for each renovated neighborhood due to unobserved characteristics, such as neighborhood size, investment amount, et al. Adding this term to our regression can effectively control various time changes of each renovated neighborhood and capture the linear dynamic effect of the ONUP. If $t > s_j$, then $trend_{tj} = t - s_j$; otherwise, it is 0. We interact this term with the treatment variable, $treat_{ij}$, to examine how the treatment effect varies as the duration of treatment time increases.

$$\begin{aligned} lnprice_{ijt} = \alpha + \beta treat_{ij} + \gamma renewal_{ijt} + \delta renewal_{ijt} * dist_{ij} \\ + \tau treat_{ij} * trend_{tj} + X_{it} + \varphi_d + \eta_j + \lambda_t + \varepsilon_{ijt} \end{aligned} \tag{3}$$

Compared to Eqs. (1) and (2), Eq. (3) is more flexible and allows us to isolate the heterogeneous impact of the upgrading time on the treatment group. The regression coefficient τ represents the time dynamic effect of the premium effect of the renovated neighborhoods, while the definitions of other variables remain the same as in Eqs. (1) and (2).

4.2 Data

The top-down nature of this upgrading plan, issued by the provincial-level administrative bureau, ensures that it is exogenous to the neighborhoods situated within the streets and alleys. This satisfies the exogeneity assumption necessary for policy evaluation. To delineate the influence radius of the ONUP, we employed ArcGIS buffer analysis. This allowed us to generate both the treatment group and the control group for our study. To ensure the robustness of our results, we set different influence radii of 400, 500, 600, and 700 m, respectively. This variation in radius helps us examine the potential impact of different distance thresholds on the premium effects observed in the housing market.

For obtaining other neighborhood data, we primarily relied on Anjuke.com, one of the largest real estate agent websites in China. We conducted web crawling to collect the data from March 2016, June 2016, September 2016, and December 2016. From 2017 to 2021, we performed annual crawls updated information in September. The raw data obtained from these crawls are cross-sectional. To create a balanced panel dataset, we matched the neighborhoods based on their names across each cross-section. As a result, we constructed a panel dataset consisting of 1,852 neighborhoods observed over 9 time periods.

In addition to the housing price of the neighborhoods (price), we also crawl several physical attributes of the neighborhood, such as the built year of the neighborhoods (build_year), the average greening rate (green), the average floor area ratio (floor_ratio), and the average property management fees (property fee). We use ArcGIS to calculate locational at-tributes of neighborhoods and obtain the distance to the nearest metro station (metro_dis), to tertiary hospital (hospi_dis), to landscape park (park_dis) and the distance to the city center (CBD_dis). The old neighborhood upgrading project accounts for approximately 12% of the total neighborhood samples. These neighborhoods mainly locate in inner-ring of Hefei city and were built before the year 2000(Fig. 1).

Table 1 presents the descriptive statistics of both the treatment and control neighborhoods. We calculated the differences in characteristics between the two groups, both before and after the implementation of the upgrading projects. The simple comparison of these characteristics reveals some notable patterns in our data. Firstly, the average price and

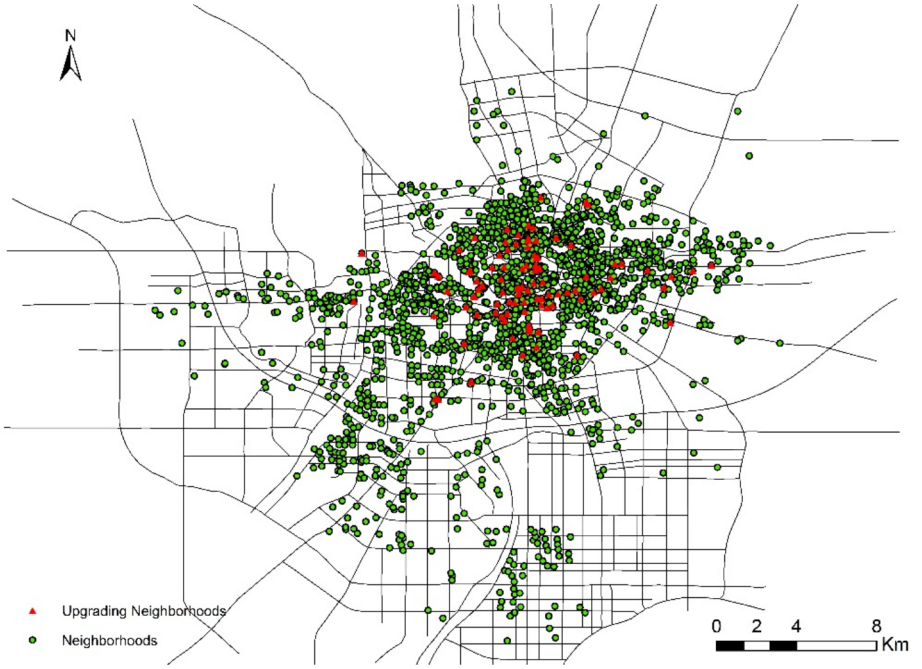

Fig. 1 Map of research samples

change rates are higher in the treatment group. The average price of the treatment group increased by 23.3% after the implementation of the upgrading projects, while the control group experienced an increase of 18.5%. Secondly, the treatment group enjoys location advantages compared to the control group. They are situated closer to public goods such as metro stations, parks, and hospitals. Thirdly, the treatment neighborhoods tend to be older in terms of construction. They were built around the year 2000, which is approximately 5 years earlier than the control group. By including these variables in our specification, we ensure that our analysis compares neighborhoods with similar housing attributes, thereby providing more convincing estimates of the effects of the upgrading projects.

5 Results

5.1 Baseline regression

Table 2 presents the baseline regression results of the impact of the ONUP on the nearby neighborhoods' prices. Columns (1) and (2) report the estimated results of Eq. (1), and columns (3) and (4) report the spatial heterogeneous impacts based on Eq. (2). We control the time fixed effect, district fixed effect and match fixed effect in all the specifications.

The estimates of Eqs. (1) and (2) reveal a significant positive effect of the ONUP on the nearby neighborhoods' prices. The estimates of *renewal* and *renewal *distance* are significant statistically. According to our estimate in Eq. (2), compared to neighborhoods locate beyond a 500-meter radius from the upgrading neighborhoods, the old neighborhood

Table 1 Descriptive statistics of variables

Panel A	Before the Upgrading Projects			After the Upgrading Projects		
Simple Comparison	Treat	Control	Mean Diff	Treat	Control	Mean Diff
lnprice	9.490	9.480	0.011*	9.700	9.650	0.049***
property fee	0.460	0.760	-0.296***	0.460	0.760	-0.296***
floor_ratio	2.400	2.360	0.0370	2.400	2.360	0.0370
build_year	2000	2005	-5.736***	2000	2005	-5.736***
green	0.430	0.610	-0.185***	0.430	0.610	-0.185**
metro_dis	2.220	4.150	-1.925***	0.960	1.450	-0.496***
park_dis	1.130	1.330	-0.208***	1.130	1.330	-0.208***
hospi_dis	1.100	2.370	-1.264***	1.100	2.370	-1.264***
CBD_dis	2.680	6.690	-4.011***	2.680	6.690	-4.011***
observations	3605	5610	-	2884	4488	-

Panel B Summary Statistics	N	Mean	SD	Min	Max
lnprice	16,587	9.560	0.320	6.990	10.95
treat	16,587	0.390	0.490	0	1
renewal	16,587	0.440	0.500	0	1
renewal treat	16,587	0.170	0.380	0	1
property fee	16,587	0.640	0.560	0	4.500
floor_ratio	16,587	2.380	1.060	0.100	9.650
build_year	16,587	2003	7.340	1956	2016
green	16,587	0.540	3.140	0	60
metro_dis	16,587	2.440	2.540	0.0400	17.90
park_dis	16,587	1.250	0.660	0.0700	4.510
hospi_dis	16,587	1.870	1.420	0.0700	9.080
CBD_dis	16,587	5.120	3.520	0.120	17.19

Notes ∗significant at 10%; ∗∗significant at 5%; ∗∗∗significant at 1%

upgrading projects increase the price of nearby neighborhoods within 500 m by 6.01%. To illustrate the magnitude of our estimates, consider that the average price of treatment neighborhoods before the upgrading projects is 13226.8 RMB, then the estimates indicate the upgrading project would increase the treatment neighborhoods by 794.9 RMB per square meter. Meanwhile, the estimates of column (4) indicate the distance between the upgrading projects and the treatment neighborhoods increases 100 m, the average premium effect decrease by 2.87%.

A concern that the presence of spatial spillovers may often arise when exploiting such geographical design[2]. However, in our analysis, the trouble caused by spillovers should be minor. Firstly, we control for a matched fixed effect that define each upgrading project and its nearby neighborhoods belong to a same group. By controlling for such fixed effect we can rule out all time-invariant unobserved common factors that affect housing price within the same matched group. Secondly, we also cluster the standard error at the neighborhood-match level to allow for arbitrary correlation of disturbance that belong to the same matched group. Moreover, even with the presence of spatial spillovers, our model can only underestimate the effect of ONUP. This is because that the effect of spillover to the control units is more likely to be positive, since the premium is a positive decaying function of the distance. Therefore, the outcome of the control units is more likely to be higher than the counterfac-

[2] We thank both reviewers for pointing out such issue.

Table 2 Baseline regression results

	(1)	(2)	(3)	(4)
renewal	0.0460**	0.0601***	0.1373***	0.1756***
	(0.0210)	(0.0191)	(0.0285)	(0.0245)
treat	-0.0064	-0.0281**	-0.0169	-0.0518***
	(0.0143)	(0.0139)	(0.0200)	(0.0183)
*renewal *distance*			-0.0276***	-0.0287***
			(0.0057)	(0.0051)
property fee		0.0931***		0.0927***
		(0.0083)		(0.0082)
build_year		0.0024**		0.0026***
		(0.0010)		(0.0010)
floor_ratio		-0.0048		-0.0052
		(0.0032)		(0.0032)
green		0.0027**		0.0027**
		(0.0012)		(0.0012)
metro_dis		-0.0154***		-0.0130***
		(0.0035)		(0.0033)
park_dis		-0.0893***		-0.0894***
		(0.0145)		(0.0147)
hospi_dis		-0.0323***		-0.0294***
		(0.0085)		(0.0088)
CBD_dis		0.0002		-0.0107
		(0.0052)		(0.0066)
Time Fixed Effect	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes
Matched Fixed Effect	Yes	Yes	Yes	Yes
Observations	16,587	16,587	16,587	16,587
R^2	0.4842	0.5644	0.4878	0.5716

Notes Standard errors in parentheses are clustered at the neighborhood-match level, which each upgrading projects and its' nearby neighborhood belongs to a matched group. ∗significant at 10%; ∗∗significant at 5%; ∗∗∗significant at 1%

tual without spillover, and the comparison between treated and control units is thus more likely to results in an estimation of the lower bound.

5.2 Event study specification

Precisely estimating the treatment effect of ONUP requires the parallel trend assumption, in which the control neighborhoods need to be served as appropriate counterfactuals for the treatment neighborhoods. Our baseline specifications would be invalid if the housing price trajectories of treatment and control groups diverged before the projects. To formally test the existence of such pre-trend, we estimate the following event study specification:

$$lnprice_{ijt} = \alpha + \beta_t \sum_{t=-8, t\neq -1}^{3} treat_{ij} * I_{ijt} + X_{it} + \varphi_d + \eta_j + \lambda_t + \varepsilon_{ijt} \tag{4}$$

Where, I_{ijt} is the set of dummy indicators that specifies the time of the ONUP. We set the reference period as the upcoming period before the treatment, and omit the corresponding dummy in the regression. Other variables are equally defined as in preceding specifications.

As discussed by Sun and Abraham (2021), the effectiveness of dynamic version of the TWFE model is limited due to the homogeneity treatment effect, which we use in baseline specification. To allow for treatment effects varies across time and the treatment units, we present the event study figures (Fig. 2) generated by a set of recently proposed estimators that are robust to treatment effect heterogeneity (Borusyak et al., 2023; Callaway & Sant'Anna, 2021; Sun & Abraham, 2021). We overlay the event-study plots constructed using four different estimators: a dynamic version of the TWFE model, estimated using OLS (in orange with square markers); Sun and Abraham (2021) (in green with triangle markers); Callaway and Sant'Anna (2021) (in blue with diamond markers); and Borusyak et al. (2023) (in red with cross markers).

Regardless of these estimators, the following results are consistent with the parallel trend assumption: the coefficients on the periods before the housing renewal are all close to zero and exhibit no discernible pre-trends in all estimators.

5.3 Dynamic effect specification

Based on Eq. (3), we estimate the dynamic effect of the ONUP on neighborhoods' prices in Table 3. We estimate the time-dynamic effect in columns (1) and (2) reports the, and the time-spatial dynamic effect in columns (3) and (4) and Fig. 3. In Fig. 3, the horizontal axis represents the distance between the treatment neighborhoods and the nearest upgrading neighborhoods, while the vertical axis represents the premium effect of the treatment

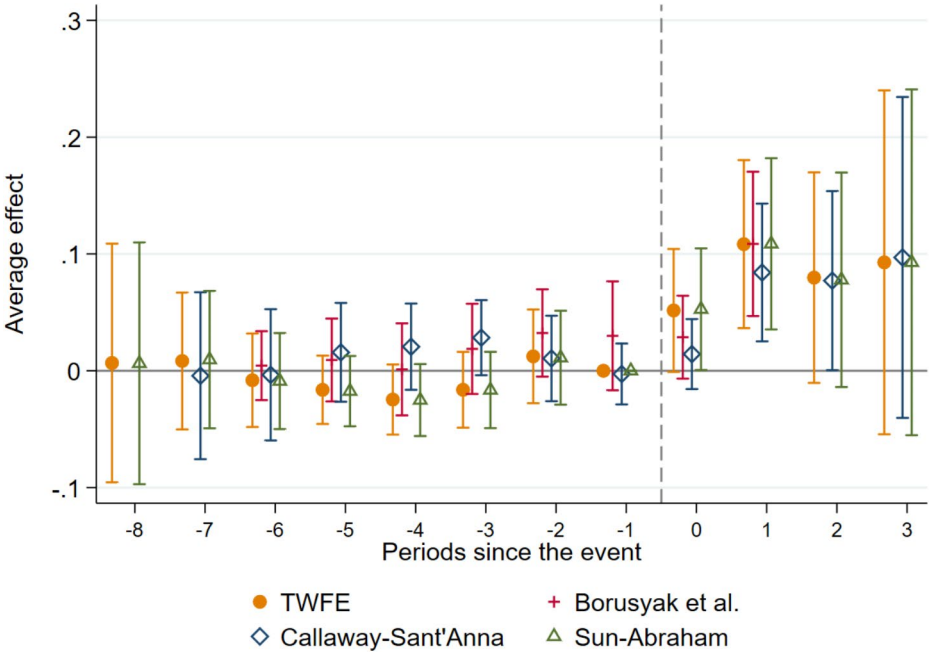

Fig. 2 Event study plots

Table 3 Results of dynamic effect specification

	(1)	(2)	(3)	(4)
renewal	0.0423**	0.0546***	0.1333***	0.1696***
	(0.0199)	(0.0184)	(0.0280)	(0.0237)
treat	-0.0045	-0.0255*	-0.0145	-0.0488***
	(0.0143)	(0.0137)	(0.0202)	(0.0182)
*treat*trend*	0.0115	0.0188**	0.0122	0.0199**
	(0.0098)	(0.0084)	(0.0095)	(0.0080)
*renewal *distance*			-0.0274***	-0.0284***
			(0.0057)	(0.0051)
Control Variables	No	Yes	No	Yes
Time Fixed Effect	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes
Matched Fixed Effect	Yes	Yes	Yes	Yes
Observations	16,587	16,587	16,587	16,587
R^2	0.4846	0.5655	0.4883	0.5729

Notes Standard errors in parentheses are clustered at the neighborhood-match level, which each upgrading projects and its' nearby neighborhood belongs to a matched group. ∗significant at 10%; ∗∗significant at 5%; ∗∗∗significant at 1%

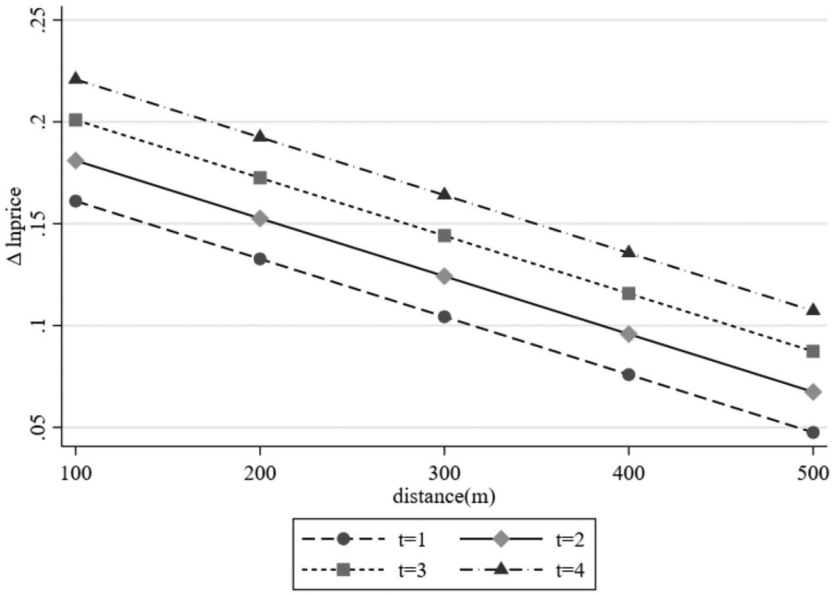

Fig. 3 Spatial-temporal dynamic of the ONUP' spillover

neighborhoods in comparison with the control neighborhoods. t-1 to t-4 represent the first to the fourth year after the implementation of upgrading projects. We specify the dynamic effect by two terms from Table 3, i.e., the estimated coefficient of *renewal* and *treat*trend*, where the former represent the treatment effect in current period and the latter represent the

linear trend of treatment effect. We multiply the duration of treatment (i.e., 1,2,3 or 4) with estimates of *treat*trend*, and add it with estimates of *renewal* to obtain the dynamic effect.

Our findings reveal that as time progresses after the implementation of the ONUP, the premium effect on the treatment neighborhoods steadily increases, with an average annual increase in housing prices of 1.88%. This suggests that ONUP has a sustained spatial spillover effect on the surrounding housing market, leading to an appreciation in housing prices over time. However, it is important to note that the premium effect of the ONUP gradually diminishes as the distance from the upgrading neighborhoods increases. This distance decay effect indicates that the impact of the ONUP on housing prices becomes less pronounced as the distance between the upgraded areas and the surrounding neighborhoods grows.

5.4 Heterogeneity analysis

5.4.1 Administrative districts

Hefei city is divided into four districts, each with its own distinct characteristics and historical development. The initial urban planning of Hefei, as outlined in the first edition of the city's overall urban planning (1979–2000), focused on the old town and three new districts. The old town of Hefei is the core area that houses numerous government institutions and administrative centers. It serves as the historical center of the city. The three new districts, were established to accommodate the city's expanding commercial enterprises and universities. These districts have experienced significant growth and development in recent years. In 2002, the old town was officially designated as the Luyang District, while the other three districts were renamed as Shushan District, Baohe District, and Yaohai District. This division of Hefei into four districts reflects the city's strategic urban planning and development approach, with a focus on both preserving the historical center and facilitating the growth of commercial and educational sectors in different areas.

The distribution of these neighborhoods is closely tied to the historical functions and development of the different districts. Luyang District, being the location of the former Anhui Provincial Government and Hefei Municipal Government, has a concentration of welfare housing units that were primarily designated for employees of public institutions. On the other hand, the old neighborhoods in the other districts, such as Shushan District, Baohe District, and Yaohai District, are characterized by dormitories that were originally built to accommodate employees of industrial enterprises or universities. Given the different historical functions and characteristics of these districts, it is plausible to expect variations in the premium effects of the ONUP across these areas.

Thus, we use a subsample of Luyang district and other districts to examine the heterogeneity of administrative districts. The results in Table 4 show no administrative district heterogeneity of the impact ONUP on nearby neighborhood prices, indicating both the upgrading projects on welfare housing units, and the dormitories of industrial enterprises or universities can increase the housing price of nearby neighborhoods.

5.4.2 Community types

The ONUP in Hefei encompasses two distinct community types: commercial communities and *danwei* compounds. These community types reflect different housing ownership and

Table 4 Heterogeneity analysis results of administrative districts

	Luyang district		Other districts	
	(1)	(2)	(3)	(4)
renewal	0.1353**	0.1456**	0.0968***	0.1020***
	(0.0523)	(0.0569)	(0.0344)	(0.0326)
treat	-0.0937***	-0.0927***	0.0082	0.0058
	(0.0350)	(0.0322)	(0.0227)	(0.0219)
*renewal *distance*		-0.0200***		-0.0200***
		(0.0058)		(0.0058)
Control Variables	Yes	Yes	Yes	Yes
Time Fixed Effect	Yes	Yes	Yes	Yes
District Fixed Effect	No	No	Yes	Yes
Matched Fixed Effect	Yes	Yes	Yes	Yes
Observations	3319	3319	13,265	13,265
R^2	0.6638	0.6388	0.4517	0.5330

Notes Standard errors in parentheses are clustered at the neighborhood-match level, which each upgrading projects and its' nearby neighborhood belongs to a matched group. ∗significant at 10%; ∗∗significant at 5%; ∗∗∗significant at 1%

development patterns. Commercial communities refer to housing units that are developed, constructed, and sold by real estate developers on the market for profit. These properties are typically owned by individuals or investors who have purchased them from the developers. On the other hand, *danwei* compounds refer to housing units that were originally built by the government or industrial enterprises (Zhang et al., 2021). These units were typically collectively owned and provided as housing for employees of these institutions. However, since the housing system reform in 1998, there has been a transformation of these collectively-owned properties into individually-owned properties. This reform allowed individuals to acquire ownership rights over the housing units they occupied within the *danwei* compounds. The distinction between commercial communities and *danwei* compounds in the ONUP highlights the different ownership structures and historical development processes of these neighborhoods. Thus, we use subsample of commercial communities and *danwei* compounds to examine the heterogeneity of community types.

The results presented in Table 5 indicate that both commercial communities and *danwei* compounds experience similar premium effects from the upgrading projects. In other words, the implementation of ONUP in both types of communities leads to an increase in the housing prices of nearby neighborhoods. This finding suggests that the upgrading projects carried out in commercial communities, which are privately developed and owned, and in *danwei* compounds, which are transformed from collectively-owned to individually-owned properties, have a positive impact on the surrounding housing market. Furthermore, the results highlight that the premium effect of ONUP on *danwei* compounds is more robust. This indicates that the marginal effect of the upgrading projects is more pronounced for *danwei* compounds, which may have been in a state of disrepair before the projects.

5.4.3 Upgrading types

The ONUP can be classified into three distinct types: basic-oriented, improvement-oriented, and upgrading-oriented. Again, we use subsample to examine the heterogeneity of upgrad-

Table 5 Heterogeneity analysis results of community types

	Commercial community		Danwei compounds	
	(1)	(2)	(3)	(4)
renewal	0.0222	0.0946**	0.0658**	0.1945***
	(0.0199)	(0.0359)	(0.0307)	(0.0340)
treat	-0.0089	-0.0350	-0.0340*	-0.0606***
	(0.0171)	(0.0250)	(0.0186)	(0.0227)
*renewal*distance*		-0.0159*		-0.0304***
		(0.0081)		(0.0064)
Control Variables	Yes	Yes	Yes	Yes
Time Fixed Effect	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes
Matched Fixed Effect	Yes	Yes	Yes	Yes
Observations	7821	7821	8766	8766
R^2	0.5889	0.5931	0.5861	0.5941

Notes Standard errors in parentheses are clustered at the neighborhood-match level, which each upgrading projects and its' nearby neighborhood belongs to a matched group. ∗significant at 10%; ∗∗significant at 5%; ∗∗∗significant at 1%

Table 6 Heterogeneity analysis results of upgrading types

	Basic-oriented		Improvement-oriented		Upgrading-oriented	
	(1)	(2)	(3)	(4)	(5)	(6)
renewal	0.0618**	0.0532	0.0704**	0.2066***	0.0612	0.1680**
	(0.0249)	(0.0415)	(0.0310)	(0.0369)	(0.0621)	(0.0759)
treat	-0.0203	0.0126	-0.0020	-0.0296	0.0187	-0.0097
	(0.0202)	(0.0344)	(0.0203)	(0.0264)	(0.0502)	(0.0630)
*renewal*distance*		-0.0041		-0.0352***		-0.0248*
		(0.0085)		(0.0076)		(0.0123)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Matched Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3616	3616	7028	7028	1377	1377
R^2	0.5660	0.5690	0.5782	0.5884	0.6490	0.6619

Notes Standard errors in parentheses are clustered at the neighborhood-match level, which each upgrading projects and its' nearby neighborhood belongs to a matched group. ∗significant at 10%; ∗∗significant at 5%; ∗∗∗significant at 1%

ing types. The results in Table 6 show the improvement-oriented and upgrading-oriented types have premium effects when controlling for spatial heterogeneity, indicating that projects highlighting living conditions and public service will increase housing prices in nearby neighborhoods. However, we only investigate this heterogeneity from the community type but not the investment structure on elevators, parking lots or elder care which requires more detailed investment budget data.

5.5 Robustness checks

5.5.1 Alternative distance range

In the baseline regression, we set the neighborhoods within a 500-meter radius of their nearest upgrading neighborhood as the treatment neighborhoods. However, previous literature on the premium of urban renewal often sets different distance ranges based on the characteristics of the case cities (Liu & Chen, 2021; Zhang et al., 2023), thus may cause potential sample selection bias and estimation results biased. So, we re-adjust the distance radius settings to exclude potential sample selection bias. We re-run the Eq. (1) with the distance radius of 400, 600 and 700 m respectively in column (1) to (3) in Table 7, and the results are consistent with the baseline specifications.

5.5.2 Propensity score matching

The staggered DID demands comparability between the treatment group and the control group. However, the descriptive statistics show the treatment neighborhoods and the control neighborhoods have significant differences in the physical and locational characteristics, which may confound with our specifications. Although we control for the physical attributes and locational characteristics of neighborhoods, there may still be potential unobservable variables bias.

To alleviate this concern, we conduct propensity score matching (PSM) to rematch the treatment neighborhoods and the control neighborhoods. This matching process is based on the similarities in the observed physical attributes and locational characteristics of the neighborhoods. Specifically, we employ a k-nearest neighbor matching and set k to be 1, with a caliper radius to be 0.01. To ensure that our matching process indeed balanced our sample, we conduct a balance test and plot the results in Fig. 4. As shown in the figure, the unmatched sample are highly varied in terms of covariates, especially for their distance to the city center and hospital. However, after matching, the differences in covariates between

Table 7 Robustness checks results

	(1) 400 m	(2) 600 m	(3) 700 m	(4) PSM-DID	(5) PSM-DID
renewal	0.0724***	0.0399***	0.0240***	0.0421**	0.1375***
	(0.0102)	(0.0090)	(0.0089)	(0.0188)	(0.0238)
treat	-0.0286***	-0.0299***	-0.0233**	-0.0183	-0.0361**
	(0.0091)	(0.0098)	(0.0099)	(0.0129)	(0.0171)
*renewal *distance*					-0.0211***
					(0.0049)
Control Variables	Yes	Yes	Yes	Yes	Yes
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes	Yes
Matched Fixed Effect	Yes	Yes	Yes	Yes	Yes
Observations	16,587	16,587	16,587	16,160	16,160
R^2	0.5650	0.5637	0.5632	0.5671	0.5732

Notes Standard errors in parentheses are clustered at the neighborhood-match level, which each upgrading projects and its' nearby neighborhood belongs to a matched group. ∗significant at 10%; ∗∗significant at 5%; ∗∗∗significant at 1%

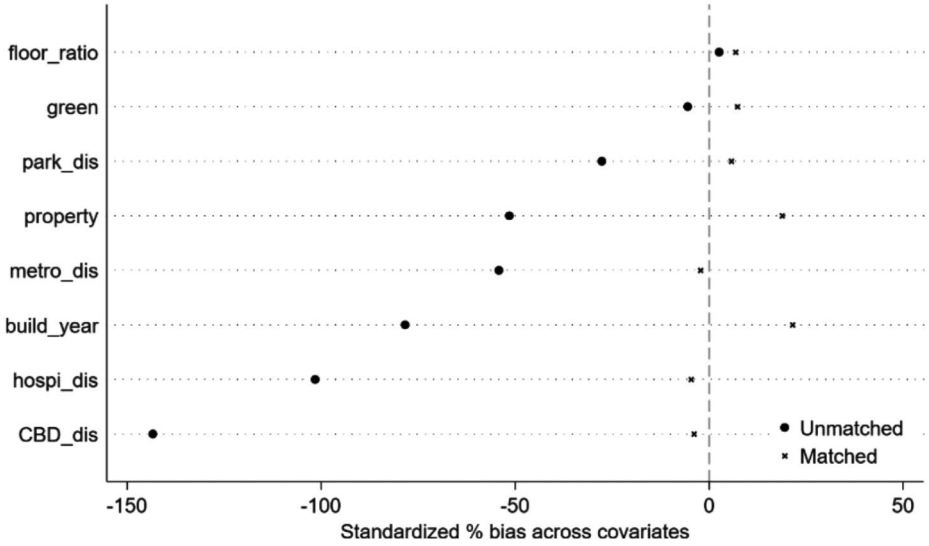

Fig. 4 Balancing test

treated and control groups significantly reduce and are close to zero. By employing PSM and re-matching the treatment and control groups, we aim to create a more comparable set of neighborhoods, reducing the potential bias arising from differences in these characteristics. Thus, we rerun the estimation on Eqs. (1) and (2). Reassuringly, the estimates are significant statistically in columns (4) and (5) in Table 4, which indicates the baseline regression is robust.

5.5.3 Placebo tests

To further inspect whether our estimated effects of the upgrading projects are originated from other unobservable factors, we conduct a placebo test. We randomly assign the time and the treatment group of the upgrading projects, and re-run the baseline regression to estimate the coefficient and its significance for 500 times, and obtain 500 coefficients and p-values. The distribution of these coefficients and p-values are plotted in Fig. 5 − 1 and 5 − 2. For comparison, we add a vertical dash line to denote the true estimated effect reported in column (2), Table 2.

5.6 Potential explanations

Previous studies have indicated that the renewal of shantytowns or urban villages can lead to an increase in commercial spaces, which in turn promotes community vitality and appreciation of housing prices in surrounding neighborhoods (Liu & Chen, 2021). Bantman-Masum (2020) provides evidence from Paris, highlighting the proliferation of commercial and leisure spaces such as café chains and boutiques after urban renewal. This expansion of commercial and leisure amenities caters to the consumption demands of the growing middle

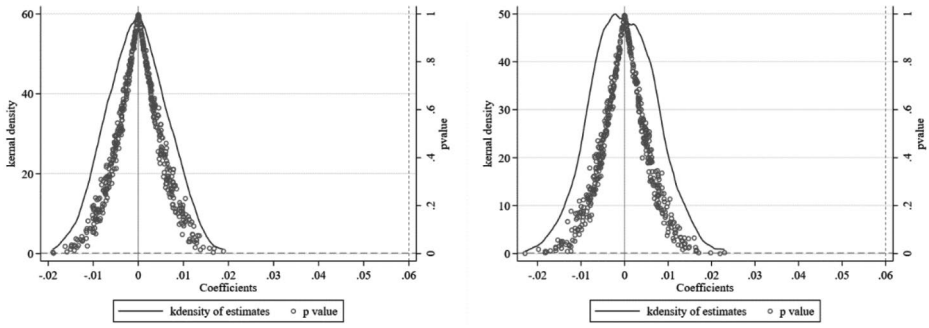

Fig. 5 (5-1) Randomly assignment of the upgrading projects' time. (5-2) Randomly assignment of the upgrading projects' treatment neighborhoods

class. As a result, the surrounding neighborhoods become more attractive and desirable, leading to an increase in housing prices in those areas.

Inspired by these studies, we follow Ma et al. (2023) that employ POI data to measure commercial activities in surrounding neighborhoods, and calculate the number of commercial POI of each neighborhood within a radius of 1 km. This distance setting is referenced to the "quarter-clock community living circle", a nationally advocated community plan that meets the residents within a suitable walking distance (Chan & Li, 2022). We classify four categories of commercial POI, that is, Catering (e.g., Chinese and foreign restaurants), Finance (e.g., banks, and insurance agents), Shopping (e.g., supermarkets and convenient stores) and Recreation (e.g., theatres, amusement parks, bar, gym, KTV, and stadium). The majority of POIs are related to leisure activities such as shopping, dining, and entertainment, which is consistent with pedestrian activities for urban vitality analysis.

Data are drawn from map.baidu.com, one of the biggest china navigation map websites. Thus, we generate *vitality* variable, which is the log number of the above four measures of commercial activities of each neighborhood with a distance of 1 km. So, we interact the *vitality* with other key variables in Eq. (4) to examine the impact of community vitality as follows:

$$\begin{aligned} lnprice_{ijt} = \alpha + \beta treat_{ij} + \gamma renewal_{ijt} + \delta renewal_{ijt} * vitality_{it} \\ + X_{it} + \varphi_d + \eta_j + \lambda_t + \varepsilon_{ijt} \end{aligned} \tag{4}$$

where, $vitality_{it}$ represents the log number of the above five measures of commercial activities of each neighborhoods with a distance of 1 km. We focus on the coefficient δ, which captures the price changes induced by nearby commercial activity number changes of upgrading projects *j*. In addition, Eq. (4) also has a series of control variables and fixed effects, which are equally defined as in the preceding specifications. The results in Table 8 show that *renewal* **vitality* is significant statistically in all specifications, indicating the increasing commercial activities after the upgrading projects drive up the housing prices of surrounding neighborhoods. In other words, the ONUP will cause positive premium effects through community vitality.

Table 8 Potential explanation: urban vitality

	(1)	(2)	(3)	(4)	(5)
*renewal *ln(1+catering)*		0.086***			
		(0.018)			
*renewal *ln(1+shopping)*			0.072***		
			(0.016)		
*renewal *ln(1+finance)*				0.062***	
				(0.015)	
*renewal *ln(1+recreation)*					0.140***
					(0.020)
renewal	-0.0001	0.003	-0.005	0.024***	0.019***
	(0.0003)	(0.007)	(0.006)	(0.007)	(0.007)
treat	-0.0014**	-0.019	-0.023*	-0.014	-0.008
	(0.0006)	(0.013)	(0.013)	(0.013)	(0.012)
Control Variables	Yes	Yes	Yes	Yes	Yes
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes	Yes
Matched Fixed Effect	Yes	Yes	Yes	Yes	Yes
Observations	16,587	16,587	16,587	16,587	16,587
R^2	0.5634	0.567	0.567	0.569	0.578

Notes: Standard errors in parentheses are clustered at the neighborhood-match level, which each upgrading projects and its' nearby neighborhood belongs to a matched group. ∗significant at 10%; ∗∗significant at 5%; ∗∗∗significant at 1%

6 Conclusion and discussion

We take the old residential neighborhood upgrading projects in Hefei city from 2016 to 2021 as quasi-natural experiments, and use the staggered DID method to evaluate the premium effect of urban ONUP on housing markets. The ONUP causes an average increase of 6.01% in housing prices within a 500-meter radius. After a series of tests such as distance range adjustments and PSM-DID, the results remain robust. This positive spillover effect exhibits both temporal persistence and distance decay trends. Following the implementation of the projects, housing prices in the surrounding areas experience an average annual increase of 1.88%. Moreover, for every 100-meter increase in distance from the upgrading neighborhoods, the average premium effect decreases by 2.87%, indicating a diminishing impact as the distance from the upgraded areas increases. Mechanism analysis indicates that the ONUP enhances the vitality of the neighborhoods, thereby increasing housing prices in the surrounding areas.

We verify that the ONUP can activate the demand of the surrounding housing market, and three key policy implications can be derived:

Firstly, the government's early promotion of ONUP can attract private capital, thereby relieving the public finance. Constrained by public fiscal budgets, urban renewal has been transforming from the government-led mode, which was initiated, funded and implemented solely by the government to the public-private cooperation mode. Private capital is a potential and promising source of the renewal funds, and can be invested through public-private-partnership (PPP), build-operate-transfer (BOT), stock dividend, REITs, and other forms (Han and Guo, 2024; Li et al., 2023). In recent years, private capital has gradually begun to

participate in China's ONUP by PPP or BOT model, and has won high praise from residents (Chen & Qu, 2020). The key to attracting private capital is the appreciation of housing prices. Our study suggests that promoting the renovation and revitalization of old neighborhoods can stimulate residents' demand for the surrounding housing market, which would attract the private capital flow in, thereby relieving the public finance and sustaining the capital flow for urban renewal.

Secondly, ONUP's project selection should take into account the spatial relationship among them to maximize the efficiency of fiscal funds. Previous studies highlight the evaluation methods for ONUP from the urban planning, renovation scheme, or renovation performance, and most study indicate that the renovation sequence of ONUP is important (Chen et al., 2023). However, our study finds ONUP didn't vary significantly based on administrative districts or community types, indicating both the upgrading projects on welfare housing units, the dormitories of industrial enterprises or universities, commercial communities or *danwei* compounds can increase the housing price of nearby neighborhoods. And the positive premium effect of ONUP exhibits both temporal persistence and distance decay trends. Therefore, ONUP's project selection should not examine the potential renovated neighborhoods separately, but take into account the spatial relationship between them. From our empirical results, the potential renovated neighborhoods should locate around 1.4 km (700 m multiply by 2), thus the surrounding neighborhood would benefit from the positive spillover effect of renovated neighborhoods.

Lastly, investment funds should be invested more on improvement-oriented or upgrading-oriented types of ONUP. Our study finds that the improvement-oriented or upgrading-oriented types of ONUP have premium effects when controlling for spatial heterogeneity, however the basic-oriented type of ONUP is weaker. Thus, investment should prioritize residents with increased convenience and quality of life by installing elevators, building retrofitting, and improving energy efficiency. These projects include improvements to accessibility, neighborhood green spaces, lighting, aged-friendly facilities, parking lots, recreational or fitness facilities, elderly care, childcare, medical, and convenience stores. These improvements will contribute to the overall livability and attractiveness of the renovated neighborhoods, further boosting the demand for housing in the surrounding areas.

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Declarations

Competing interests The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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