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Health resilience of green buildings in a Dense City: Evidence from COVID-19 infections in Hong Kong

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ABSTRACT

This study examines whether green buildings contribute to health resilience during public health crises in a dense city. Utilizing a dataset of 1552 public housing blocks in Hong Kong from January 2020 to December 2022, our findings suggest that residents living in green buildings are associated with significantly lower infection rates compared to those in non-green buildings. This effect is most pronounced during Hong Kong's fifth wave of the COVID-19 pandemic, when community transmission and case counts peaked. These findings remain robust after controlling for building prototype fixed effect and isolating the confounding effect of building age and post-SARS upgrades. Heterogeneity analyses further suggest that the association between green buildings and lower infection rates is stronger for higher certification levels (e.g., BEAM Plus Gold or Platinum), and is particularly pronounced in contexts characterized by structural vulnerability and elevated epidemiological risk, including districts with higher population density, elevated infection risk, and lower resident income. Overall, our study provides novel empirical evidence on the social value of greenness during pandemics, highlighting the potential of green buildings to serve as a defense mechanism in dense urban environments. These findings suggest that health resilience should be integrated into future green building standards and public housing policy.

1. Introduction

The COVID-19 pandemic has fundamentally reshaped our understanding of the built environment's role in public health. As governments around the world implemented lockdowns, stay-at-home orders, and social distancing measures (Li et al., 2022), residential buildings became more than just homes - they emerged as critical frontlines in the fight against infectious diseases. In high-density cities like Hong Kong, where 7.5 million residents live in compact high-rise buildings and the median per capita living space is only 16 square meters (based on 2021 data from the Census and Statistics Department),[1] the design and quality of residential environments have played a crucial role in curbing disease transmission. With prolonged periods of home confinement and limited social interaction, the risk of intra-household and inter-unit virus spread has intensified. During the peak of Hong Kong's fifth wave of outbreak in early 2022, the number of confirmed cases boomed to an unprecedented height, highlighting the urgent need to understand how residential infrastructure influences infection dynamics.

In this public health crisis, the broader societal functions of green buildings have come into focus. Beyond well-documented economic and energy benefits such as rental premiums and reduced operating costs (Eichholtz et al., 2010; Fuerst & McAllister, 2011; Hui & Yu, 2021; Sun et al., 2024), a growing literature has associated green building with chronic health or cognitive performance outcomes, given their unique advantages in building ventilation and indoor environmental quality (IEQ) (Allen et al., 2015, 2016; MacNaughton et al., 2016; Mannan & Al-Ghamdi, 2021; Robinson et al., 2016; Worden et al., 2020). However, due to the lack of precise data, it remains unclear whether green-certified buildings could mitigate infectious disease transmission, especially in dense, high-rise public housing settings.

Hong Kong sets a suitable context to examine the health impact of green buildings during the pandemic. First, the mandatory

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[1] https://www.censtatd.gov.hk/en/scode600.html.

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implementation of the Building Environmental Assessment Method Plus (BEAM Plus) certification since 2011 results in the coexistence of green-certified blocks and non-certified ones that share similar construction standards under the Hong Kong Housing Authority (HKHA)'s centralized planning. Following the mandate, all new public rental developments are required to achieve at least a Gold rating, which incorporates specific design interventions, including independent drainage stacks and dual-aspect layouts (HKGBC, 2021). We hypothesize that these structural upgrades in green-certificated blocks could serve as a passive barrier, thereby helping mitigate the vertical spread of infection risks through drainage and airborne accumulation (Gao et al., 2008; Qiao et al., 2025). Second, the HKHA's waitlist-based and computer-randomized allocation system helps alleviate the self-selection bias often found in private markets (Chung, 2015; Millard-Ball et al., 2022). As residents are assigned units based on eligibility rather than their willingness to pay,[2] their socioeconomic profiles are likely more comparable across green-certified and non-certified blocks. Third, Hong Kong's Centre for Health Protection releases confirmed cases and lockdown orders at the block level. These high-frequency, high-resolution data enable us to match each infection record precisely with the green-certification registry, thereby reducing the measurement error that often plagues neighborhood-level studies.

Our empirical analysis is built on a comprehensive dataset of 1552 blocks of public housing in Hong Kong, covering confirmed COVID-19 cases across five waves of the pandemic from January 2020 to December 2022. The results suggest that green buildings are associated with significantly lower infection rates than their non-green counterparts. Over the full sample period, flats in green-certificated buildings showed an average 0.132 percentage point lower infection rate than those in non-green buildings. The magnitude is economically significant as the overall infection rate in the public housing is 0.96%. This effect is particularly pronounced during the fifth wave (December 2021 to June 2022), when daily infections in Hong Kong reached their peak. Our results remain robust across a range of specifications. We perform an interaction analysis for the fifth wave to examine differential infection patterns, construct a building-weekly sample using alternative outcome measures and model specifications, control for building prototype fixed effects to account for systematic differences in structural design and layout, and isolate the effects of building age and post-SARS upgrades through a post-SARS dummy and a pre-SARS subsample analysis. Across these robustness tests, green buildings consistently show lower infection levels, particularly under high transmission conditions, supporting the reliability of the observed associations. Further heterogeneity analyses reveal that higher levels of green certification correspond to greater infection reduction effects, and gold and platinum-certified buildings demonstrate the most pronounced decline relative to non-certified buildings. The effect of green buildings is also more pronounced in districts with elevated infection risk, higher population density, or lower household income, suggesting that green buildings may offer greater benefits under conditions of heightened structural or epidemiological vulnerability. These findings highlight the health effects of green buildings, especially under high infection pressure, and provide implications for incorporating sustainability standards into urban housing policy.

This study makes some key contributions. First and most important, this study extends the growing literature on the health impacts of green buildings by shifting the focus from general health to resilience during the pandemic. While a substantial body of work has established the benefits of green certification (and specialized health certification like Fitwel and WELL) for cognitive function and respiratory health (Allen et al., 2015, 2016; Ildiri et al., 2022; MacNaughton et al., 2016; Mannan & Al-Ghamdi, 2021; Worden et al., 2020), empirical evidence linking these building standards specifically to viral transmission risks remains scarce. By leveraging high-frequency, block-level infection data, we provide one of the first empirical assessments of whether green buildings help to against infectious disease outbreaks in a high-density setting. Second, compared with previous private market studies (Chung, 2015; Fuerst & McAllister, 2011; MacNaughton et al., 2016; Millard-Ball et al., 2022; Singh et al., 2010), our work can better alleviate selection bias where wealthier or health-conscious tenants sort into green buildings, given the waiting list-based and computer-randomized allocation of HKHA's public housing system. Finally, our work echoes the broader literature and policy concerns on the built environment and healthy cities (Liu et al., 2024; Liu & Liu, 2024; Morawska et al., 2024). While recent studies advocate health-resilient urban planning, most evidence is derived from district aggregates, and little research to date leverages variation in building standards to assess infection outcomes. By combining block-specific compulsory-testing records with green building certification progress in Hong Kong, we provide finer-level evidence and offer policymakers and urban planners actionable insights to integrate green standards into future urban planning.

The remainder of the study is structured as follows. Section 2 provides the background, reviews the relevant literature, and develops the research hypotheses. Section 3 details the data and sample used in our research. Section 4 reports our empirical results. The conclusion and discussion are given in Section 5.

2. Background, literature review and hypothesis development

2.1. Background

The prevalence of COVID-19 has highlighted a range of unique health risks in densely populated urban centers, including crowding in vertical neighborhoods, shared lift lobbies and light wells, and aging internal services that can propagate aerosols beyond the household level (Arbel et al., 2022; Banai, 2020). Hong Kong epitomizes this setting, where 7.5 million residents live in compact high-rise buildings and the median per capita living space is only 16 square meters (Census and Statistics Department, 2021). This type of hyper-dense built environment renders the city acutely vulnerable to outbreaks of highly transmissible pathogens. Fig. 1 shows that between 2020 and 2022, Hong Kong experienced five distinct epidemic waves. Prior to the Omicron incursion, the first four waves were relatively contained—only 12,636 cumulative infections (less than 0.2% of the population) had been recorded by December 2021. According to the statistics of Qiao et al. (2025), the sporadic confirmed cases in the first four waves were concentrated in public housing communities. The fifth wave (January–May 2022) dramatically reversed this record: within three months, confirmed cases surpassed 1.1 million, ultimately reaching nearly 2.9 million by mid-2023 (approximately 39% of residents) and stretching hospital capacity to its limit.

The Omicron surge highlighted the insufficiency of conventional behavioral interventions (e.g., masking, social distancing) in such ultra-high-density settings, shifting policy attention towards architectural and ventilation-based safeguards. Among the real estate properties in Hong Kong, public housing warrants particular scrutiny. Since the mid-1950s, the HKHA has constructed an extensive stock of high-rise rental estate that today houses nearly one-third of the total population. However, rapid construction left a legacy stock characterized by aging mechanical services, single-aspect units that inhibit cross-ventilation, energy-intensive envelopes, and continuous drainage stacks, features now implicated in higher operating costs and elevated aerosol-borne disease risk (Dai et al., 2024; Kandt et al., 2017). Additionally, the residents living in public rental housing are typically low-income and elderly, who tend to spend more time indoors and possess limited capacity to upgrade their living environments. This kind of resident sorting amplifies the significance of the built environment in determining infection risk and health equity.

[2] See https://www.housingauthority.gov.hk/tc/flat-application/application-guide/index.html

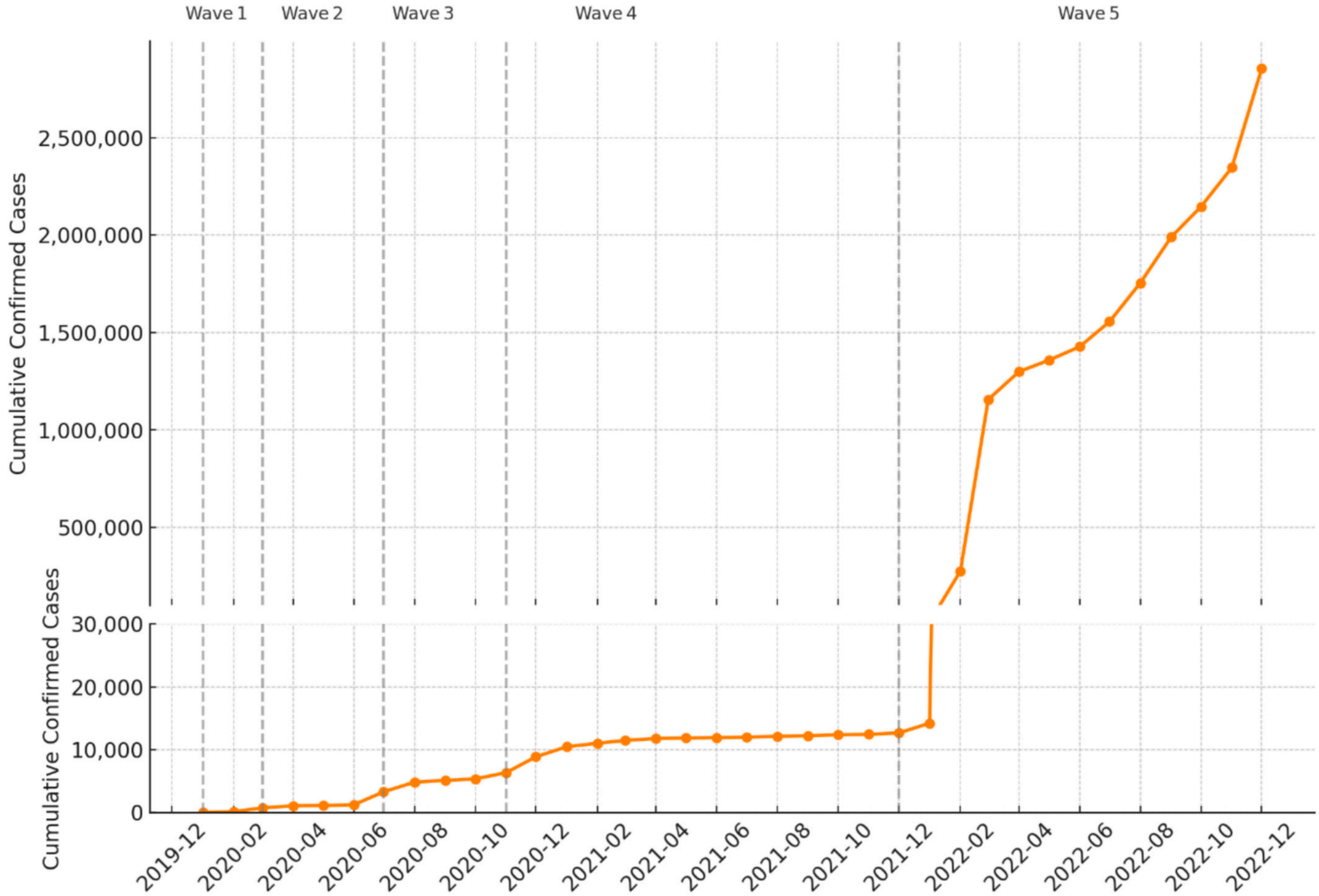

Fig. 1. Cumulative Confirmed COVID-19 Cases in Hong Kong.

Hong Kong's green-building assessment system, BEAM Plus, provides an opportunity for high-rise public estates to reduce health risks. BEAM Plus serves as the leading sustainability rating tool in Hong Kong, comparable to LEED in the U.S. The assessment classifies building performance across key categories, including Energy Use (EU) and IEQ (Hui et al., 2017). Based on the credits achieved, building blocks are awarded one of four hierarchical ratings: Platinum (the highest tier), Gold, Silver, and Bronze.[3] In 2011, the HKHA formally embedded the BEAM Plus scheme into its public rental developments, mandating that all new Housing Authority blocks achieve at least a Gold rating and prioritize legacy estates for phased green retrofits (HKMA, 2013).[4] Specifically, the Gold rating standard requires pressurized, separated drainage stacks, dual-aspect layouts that raise air-change rates by 30–40% over pre-2000 blocks (HKGBC, 2021).[5] By 2019, there was a 4% green building penetration rate in Hong Kong (Hong Kong Economic Times, 2019).[6] The coexistence of green public housing blocks and otherwise comparable, but uncertified, legacy blocks allows us to compare health outcome differences across the two types of blocks.

The following two stylized facts in Hong Kong further strengthen the credibility of our research design. First, the HKHA applies uniform eligibility criteria and a centralized waiting list for all public estates. In other words, residents living in certified and non-certified public housing are likely to share comparable demographics, such as income, age, and socioeconomic status, thereby limiting self-selection bias that arises from differential preventive behaviors or healthcare access. Second, the Centre for Health Protection released confirmed cases and lockdown orders at the block level. These high-frequency, high-resolution data enable us to match each infection record precisely with the green-certification registry, thereby alleviating the measurement error that often plagues neighborhood-level studies.

2.2. Literature review

Our work is related to two strands of literature. First, our work contributes to the growing body of literature on the impact of green buildings. Beyond the economic and environmental value of certified "green" buildings, such as rental premiums and reduced operating costs (Eichholtz et al., 2010; Fan et al., 2024; Fuerst & McAllister, 2011; Hui & Yu, 2021), energy savings (Sun et al., 2024), and improved waste management (Lu et al., 2019), a growing body of literature now links green building to broad health outcomes, driven by the rise of ESG frameworks and health-oriented certification systems such as WELL and Fitwel. These studies find that green buildings are associated with higher cognitive function scores in office workers (Allen et al., 2016), reduced symptoms of sick building syndrome (Singh et al., 2010), lower heart

[3] While granular IEQ sub-scores are publicly disclosed for only a subset of BEAM Plus–certified buildings, IEQ constitutes a core component of the BEAM Plus assessment framework. Available disclosures indicate that higher certification tiers are generally associated with better IEQ performance. Among buildings with reported scores, Platinum-rated projects exhibit average IEQ scores approximately 9.62 (out of 100) higher than those rated Gold.

[4] https://www.housingauthority.gov.hk/mini-site/hasr1314/sc/common/pdf/full.pdf

[5] https://www.hkgbc.org.hk/eng/beam-plus/beam-plus-references/manuals-assessment/ManualsFiles/BEAMPlus_New_Buildings_v2_0(2021Edition).pdf

[6] https://www.hkengineer.org.hk/issue/vol47-jun2019/cover_story/

Table 1
Summary statistics.

Variable	Obs.	Mean	Std. Dev.	Min	Max
CASERATIO (%)	1552	0.96	1.18	0.00	11.20
GB	1552	0.07	0.26	0.00	1.00
LNFLTATNO	1552	5.99	0.81	3.22	7.11
LNAGE	1552	3.24	0.68	0.00	4.20
LNMINSIZE	1552	2.79	0.35	2.10	3.57
LNMAXSIZE	1552	3.91	0.19	3.16	4.27
POST_SARS	1552	0.18	0.38	0	1
LNHH_SIZE	54	1.00	0.05	0.88	1.10
POSTEDU_RATIO (%)	54	27.15	8.41	16.80	46.10
LNPOP_DENSITY	54	9.33	1.21	6.91	11.03

rate (MacNaughton et al., 2016), and better respiratory health (Coombs et al., 2016; Robinson et al., 2016). Despite the rich literature on chronic health and productivity, empirical evidence regarding infectious disease transmission in residential environments remains limited. This study bridges this gap by providing one of the first empirical analyses linking green certification to COVID-19 infections at the building level in a dense public housing setting.

Our work also relates to the literature on the urban built environment and health. A large body of public health and urban planning research links poor ventilation, neighborhood density and building deterioration with higher rates of airborne infection and mental distress (Liu et al., 2024; Liu & Liu, 2024; Morawska et al., 2024; Rao et al., 2007). Yet, most evidence is derived from district aggregates, and little research to date leverages variation in building standards to assess infection outcomes. By combining block-specific compulsory-testing records with green building certification progress in Hong Kong, we alleviate the spatial-scale measurement error and selection bias that hinder existing studies. Our findings extend the urban health literature to the finer building scale, demonstrating the pandemic-mitigation benefits of codified green-building design.

Table 2
Confirmed case ratio (%).

Period	Range	GB	Non-GB	Diff.	t-statistics
Overall period	2020.01–2022.12	0.480	0.994	−0.513***	(−4.41)
Wave 1	2020.01–2020.02	0.000	0.000	−0.000	(−0.71)
Wave 2	2020.03–2020.04	0.000	0.003	−0.003	(−1.20)
Wave 3	2020.07–2020.09	0.020	0.036	−0.016	(−1.61)
Wave 4	2020.11–2021.04	0.016	0.046	−0.029**	(−2.32)
Wave 5	2021.12–2022.06	0.144	0.292	−0.149***	(−4.05)

2.3. Hypothesis development

SARS-CoV-2, the virus responsible for COVID-19, is primarily transmitted through respiratory droplets and aerosols, both of which are strongly influenced by indoor environmental conditions (Morawska & Milton, 2020). Poor ventilation and high residential density can increase the concentration of viral particles in the air, thereby elevating the risk of transmission. Green buildings consider the impact on the environment and the quality of life of occupants throughout the life cycle of the building, from design, operation, maintenance, renovation, to demolition (HKGBC, 2022). Although certification does not guarantee superior operational IEQ, the criteria embedded in BEAM Plus incentivize design and system features that support improved ventilation, pollutant filtration, and air-moisture control relative to conventional practices. For example, requirements such as increased air exchange rates, improved filtration performance, and dual-aspect layouts are intended to enhance airflow and reduce indoor pollutant accumulation.

Empirical studies provide evidence that many green-certified buildings tend to exhibit higher-performing ventilation and air-quality systems, contributing on average to better IEQ outcomes than non-certified buildings, though performance varies across operational contexts (Altomonte et al., 2019; Newsham et al., 2013). In the context of COVID-19, studies have further shown that the design and system features of green-certified buildings can facilitate faster removal of stale air and more effective dilution of airborne pathogens, thereby reducing the likelihood of viral transmission (Allen & Marr, 2020; Morawska and Milton, 2020).

In addition to mechanical systems, green buildings often incorporate spatial design features that reduce crowding. For example, green buildings with larger and more dispersed communal areas, wider corridors, and well-placed amenities can minimize close contact between

Table 3
Multicollinearity tests.

Panel A. Correlation matrix.

Variable	GB	LNFLTATNO	LNAGE	LNMINSIZE	LNMAXSIZE	LNHH_SIZE	POSTEDU_RATIO	LNPOP_DENSITY
GB	1.0000							
LNFLTATNO	0.1289	1.0000						
LNAGE	−0.2787	−0.2927	1.0000					
LNMINSIZE	−0.0383	−0.1999	0.2007	1.0000				
LNMAXSIZE	−0.0945	−0.2395	0.5187	0.1165	1.0000			
LNHH_SIZE	−0.0787	−0.0065	0.0706	0.1083	0.0691	1.0000		
POSTEDU_RATIO	−0.0797	−0.1157	0.0027	0.0897	−0.0447	0.2636	1.0000	
LNPOP_DENSITY	0.0357	0.1881	0.0444	−0.1457	0.0124	−0.3712	−0.3818	1.0000

Panel B. Variance Inflation Factor (VIF) Statistics.

	VIF	1/VIF
LNAGE	1.58	0.6329
LNMAXSIZE	1.40	0.7136
LNPOP_DENSITY	1.36	0.7330
LNHH_SIZE	1.22	0.8206
POSTEDU_RATIO	1.21	0.8262
LNFLTATNO	1.20	0.8341
GB	1.10	0.9077
LNMINSIZE	1.09	0.9176
Mean VIF	**1.27**	

Table 4
Regression results.

Panel A. Overall period.

	(1)	(2)
Dependent variable:	CASERATIO	
GB	−0.512***	−0.132***
	(−9.51)	(−4.12)
LNFLTATNO		−1.208***
		(−20.98)
LNAGE		−0.144***
		(−6.00)
LNMINSIZE		0.084
		(1.57)
LNMAXSIZE		−0.017
		(−0.13)
LNHH_SIZE		2.693***
		(4.35)
POSTEDU_RATIO		−0.018***
		(−4.97)
LNPOP_DENSITY		0.015
		(0.72)
Constant	0.993***	6.053***
	(32.20)	(5.47)
District Fixed Effect	Yes	No
N	1552	1552
R-squared	0.0972	0.6535

Panel B. By wave.

	(1)	(2)	(3)	(4)	(5)
Dependent variable:	CASERATIO				
	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5
GB	−0.000**	−0.001*	−0.008	−0.015***	−0.046***
	(−2.46)	(−1.93)	(−1.63)	(−3.35)	(−3.99)
LNFLTATNO	−0.001	−0.005***	−0.030***	−0.051***	−0.334***
	(−1.47)	(−2.74)	(−5.20)	(−6.27)	(−17.43)
LNAGE	−0.000	0.000	−0.003	−0.012***	−0.047***
	(−1.23)	(0.12)	(−1.02)	(−3.08)	(−6.03)
LNMINSIZE	0.000	−0.002	−0.006	0.009	0.017
	(0.19)	(−1.15)	(−0.70)	(0.88)	(0.93)
LNMAXSIZE	−0.000	−0.007	0.008	0.032*	0.062
	(−0.55)	(−1.40)	(0.70)	(1.68)	(1.43)
LNHH_SIZE	0.016**	0.046**	0.091	0.309***	0.478**
	(2.16)	(2.43)	(1.40)	(3.17)	(2.42)
POSTEDU_RATIO	0.000	−0.000	−0.001***	−0.001	−0.006***
	(0.28)	(−0.25)	(−3.30)	(−1.25)	(−4.48)
LNPOP_DENSITY	0.000	−0.000	0.003	0.010***	−0.003
	(0.98)	(−0.54)	(1.34)	(3.37)	(−0.38)
Constant	−0.012*	0.021	0.125	−0.155	1.837***
	(−1.93)	(0.82)	(1.64)	(−1.20)	(4.78)
N	1552	1552	1552	1552	1552
R-squared	0.0125	0.0331	0.0617	0.1075	0.5173

Note: (i) The *t*-statistics are reported in parentheses and standard errors are robust to heteroskedasticity. ***, **, and * indicate that the point estimate is significantly different from 0 at the 1%, 5%, and 10% levels, respectively.
(ii) *GB* is a dummy variable; *LNFLTATNO*, *LNAGE*, *LNMINSIZE*, *LNMAXSIZE*, *LNHH_SIZE,* and *LNPOP_DENSITY* are in their log form; *CASERATIO* and *POSTEDU_RATIO* are in their original form.

occupants, consistent with the physical distance guidelines that are critical during pandemics (D'Alessandro et al., 2020; Megahed & Ghoneim, 2021). These designs are particularly relevant to public housing in Hong Kong, where high-rise buildings typically house thousands of people, and communal spaces such as elevators and lobbies are potential transmission hotspots. Therefore, the first hypothesis (*H1*) is formulated as follows:

H1. Green buildings are associated with lower infection rates than non-green buildings during COVID-19.

Green building certifications are typically tiered to reflect different levels of sustainability and performance. In Hong Kong, for example, the BEAM Plus rating system assigns buildings a score-based rating, Platinum, Gold, Silver, or Bronze, based on their overall performance. Higher certification levels require stricter adherence to criteria related to indoor air quality (IAQ), thermal comfort, natural lighting, and sustainable materials and technologies (HKGBC, 2019).[7] For instance, a Platinum-certified building must score above 75%, while non-certified buildings typically score below 40%.

Higher certification levels, therefore, are associated with more demanding standards and a greater number of IEQ-related design and performance criteria. Although certification does not guarantee

[7] https://www.hkgbc.org.hk/eng/beam-plus/file/BEAMPlus_New_Buildings_v2_0.pdf

Table 5
Robustness check: interaction analysis for the fifth wave (monthly sample).

	(1)	(2)
Dependent variable:	CASERATIO	
GB	−0.002***	0.009***
	(−5.03)	(16.47)
WAVE5	0.066***	0.068***
	(78.87)	(68.99)
GB × WAVE5	−0.034***	−0.034***
	(−29.36)	(−29.52)
LNFLTATNO		−0.034***
		(−41.17)
LNAGE		−0.004***
		(−10.97)
LNMINSIZE		0.003***
		(3.98)
LNMAXSIZE		−0.003
		(−1.34)
LNHH_SIZE		−0.131***
		(−7.83)
POSTEDU_RATIO		−0.001*
		(−1.93)
LNPOP_DENSITY		0.523***
		(13.00)
Constant	0.004***	−4.661***
	(20.37)	(−12.71)
District Fixed Effect	Yes	No
N	55,872	55,872
R-squared	0.1774	0.2933

Note: (i) The *t*-statistics are reported in parentheses and standard errors are robust to heteroskedasticity. ***, **, and * indicate that the point estimate is significantly different from 0 at the 1%, 5%, and 10% levels, respectively.
(ii) *GB and WAVE5* are dummy variables; *LNFLTATNO*, *LNAGE*, *LNMINSIZE*, *LNMAXSIZE*, *LNHH_SIZE,* and *LNPOP_DENSITY* are in their log form; *CASERATIO* and *POSTEDU_RATIO* are in their original form.

consistently better indoor environmental performance, higher-rated buildings are generally designed to incorporate more robust environmental strategies. In the context of public housing in Hong Kong, where resource constraints may hinder the consistent maintenance of building systems, higher-rated green buildings are more likely to sustain robust environmental quality. These features suggest that higher-rated green buildings could be better positioned to support improved IEQ that are relevant to mitigating virus transmission risks and protecting occupant health, particularly in densely populated residential settings. Therefore, we propose the hypothesis:

H2. Higher-rated green buildings are associated with lower infection rates.

According to environmental buffering, characteristics of the built environment can moderate the relationship between external stressors and individual health outcomes (Evans, 2003). In environments where the risk of viral transmission is high, such as periods or areas with high infection rates, design and operational features associated with green buildings may become even more relevant in shaping exposure patterns.

First, during severe outbreaks, individuals spend significantly more time indoors, up to 90% of the day, making them more reliant on the indoor environment to mitigate infection risks. In addition, in high-risk communities, elevated population density and mobility may exacerbate the spread of the virus, further amplifying the role of building design in controlling transmission. In this context, green building-related features may contribute to conditions that are associated with lower infection rates. These potential moderating pathways are especially relevant for public housing in Hong Kong, where lower-income residents face heightened health vulnerabilities and depend more heavily on infrastructure during lockdown. Therefore, we propose the hypothesis:

H3. The negative correlation between green buildings and infection rates is more pronounced in areas with higher infection severity.

3. Data, sample and variables

We obtain information on public housing from documents published by the HKHA, which is responsible for planning, constructing, and managing all public rental housing in Hong Kong. The dataset includes all public housing buildings constructed and maintained by the HKHA as of 2022. For each building, the dataset provides detailed structural and locational information, including estate name, building/block name, geographic district, number of flats per block, flat size (area in square meters), year of completion (building age), and total number of flats in the estate.

To classify buildings by environmental performance, we match the public housing dataset with green building records from the Hong Kong Green Building Council (HKGBC), the official body responsible for administering the BEAM Plus green building assessment scheme. All residential public housing buildings certified under BEAM Plus as of 2022 are identified and categorized according to their certification level. Buildings are classified as green-certified if they appear in the official HKGBC green building registry. Certification levels include Platinum, Gold, Silver, Bronze, and Unrated, based on overall environmental performance scores across six categories: Site Aspects, Material Aspects, Energy Use, Water Use, IEQ, and Innovations and Additions.[8]

Data on confirmed COVID-19 cases were obtained from multiple official government platforms, such as the Centre for Health Protection and the Hong Kong GeoData Store. These sources publish daily anonymized case records from January 2020 to December 2022, covering all five major waves of COVID-19 outbreaks in Hong Kong. Each case record includes the confirmation date and the building/block address of the infected individual. Then, we aggregated the number of confirmed cases at the block level. To account for variations in building size, we normalize the total case count by the number of flats in each building and construct a standardized measure of infection: the case ratio (confirmed cases per 100 flats) for the full sample period and each pandemic wave.

Finally, we manually match public rental housing records with green building certification data and COVID-19 infection records based on building names and addresses. Additionally, we incorporate other district-level variables to account for additional factors that might impact infection rates, including district average household size (*LNHH_SIZE*), percentage of post-secondary education in the district (*POSTEDU_RATIO*), and district population density (*LNPOP_DENSITY*). Our final sample spans the period from January 31, 2020 to December 30, 2022, and includes 1552 public housing buildings distributed across Hong Kong.

Table 1 reports summary statistics for the variables used in our analysis. The dependent variable, *CASERATIO*, measures the number of confirmed COVID-19 cases per flat at the building block level (multiplied by 100). Across the full sample of 1552 buildings, the highest case ratio is 11.2%, with a mean of 0.96% and a standard deviation of 1.18, indicating a wide range of variation in case ratios across buildings. In addition, among our sample, 7% of buildings are classified as green buildings, with a standard deviation of 0.26, suggesting a relatively low prevalence of environmentally friendly buildings within the public housing sector. Moreover, the buildings chosen are relatively old, the log-transformed building age (*LNAGE*) has a mean of 3.24, indicating that most buildings in the sample were aged 36 years or older in 2023.

Table 2 presents the average case ratios for green-certified and non-certified buildings across the entire study period (January 2020–December 2022) and within each of the five COVID-19 waves. Over the whole period, green-certified buildings have a significantly

[8] A building is classified as green if it has been certified under the BEAM Plus scheme, which evaluates environmental performance based on a weighted scoring system. Certification levels are awarded based on the overall percentage score.

Table 6
Robustness check: using a block-weekly sample.

Panel A. Log-linear fixed effects estimates.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	LNCASES					
	Overall	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5
GB	−0.027***	−0.009***	−0.018***	−0.030*	−0.017**	−0.083***
	(−6.52)	(−4.16)	(−3.14)	(−1.73)	(−1.98)	(−6.06)
LNFLTATNO	0.040***	−0.001	0.001	0.051***	0.012***	0.091***
	(27.48)	(−0.54)	(0.44)	(9.76)	(4.06)	(20.35)
LNAGE	−0.036***	−0.001	−0.001	−0.003	−0.003	−0.068***
	(−18.99)	(−0.69)	(−0.20)	(−0.45)	(−0.71)	(−11.33)
LNMINSIZE	0.001	−0.002	−0.012**	0.017	0.011	−0.032***
	(0.43)	(−0.39)	(−2.18)	(1.40)	(1.55)	(−3.44)
LNMAXSIZE	0.083***	−0.005	−0.012	0.046**	−0.002	0.200***
	(13.11)	(−0.77)	(−1.17)	(2.02)	(−0.11)	(10.21)
LNHH_SIZE	−0.635***	0.275***	0.207***	−0.115	0.235***	0.406***
	(−8.68)	(3.86)	(2.80)	(−1.00)	(3.04)	(3.52)
POSTEDU_RATIO	0.015***	0.001**	0.000	−0.005***	−0.001**	−0.006***
	(8.12)	(2.26)	(1.15)	(−6.54)	(−2.13)	(−8.44)
LNPOP_DENSITY	1.760***	0.001	−0.003	0.012***	0.016***	−0.030***
	(20.95)	(0.71)	(−1.52)	(3.50)	(7.24)	(−9.03)
Constant	−16.555***	−0.262***	−0.091	−0.213	−0.340***	−0.154
	(−21.28)	(−3.87)	(−1.06)	(−1.51)	(−3.70)	(−1.05)
District Fixed Effect	Yes	No	No	No	No	No
Week Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
N	232,800	6208	13,968	21,728	41,904	48,112
R-squared	0.7183	0.0070	0.0156	0.0850	0.0741	0.4669

Panel B. Negative Binomial regression estimates.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	CASES					
	Overall	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5
GB	−0.049*	−17.766	−1.010*	−0.142	0.104	−0.260***
	(−1.74)	(−0.01)	(−1.66)	(−1.07)	(0.84)	(−6.61)
LNFLTATNO	0.097***	0.106	0.208	0.156***	0.014	0.189***
	(9.89)	(0.21)	(1.41)	(3.01)	(0.32)	(13.98)
LNAGE	−0.173***	0.322	−0.064	0.031	−0.033	−0.157***
	(−12.75)	(0.31)	(−0.26)	(0.45)	(−0.56)	(−8.60)
LNMINSIZE	−0.080***	0.174	−0.234	−0.089	−0.068	−0.064**
	(−3.71)	(0.16)	(−0.66)	(−0.93)	(−0.81)	(−2.22)
LNMAXSIZE	0.333***	0.740	0.651	0.236	−0.038	0.343***
	(7.61)	(0.21)	(0.79)	(1.05)	(−0.21)	(5.62)
LNHH_SIZE	4.068***	35.668**	2.349	0.293	1.274	0.864**
	(6.96)	(2.52)	(0.77)	(0.26)	(1.33)	(2.48)
POSTEDU_RATIO	−0.081***	0.047	−0.011	−0.006	−0.007	−0.007***
	(−5.44)	(0.72)	(−0.54)	(−0.88)	(−1.19)	(−3.58)
LNPOP_DENSITY	5.226***	0.142	−0.172*	0.084***	0.051*	−0.084***
	(8.24)	(0.25)	(−1.70)	(2.69)	(1.88)	(−7.85)
Constant	−55.066***	−47.020*	−7.082	−9.365***	−3.309**	−8.558***
	(−9.23)	(−1.92)	(−1.49)	(−5.26)	(−2.45)	(−10.20)
District Fixed Effect	Yes	No	No	No	No	No
Date Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
N	232,800	6208	13,968	21,728	41,904	48,112

Note: (i) The *t*-statistics are reported in parentheses and standard errors are robust to heteroskedasticity. ***, **, and * indicate that the point estimate is significantly different from 0 at the 1%, 5%, and 10% levels, respectively.
(ii) *GB* is a dummy variable; *LNCASES*, *LNFLTATNO*, *LNAGE*, *LNMINSIZE*, *LNMAXSIZE*, *LNHH_SIZE*, and *LNPOP_DENSITY* are in their log form; *CASES* and *POSTEDU_RATIO* are in their original form.

lower average case ratio (0.480%) compared to non-green buildings (0.994%), with a statistically significant difference of −0.513 cases per 100 units. This indicates a strong negative association between green certification and COVID-19 infections.

When examining infection rates by pandemic wave, no significant differences are observed during Waves 1, 2 and 3, where case ratios are near zero or very low in both building groups. However, during Wave 4, green buildings were associated with a significantly lower infection rate (0.016%) compared to non-green buildings (0.046%), with a difference of −0.029%. The most pronounced divergence occurred during Wave 5, which saw the highest overall infection rates. During this period, the average infection rate for green buildings is 0.144%, which is significantly lower than the 0.292% for non-green buildings, representing a difference of 0.148 percentage points. These results provide preliminary evidence supporting the hypothesis that green buildings may offer enhanced resilience against viral transmission, particularly during periods of severe outbreaks.

Table 7
Robustness check: controlling for building prototype fixed effects.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	CASERATIO					
	Overall	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5
GB	−0.072**	−0.000*	−0.000	−0.003	−0.011**	−0.027**
	(−2.07)	(−1.71)	(−0.32)	(−0.52)	(−2.28)	(−1.97)
LNFLTATNO	−1.211***	−0.001	−0.006***	−0.031***	−0.052***	−0.337***
	(−21.84)	(−1.33)	(−2.70)	(−4.87)	(−6.11)	(−18.83)
LNAGE	−0.172***	−0.000	−0.001	−0.015***	−0.024***	−0.072***
	(−3.52)	(−1.15)	(−1.51)	(−3.43)	(−4.19)	(−4.24)
LNMINSIZE	0.193***	0.000	−0.001	0.003	0.021	0.064***
	(3.36)	(0.37)	(−0.70)	(0.26)	(1.62)	(3.09)
LNMAXSIZE	−0.390**	−0.001	−0.013*	−0.018	0.004	−0.068
	(−2.40)	(−1.06)	(−1.78)	(−1.11)	(0.18)	(−1.30)
LNHH_SIZE	2.175***	0.015**	0.041**	0.020	0.228**	0.340*
	(3.90)	(2.11)	(2.27)	(0.30)	(2.37)	(1.66)
POSTEDU_RATIO	−0.015***	0.000	−0.000	−0.001***	−0.001	−0.005***
	(−4.08)	(0.36)	(−0.06)	(−3.17)	(−0.89)	(−3.70)
LNPOP_DENSITY	0.019	0.000	−0.000	0.002	0.010***	−0.002
	(1.11)	(1.06)	(−0.36)	(1.10)	(3.33)	(−0.31)
Constant	7.731***	−0.008	0.059	0.321***	0.045	2.424***
	(8.26)	(−1.34)	(1.57)	(3.25)	(0.33)	(7.17)
Prototype Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
N	1552	1552	1552	1552	1552	1552
R-squared	0.6637	0.0137	0.0399	0.0752	0.1168	0.5337

Note: (i) The *t*-statistics are reported in parentheses and standard errors are robust to heteroskedasticity. ***, **, and * indicate that the point estimate is significantly different from 0 at the 1%, 5%, and 10% levels, respectively.
(ii) *GB* is a dummy variable; *LNFLTATNO*, *LNAGE*, *LNMINSIZE*, *LNMAXSIZE*, *LNHH_SIZE*, and *LNPOP_DENSITY* are in their log form; *CASERATIO* and *POSTEDU_RATIO* are in their original form.

4. Empirical results

4.1. Baseline estimates

To examine the relationship between green buildings and COVID-19 infection rates, we conduct a series of baseline regressions at the building level. Specifically, we begin with a full-sample analysis covering the entire observation period from January 2020 to December 2022. We then perform wave-specific regressions for each of the five major COVID-19 outbreaks in Hong Kong. This dual approach allows us to assess both the average effect of green certification and its heterogeneity across different phases of the pandemic. The main regression specification is as follows:

$$CASERATIO_i = \alpha + \beta_1 GB_i + \beta_2 Controls_i + District_i + \varepsilon_i \quad (1)$$

where $CASERATIO_i$ denotes the ratio of confirmed COVID-19 cases in building *i* at time *t*. GB_i is a dummy variable indicating whether the building is green-certified. $Controls_i$ represents a set of building- and district-level control variables, including number of units (*LNFLTATNO*), building age (*LNAGE*), minimum size of properties in block (*LNMINSIZE*), maximum size of properties in block (*LNMAXSIZE*), and a set of district-level demographic and socioeconomic controls, including district average household size (*LNHH_SIZE*), percentage of post-secondary education in the district (*POSTEDU_RATIO*), and district population density (*LNPOP_DENSITY*). District fixed effect $District_i$ is included to control for unobserved heterogeneity at the district level. However, district fixed effects are not included in the fully controlled models, as many key control variables are defined at the district-year level.[9]

To address concerns regarding potential multicollinearity among the explanatory variables, we compute pairwise correlation coefficients between the green-building indicator (*GB*) and all control variables, and we further report the corresponding Variance Inflation Factor (VIF) statistics. These diagnostics are presented in Panels A and B of Table 3. The correlation matrix indicates generally low levels of correlation across covariates. The strongest correlation is observed between building age (*LNAGE*) and the maximum property size within a building (*LNMAXSIZE*), at 0.5187. Other notable correlations, such as those between *LNAGE* and *LNFLTATNO* (−0.2927) and between *GB* and *LNAGE* (−0.2787), remain moderate in magnitude, suggesting the absence of structural collinearity. Consistent with this evidence, the VIF values range from 1.09 (*LNMINSIZE*) to 1.58 (*LNAGE*), with an average VIF of 1.27. These values fall well below commonly used thresholds of 5 (or even 10), indicating that multicollinearity is unlikely to exert a meaningful influence on our coefficient estimates.

Table 4 presents the baseline regression results. Panel A reports the estimates based on the full sample period, while Panel B provides wave-specific estimates corresponding to the five major waves of COVID-19 outbreaks in Hong Kong. In Panel A, column (1) shows a significant coefficient for *GB* of −0.512. After incorporating a set of control variables, the estimated coefficient in column (2) suggests that, on average, the COVID-19 case ratio in green-certified public housing buildings is 0.132 percentage points lower than that in non-green buildings. This suggests a robust negative association between green building design and infection rates: residents living in green-certified buildings are linked to lower reported infection levels during the observation period. This magnitude is economically significant as the average COVID-19 case ratio in the sample is 0.96 percentage points.

To further explore the temporal heterogeneity of this relationship, we re-estimate eq. (1) separately for each of the five major waves of the pandemic. Panel B of Table 4 reports the wave-specific regression results. The estimates reveal that the association between green buildings and lower infection rates is most pronounced during Wave 5, which corresponds to the most severe outbreak in Hong Kong. During the period, the case ratio in green buildings was 0.046 percentage points lower than in non-green buildings, and the estimate is statistically significant at the 1% level. In contrast, during earlier and less severe waves, such as Waves 1, 2 and 3, the impact of green buildings is insignificant,

[9] District fixed effects would absorb district-level variables such as average household size, income, education, and population density. The model without district fixed effect allows us to retain and interpret the influence of these contextual factors on the COVID-19 infections.

Table 8
Robustness check: isolating the effects of building age and post-SARS upgrades.

Panel A. Controlling for post-SARS building upgrades.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	CASERATIO					
	Overall	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5
GB	−0.133***	−0.000**	−0.001*	−0.008*	−0.015***	−0.046***
	(−4.13)	(−2.47)	(−1.94)	(−1.65)	(−3.37)	(−3.98)
LNFLTATNO	−1.206***	−0.001	−0.005***	−0.030***	−0.051***	−0.333***
	(−20.92)	(−1.47)	(−2.74)	(−5.18)	(−6.20)	(−17.32)
LNAGE	−0.168***	−0.000	−0.000	−0.005	−0.015***	−0.058***
	(−5.41)	(−1.07)	(−0.13)	(−1.56)	(−2.99)	(−5.15)
LNMINSIZE	0.089	0.000	−0.002	−0.005	0.010	0.020
	(1.63)	(0.19)	(−1.12)	(−0.62)	(0.91)	(1.05)
LNMAXSIZE	−0.027	−0.000	−0.007	0.007	0.031	0.058
	(−0.20)	(−0.54)	(−1.39)	(0.59)	(1.59)	(1.33)
LNHH_SIZE	2.677***	0.016**	0.046**	0.088	0.308***	0.470**
	(4.34)	(2.16)	(2.42)	(1.36)	(3.16)	(2.40)
POSTEDU_RATIO	−0.018***	0.000	−0.000	−0.001***	−0.001	−0.006***
	(−4.94)	(0.28)	(−0.24)	(−3.28)	(−1.21)	(−4.47)
LNPOP_DENSITY	0.015	0.000	−0.000	0.003	0.011***	−0.003
	(0.76)	(0.97)	(−0.52)	(1.39)	(3.41)	(−0.33)
POST_SARS	−0.056	−0.000	−0.000	−0.007	−0.007	−0.027
	(−1.45)	(−0.08)	(−0.32)	(−1.38)	(−0.99)	(−1.59)
Constant	6.159***	−0.012*	0.022	0.138*	−0.142	1.888***
	(5.58)	(−1.93)	(0.83)	(1.77)	(−1.11)	(4.95)
N	1552	1552	1552	1552	1552	1552
R-squared	0.6536	0.0125	0.0331	0.0620	0.1076	0.5175

Panel B. Using the pre-SARS building subsample (completed in 2003 or earlier).

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	CASERATIO					
	Overall	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5
GB	−0.090**	−0.000**	−0.001	−0.008	−0.016***	−0.031**
	(−2.36)	(−2.27)	(−0.52)	(−1.13)	(−2.65)	(−2.31)
LNFLTATNO	−1.240***	−0.001	−0.006***	−0.032***	−0.054***	−0.343***
	(−21.00)	(−1.48)	(−2.75)	(−5.18)	(−6.29)	(−17.46)
LNAGE	−0.313***	−0.000	−0.001	−0.009	−0.030***	−0.106***
	(−5.70)	(−0.77)	(−1.18)	(−1.39)	(−3.24)	(−5.32)
LNMINSIZE	0.119**	0.000	−0.002	−0.004	0.013	0.031
	(2.00)	(0.27)	(−1.04)	(−0.40)	(1.10)	(1.49)
LNMAXSIZE	−0.007	−0.000	−0.008	0.010	0.032	0.069
	(−0.05)	(−0.47)	(−1.56)	(0.81)	(1.47)	(1.48)
LNHH_SIZE	2.900***	0.018**	0.049**	0.107	0.370***	0.433*
	(3.99)	(2.07)	(2.19)	(1.41)	(3.24)	(1.89)
POSTEDU_RATIO	−0.021***	0.000	−0.000	−0.002***	−0.001	−0.007***
	(−5.07)	(0.15)	(−0.43)	(−3.30)	(−1.09)	(−4.54)
LNPOP_DENSITY	0.027	0.000	−0.000	0.004	0.013***	−0.001
	(1.08)	(1.20)	(−0.26)	(1.50)	(3.29)	(−0.09)
Constant	6.422***	−0.014**	0.030	0.119	−0.172	2.075***
	(5.09)	(−1.97)	(1.01)	(1.34)	(−1.19)	(4.80)
N	1274	1274	1274	1274	1274	1274
R-squared	0.6508	0.0131	0.0334	0.0607	0.1078	0.5117

Note: (i) The *t*-statistics are reported in parentheses and standard errors are robust to heteroskedasticity. ***, **, and * indicate that the point estimate is significantly different from 0 at the 1%, 5%, and 10% levels, respectively.
(ii) *GB* and *POST_SARS* are dummy variables; *LNFLTATNO*, *LNAGE*, *LNMINSIZE*, *LNMAXSIZE*, *LNHH_SIZE*, and *LNPOP_DENSITY* are in their log form; *CASERATIO* and *POSTEDU_RATIO* are in their original form.

suggesting that the lower infection risk associated with green buildings was limited when case counts were relatively low and lockdown measures were less stringent. Beginning in Wave 4, the negative relationship becomes significant and further intensifies in Wave 5. These findings suggest that the benefits of green building features are more pronounced under conditions of heightened risk, when individuals are more dependent on the quality of indoor environments and building systems (e.g., ventilation, sanitation).

Our results support hypotheses ***H1*** and ***H3***, indicating that residents in green buildings are associated with significantly lower COVID-19 infection rates compared to those in conventional public housing, and this association becomes more pronounced during severe phases of the pandemic. Given the observational nature of the data, our analysis does not establish strict causal relationships. However, potential mechanisms underlying the observed associations may involve features commonly incorporated in green buildings, such as advanced ventilation systems designed to enhance indoor air quality by increasing air exchange rates and filtering efficiency (Altomonte et al., 2019; Newsham et al., 2013). While these features do not ensure superior IEQ performance, they may contribute to diluting airborne viral particles, thereby reducing the risk of transmission in closed spaces (Allen & Marr, 2020). In addition, green building designs often promote spatial configurations that lower

Table 9
Heterogeneity analysis: green building rating levels.

Panel A. Overall period.

	(1)	(2)
Dependent variable:	CASERATIO	
GB_RATING	−0.209***	−0.070***
	(−8.50)	(−4.33)
LNFLTATNO		−1.208***
		(−21.02)
LNAGE		−0.148***
		(−6.20)
LNMINSIZE		0.087
		(1.60)
LNMAXSIZE		−0.023
		(−0.18)
LNHH_SIZE		2.681***
		(4.33)
POSTEDU_RATIO		−0.018***
		(−4.99)
LNPOP_DENSITY		0.015
		(0.73)
Constant	0.988***	6.104***
	(32.44)	(5.50)
District Fixed Effect	Yes	No
N	1552	1552
R-squared	0.0953	0.6538

Panel B. By wave

	(1)	(2)	(3)	(4)	(5)
Dependent variable:	CASERATIO				
	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5
GB_RATING	−0.000**	−0.001***	−0.004**	−0.006***	−0.025***
	(−2.13)	(−3.18)	(−2.01)	(−2.63)	(−4.60)
LNFLTATNO	−0.001	−0.005***	−0.030***	−0.051***	−0.334***
	(−1.48)	(−2.75)	(−5.20)	(−6.28)	(−17.47)
LNAGE	−0.000	0.000	−0.003	−0.012***	−0.049***
	(−1.22)	(0.02)	(−1.11)	(−3.06)	(−6.26)
LNMINSIZE	0.000	−0.002	−0.006	0.009	0.018
	(0.19)	(−1.14)	(−0.68)	(0.88)	(0.97)
LNMAXSIZE	−0.000	−0.007	0.008	0.031	0.060
	(−0.58)	(−1.41)	(0.67)	(1.64)	(1.39)
LNHH_SIZE	0.016**	0.046**	0.090	0.310***	0.476**
	(2.16)	(2.42)	(1.39)	(3.18)	(2.41)
POSTEDU_RATIO	0.000	−0.000	−0.001***	−0.001	−0.006***
	(0.28)	(−0.25)	(−3.31)	(−1.24)	(−4.50)
LNPOP_DENSITY	0.000	−0.000	0.003	0.010***	−0.003
	(0.98)	(−0.53)	(1.34)	(3.37)	(−0.38)
Constant	−0.012*	0.022	0.129*	−0.152	1.853***
	(−1.92)	(0.84)	(1.68)	(−1.17)	(4.81)
N	1552	1552	1552	1552	1552
R-squared	0.0125	0.0332	0.0618	0.1072	0.5177

Note: (i) The *t*-statistics are reported in parentheses and standard errors are robust to heteroskedasticity. ***, **, and * indicate that the point estimate is significantly different from 0 at the 1%, 5%, and 10% levels, respectively.
(ii) *GB_RATING* is a dummy variable; *LNFLTATNO*, *LNAGE*, *LNMINSIZE*, *LNMAXSIZE*, *LNHH_SIZE,* and *LNPOP_DENSITY* are in their log form; *CASERATIO* and *POSTEDU_RATIO* are in their original form.

occupant density and enhance social distance, facilitating physical distancing and minimizing droplet transmission in high-traffic areas such as elevators, corridors and lobbies (D'Alessandro et al., 2020; Megahed & Ghoneim, 2021). During periods of strict lockdown, such as Wave 5, when residents spent up to 90% of their time indoors, the importance of these design elements likely intensified. Increased reliance on shared indoor facilities during lockdowns also highlights the importance of regular maintenance and hygiene, which tend to be more rigorously enforced in green-certified buildings. These behavioral and institutional aspects may further reinforce the health benefits observed in our analysis.

In addition to our primary variable of interest, several control variables are also significantly associated with COVID-19 infection rates. First, the number of flats per building (*LNFLTATNO*) shows a consistently negative and statistically significant relationship with case ratios across both the full-sample and wave-specific regressions. This suggests that buildings with a larger number of flats, often correlated with larger scale and more modern infrastructure, may benefit from better ventilation and air circulation systems, thereby reducing transmission risks. In addition, building age (*LNAGE*) is negatively associated with infection rates, indicating that newer buildings tend to experience lower case ratios, which may be due to improvements in architectural design standards. Household size (*LNHH_SIZE*) is positively and significantly associated with infection rates, consistent with the possibility that larger households face greater intra-household transmission risk. Educational composition (*POSTEDU_RATIO*) is negatively associated with infection

Table 10
Heterogeneity analysis: district characteristics.

Panel A. Heterogeneity by infection severity.

	(1)	(2)
Dependent variable:	Low severity	High severity
GB	0.161	−0.096***
	(0.75)	(−2.71)
LNFLTATNO	−1.083***	−1.317***
	(−10.51)	(−23.59)
LNAGE	−0.321***	−0.059**
	(−3.10)	(−2.26)
LNMINSIZE	0.292	0.020
	(1.47)	(0.40)
LNMAXSIZE	1.173***	−0.398**
	(5.41)	(−2.58)
LNHH_SIZE	4.330***	0.342
	(5.31)	(0.48)
POSTEDU_RATIO	−0.081***	−0.004
	(−4.53)	(−0.84)
LNPOP_DENSITY	0.232***	−0.081***
	(4.81)	(−4.78)
Constant	−1.082	11.129***
	(−0.68)	(12.89)
N	377	1175
R-squared	0.6154	0.7252

Panel B. Heterogeneity by population density.

	(1)	(2)
Dependent variable:	Low population density	High population density
GB	0.275**	−0.137***
	(2.02)	(−3.89)
LNFLTATNO	−1.071***	−1.335***
	(−12.11)	(−22.48)
LNAGE	−0.004	−0.121***
	(−0.10)	(−3.85)
LNMINSIZE	0.006	0.071
	(0.06)	(1.13)
LNMAXSIZE	0.521***	−0.571***
	(3.53)	(−2.96)
LNHH_SIZE	4.628***	0.631
	(4.09)	(0.64)
POSTEDU_RATIO	−0.057***	−0.015***
	(−4.70)	(−4.55)
LNPOP_DENSITY	0.046	−0.263***
	(0.74)	(−5.16)
Constant	1.597	13.865***
	(1.17)	(8.35)
N	541	1011
R-squared	0.6171	0.7291

Panel C. Heterogeneity by household income level.

	(1)	(2)
Dependent variable:	Low income	High income
GB	−0.072*	−0.201
	(−1.95)	(−0.99)
LNFLTATNO	−1.137***	−1.472***
	(−16.10)	(−18.38)
LNAGE	−0.171***	−0.157***
	(−5.52)	(−2.70)
LNMINSIZE	0.035	0.069
	(0.54)	(0.75)
LNMAXSIZE	0.201*	−0.445*
	(1.65)	(−1.68)
LNHH_SIZE	−6.168***	−1.493
	(−5.43)	(−1.41)
POSTEDU_RATIO	−0.113***	−0.062***
	(−6.66)	(−5.16)
LNPOP_DENSITY	−0.134***	0.030
	(−4.38)	(0.73)
Constant	17.048***	14.958***
	(8.68)	(6.88)
N	1076	476
R-squared	0.6367	0.7893

Note: (i) The *t*-statistics are reported in parentheses and standard errors are robust to heteroskedasticity. ***, **, and * indicate that the point estimate is significantly different from 0 at the 1%, 5%, and 10% levels, respectively.
(ii) *GB* is a dummy variable; *LNFLTATNO*, *LNAGE*, *LNMINSIZE*, *LNMAXSIZE*, *LNHH_SIZE*, and *LNPOP_DENSITY* are in their log form; *CASERATIO* and *POSTEDU_RATIO* are in their original form.

rates in the full sample and in some waves, potentially reflecting differences in health awareness or behavioral responses across communities. Finally, population density (*LNPOP_DENSITY*) does not display a consistent pattern across specifications, showing significance only in Wave 4. While higher density can theoretically elevate transmission risk, as suggested by the positive association observed in Wave 4, such risks may be partially offset by unobserved factors such as stricter containment measures or benefited from more robust public health infrastructure, particularly during the most severe phases of the pandemic (the fifth wave).

4.2. Robustness tests

To validate the reliability of our main findings on the infection-mitigating effect of green buildings, we conduct four robustness checks. First, we perform an interaction analysis focusing on the fifth wave of the pandemic, which represents the most severe and prolonged outbreak in Hong Kong. Second, we construct a block-weekly sample with an alternative outcome variable to verify that our results are robust to temporal aggregation and model specification. Third, we include building prototype fixed effects to account for systematic differences in structural design and layout that might confound the estimated green building effect. Finally, we account for the potential confounding effects of building age and post-SARS upgrades by including a post-SARS dummy and conducting a pre-SARS subsample analysis, to investigate whether our findings are driven by general improvements in building standards or newness.

(i) Interaction analysis for high-risk epidemiological period

To further verify the protective role of green buildings during extreme health crises, we examine whether the reduction in infection rates associated with green buildings becomes more pronounced during a high-risk period, specifically the fifth wave of COVID-19 in Hong Kong, which occurred between December 2021 and June 2022. To do this, we construct a building-month sample and estimate the following interaction model using monthly-level data:

$$CASERATIO_{it} = \alpha + \beta_1 GB_i + \beta_2 Wave5_t + \beta_3 (GB_i \times Wave5_t) + \beta_4 Controls_{it} + District_i + \varepsilon_{it} \quad (2)$$

where $CASERATIO_{it}$ denotes the ratio of confirmed COVID-19 cases in building i at month t. GB_i is a dummy variable indicating whether the building is green-certified. $Wave5_t$ is a binary variable equal to 1 if the observation falls within the fifth wave period. $Controls_{it}$ contains the same set of building- and district-level covariates as in the previous section. District fixed effect $District_i$ is included to control for unobserved heterogeneity at the district level.

The estimated results are presented in Table 5. Column (1) provides the model including only the main variables and the interaction term, while column (2) incorporates a set of control variables. The positive coefficients on $Wave5_t$ indicate the increased infection pressure within the fifth wave. In contrast, the significant and negative coefficients of the interaction term emphasize that green-certified buildings were associated with lower infection rates during this period. The coefficients on the interaction term ($GB \times Wave\ 5$) are −0.034 in both specifications and are statistically significant at the 1% level. It is important to clarify how this interaction coefficient relates to the corresponding estimates reported in the wave-specific regression in Table 4, Panel B. In Table 4, the coefficient on *GB* for Wave 5 directly captures the absolute difference in infection ratios between green and non-green buildings during that wave. In contrast, the interaction term in Table 5 measures the incremental difference between Waves 1–4 and Wave 5. Thus, even though the magnitudes appear numerically similar, the two coefficients answer different statistical questions. Taken together, the results reveal a consistent pattern that green buildings tend to exhibit lower case ratios during the fifth wave compared to non-green buildings. These results reinforce our main findings by demonstrating that the infection-mitigating benefits of green buildings are not limited to average conditions but become even more critical during epidemiological peaks.

(ii) Building a weekly sample with an alternative outcome variable

To investigate whether our findings are robust to data frequency and dependent variable definition, we conduct a building-weekly sample and re-estimate the effect using two complementary model specifications. This approach enables us to capture finer temporal fluctuations in infection dynamics and control for short-term pandemic shocks through the inclusion of week-fixed effects. We then estimate (i) a log-linear model and (ii) a nonlinear count model based on a Negative Binomial (NB) regression model. In this specification, the dependent variable ($CASE_{it}$) is the weekly total number of confirmed COVID-19 cases in building *i* during week *t*.

First, we employ a log-linear model using the natural logarithm of the weekly case count at the building level as the dependent variable. The model estimated is as follows:

$$LNCASE_{it} = \alpha + \beta_1 GB_i + \beta_2 Controls_{it} + District_i + Week_t + \varepsilon_{it} \quad (3)$$

where $LNCASE_{it}$ denotes the logarithm of the number of confirmed cases in building *i* at week *t*, defined as $LNCASE_{it} = log(CASE_{it} + 1)$. GB_i is the dummy variable indicating whether the building is green-certified. $Controls_{it}$ contains the same set of building- and district-level covariates as in the previous section; and $District_i$ and $Week_t$ are district and week fixed effects, respectively.[10]

In addition, to employ a more theoretically appropriate econometric model for our count data and to address its characteristics of being highly skewed and overdispersed, we estimate a Negative Binomial regression model on the same building-weekly panel data. This method directly models the count dependent variable without relying on a logarithmic transformation to handle zero values, making it well-suited for handling overly discrete count data. This NB model includes the same set of control variables as the log-linear model and similarly incorporates district and week fixed effects.

The results are shown in Table 6. Panel A reports the results from the log-linear fixed effect model, and Panel B presents the Negative Binomial model results. In both panels, Column (1) reports the overall estimates for the full sample period, while Columns (2)–(6) report wave-specific estimates. Across both model specifications, the estimated coefficients on *GB* in Column (1) are negative and statistically significant, indicating that even at the weekly level, green buildings are consistently connected to lower COVID-19 infection counts. This reinforces the findings obtained from our baseline regression based on the full sample.

Among the five pandemic waves, Panel A shows that the log-linear estimates indicate a significantly negative association between green building (*GB*) certification and weekly confirmed cases across all waves, with the effect being most pronounced in Wave 5, when overall transmission intensity was substantially higher. In Panel B, the Negative Binomial estimates reveal significantly negative *GB* coefficients in Waves 2 and 5. The particularly large negative coefficient in Wave 2 likely reflects the fact that, although overall case counts were relatively low, infections were highly clustered in certain buildings, making differences between green-certified and non-certified buildings more pronounced. Wave 5 again shows a sizable negative association, suggesting that the link between green building certification and reduced infection levels becomes more evident during periods of widespread transmission.[11]

Overall, these robustness checks demonstrate that our findings are not sensitive to temporal aggregation or the choice of dependent variable. Both model specifications consistently demonstrate that green-certified buildings are associated with reduced infection risk, with this beneficial relation observable during both cluster-driven and high-intensity outbreaks.

(iii) Controlling for building prototype fixed effects

To mitigate the concern that the estimated effect of green building may be confounded with systematic differences in building prototype designs, we incorporate Prototype fixed effects (*ProtoType* FE) into our model to isolate potential structural confounding bias.

Public housing in Hong Kong has been constructed under a limited set of standardized architectural prototypes that evolved systematically across different eras. From the early Old Slab type in the 1970s, to the H-Type in the mid-1980s, and later to the Harmony and New Harmony series, each design generation introduced substantial improvements in space utilization, ventilation standards, plumbing layouts, and structural safety. Later prototypes, including the Harmony, H-Type, and especially the New Slab, New Harmony, and Trident types, featured systematic enhancements in several aspects of architectural design. These prototypes are inherently correlated with the building age, structural features, and post-SARS design improvements, all of which could independently influence infection risk. Given that green-certified buildings are concentrated among the newer or more optimized prototypes, the estimated *GB* effect might partially reflect prototype-related advantages rather than the incremental value of certification.

To address this concern, we construct a prototype classification variable, *ProtoType*, based on the official block type descriptions provided by the HKHA. Based on the evolution of Hong Kong's public housing layout and design standards outlined by van Ameijde and Jin (2025), we group the detailed module types into five prototype categories, following a hierarchical rule that prioritizes (i) recency of design and (ii) architectural structural distinctiveness. The classification follows this ordered logic: (1) Concord, New Harmony (newest designs; major post-SARS system upgrades); (2) Harmony, Trident, and New Slab (standardized high-rise designs built from the 1980s onward); (3) H-Type and Cruciform (transitional cross-shaped and slab blocks, including Double H, Triple H, Single H, Twin Tower, Cruciform, NCB); (4) Old Slab, Mark IV and Interim Housing (Early resettlement designs and temporary structures from the 1950s–1970s); (5) Non-standard and other specialized blocks (all remaining non-standard, small household,

[10] In this model, district fixed effects are included in the full-sample regression but excluded from the wave-specific models, because wave-specific regressions often cover only a short period in a single year, which would absorb most of the variation in district-year level controls, potentially causing multicollinearity or overfitting.

[11] The Negative Binomial model is especially sensitive to localized clustering because it directly models discrete and overdispersed counts, whereas the log-linear specification smooths short-term fluctuations. This explains why the GB effect appears relatively larger in Wave 2 under the count-based model, while Wave 5 shows consistent effects across both specifications.

Ziggurat, and other site-specific designs).[12] We then re-estimate the baseline model with *ProtoType* fixed effects, which absorb unobserved time-invariant characteristics related to the prototypes.

The estimated results are presented in Table 7. After controlling for prototype fixed effects, the estimated coefficient for *GB* in Column (1) remains significantly negative and highly consistent with the baseline results reported in panel A, Table 4. The wave-specific estimations in Columns (2)–(6) also indicate that the association between green buildings and lower infection counts is most pronounced during Wave 5, a pattern that aligns closely with the findings in panel B, Table 4. These results fail to provide evidence that the estimated green-building effect is fully driven by prototype-related design advantages, as the GB coefficient remains robust after including prototype fixed effects. In other words, even among buildings sharing the same architectural style and structural blueprint, certified buildings exhibit a systematically lower infection rate. Our findings further support the argument that the welfare benefit derived from *GB* certification represents an incremental contribution beyond the inherent design characteristics of the building prototype.

(iv) Isolating the effects of building age and post-SARS upgrades

Given that green-certified public housing blocks are typically newer constructions, another concern is that the estimated effects of *GB* might be partially confounded by building age (*LNAGE*) or the newness premium. The SARS epidemic in 2003 served as a critical institutional turning point, after which the Housing Authority progressively mandated higher standards for drainage safety, ventilation performance, and public health-oriented design. Consequently, newer buildings, regardless of green certification status, may inherently exhibit lower transmission risks. Without further analysis, the estimated GB effect might therefore partially reflect a "new construction effect" rather than the value of the certification itself. To address this identification concern, we conduct two additional robustness tests.

First, we incorporate a *POST_SARS* dummy variable (equal to 1 if the building was completed in 2004 or later) into our baseline model, thereby absorbing common structural improvements driven by post-SARS regulatory upgrades. As reported in Table 8, Panel A, after controlling for this structural shift, the estimated coefficients for *GB* remain significantly negative and are highly consistent in magnitude with the baseline regression results (in Table 4) across the full sample and all five pandemic waves. This result suggests that our main findings are not driven by general improvements in post-SARS building standards.

Then, we re-estimate the model focusing exclusively on the pre-SARS old building subsample (buildings completed in 2003 or earlier). This subsample offers two advantages. Empirically, 1274 out of the 1552 blocks in our sample (approximately 82%) fall into this category, reflecting the predominance of older public housing in Hong Kong's built environment. Conceptually, by concentrating on this early sample, we obtain a subsample where *GB* certification is less correlated with building age, allowing for a cleaner distinction between the certification effect and the advantages conferred by newer construction standards. As shown in Table 8, Panel B, the estimated *GB* effects in the pre-SARS subsample closely mirror the baseline results in both magnitude and wave-specific dynamics, indicating that the association between GB certification and lower infection rates is unlikely to be explained solely by building newness or the latest structural designs.

Taken together, whether by controlling for the post-SARS structural upgrades or by conducting a subsample analysis on pre-SARS buildings, the *GB* effect is highly robust. These results help to alleviate the confounding effects from building age, construction period, and post-SARS design improvements, suggesting that green building certification may be linked to incremental benefits beyond prototype-level building features.

[12] For cases involving multiple block types, the classification follows the priority ordering to ensure consistent and mutually exclusive classification.

4.3. Heterogeneity analysis

(i) Heterogeneity effect by green building rating levels

To verify ***H2***, we investigate whether the health benefits of green buildings in preventing infections vary across certification levels. Rather than using a simple binary green building indicator, we introduce a categorical dummy variable (*GB_RATING*), ranging from 0 (non-green) to 3 (platinum-rated), based on BEAM Plus.[13] The estimation model is specified as follows:

$$CASERATIO_i = \alpha + \beta_1 GB\_Rating_i + \beta_2 Controls_i + District_i + \varepsilon_i \tag{4}$$

where $CASERATIO_{it}$ denotes the ratio of confirmed COVID-19 cases in building i at time t. GB_Rating_i is a categorical variable that represents the level of green certification: 0 for non-green buildings, 1 for Bronze/unrated green buildings, 2 for Gold, and 3 for Platinum,[14] reflecting the increasing stringency of BEAM Plus certification tiers. $Controls_{it}$ contains the same set of building- and district-level covariates as in the previous section. $District_i$ controls for district fixed effects.

As shown in Table 9, Panel A, higher green building ratings are significantly associated with lower infection rates, and the negative association remains robust after controlling for building and household characteristics. Panel B further reveals that this association is more pronounced during more severe pandemic waves, especially in Wave 5, where the highest green building ratings correspond to the largest reductions in infection rates.

These findings support ***H2***, demonstrating that not only the presence but also the quality of green building certification plays a critical role in mitigating health risks. High-rated green buildings tend to incorporate more advanced design features that could potentially improve indoor environmental quality. The stronger effects during severe pandemic waves may partly be attributed to the increased demand for effective air quality control under heightened infection pressure. Moreover, residents in high-rated green buildings may exhibit greater health awareness and behavior, such as consistent use of air purifiers and compliance with social distancing, which may further contribute to the observed patterns. These findings emphasize the critical role that green building quality may play in reducing health risks, not just the presence or absence of green certification.

(ii) Heterogeneity effect by district characteristics

To explore how the protective effects of green buildings vary under different contextual conditions, we conduct heterogeneity analyses based on key district-level characteristics: (i) infection severity, (ii) population density, and (iii) household income levels. For each dimension, we classify districts into high- and low-groups using the median value of the corresponding indicator as the threshold and re-estimate the baseline specification within each subgroup.

Table 10 presents the results from these heterogeneity analyses. Panel A reports the results by district infection severity, based on the median case ratio. In high-severity districts, green buildings are associated with a statistically significant reduction in infection rates. In contrast, the association is insignificant in low-severity districts. This

[13] According to the BEAM Plus New Buildings version 2.0 (2019), Platinum certification requires a score $\geq$ 75%, Gold $\geq$65%, Silver $\geq$55%, and Bronze $\geq$40%. Uncertified buildings or those not listed by HKGBC are considered non-green buildings in our classification.

[14] According to the HA Environmental Report 2022–23, all new buildings are designed as certified BEAM Plus New Building that can attain Gold or Platinum rating (HKHA, 2024).

pattern suggests that the health benefits of green buildings become more pronounced when the local infection risk is elevated. In high-severity areas, factors such as greater population density, frequent social interactions, and increased movement could intensify the risk of virus transmission, making optimized ventilation and air filtration in green buildings particularly valuable. In contrast, in low-severity districts, the already low infection risk may diminish the relative contribution of green building features. Residents might engage more in outdoor activities or rely less on indoor environments, reducing their reliance on IEQ. This finding is consistent with prior studies, which have shown greater marginal health gains from environmental improvements in higher-risk settings (Braubach et al., 2011; Ding et al., 2023). It underscores the crucial role that green building design can play under elevated epidemiological pressure, thereby further supporting ***H3***.

Table 10, Panel B presents the heterogeneity by population density. The association between green buildings and infection rates is positive and statistically significant in low-density areas, indicating that green-certified buildings in these areas are unexpectedly associated with higher COVID-19 case ratios. In contrast, the relationship is negative and pronounced in high-density districts, where residents in green buildings experience a 0.137 percentage point lower infection rate compared to those in non-green buildings. This differential effect may stem from the challenges of infection control in crowded environments, where proximity and shared facilities heighten transmission risks. In such contexts, the advanced design features of green buildings are likely to provide larger marginal benefits and effectively mitigate transmission risks. Conversely, the positive association observed in low-density districts is more plausibly driven by confounding factors rather than by the inherent features of green building design. When baseline transmission risk is low, residents in low-density communities tend to spend more time outdoors and rely less on shared indoor spaces, reducing the relative contribution of indoor environmental quality. Moreover, green buildings in low-density areas may disproportionately attract residents with higher mobility, more extensive social networks, or more active lifestyles, all of which can increase exposure to community transmission despite high building quality. This evidence complements our findings on infection severity, illustrating that the health advantages of green buildings become increasingly vital under conditions that elevate contagion risk.

Panel C of Table 10 examines heterogeneity by household income levels. In low-income areas, green buildings are significantly associated with lower COVID-19 infection rates. In contrast, the coefficient for green buildings is statistically insignificant in high-income areas. This divergence might suggest that socioeconomic context plays a critical moderating role in shaping the relationship between the built environment and health outcomes. Residential conditions in low-income areas often involve inferior IEQ, including suboptimal ventilation, limited air filtration, and less effective maintenance of shared spaces. Moreover, low-income households typically lack the private resources necessary to compensate for these environmental deficiencies, such as purchasing air-cleaning devices, relocating temporarily, or engaging in remote work to reduce exposure risk. Under these constraints, the design advantages embedded in green buildings may yield substantial marginal improvements, thereby translating into a statistically significant reduction in infection rates. By contrast, residents in high-income areas generally live in higher-quality buildings and possess greater private means to undertake protective measures. These capacities substantially narrow the environmental quality gap between green and conventional buildings, making the effect of green design statistically indistinguishable.

Considering infection severity, population density, and household income simultaneously, the heterogeneity analyses demonstrate that the association between green building certification and COVID-19 infection rates is more pronounced in areas where structural or epidemiological vulnerabilities heighten residents' exposure to infection risks. In districts characterized by high infection severity or high population density, green buildings are associated with a reduction in COVID-19 transmission, supporting the view that environmental design features deliver greater marginal health benefits when baseline transmission risk is elevated. Similarly, in low-income areas where residents generally experience poorer indoor environmental quality and lack the private resources needed to compensate for environmental deficiencies, green certification also provides substantial health improvements. Taken together, these findings reveal potential inequalities in the realization of green building benefits within the public housing system. As emphasized by Braveman and Gottlieb (2014), environmental interventions must be accompanied by targeted social and economic support to achieve equitable health outcomes. Our evidence indicates that the health benefits of green buildings are most pronounced where structural vulnerabilities are greatest, acting as a critical equity tool in mitigating health disparities during pandemics.

5. Conclusion

Based on a dataset of 1552 blocks of public housing in Hong Kong that covers confirmed COVID-19 cases across five pandemic waves from January 2020 to December 2022, this study empirically examines the relationship between green building certification and infection risk and investigates whether green buildings can provide health benefits during public health crises. Our findings suggest that residents living in green-certified buildings are associated with lower infection rates compared to those in non-certified buildings. First, our baseline regressions using the full sample indicate that green certification is significantly linked to lower average COVID-19 infection rates. A wave-specific analysis further reveals that this association is most pronounced during the fifth wave, which was characterized by the highest rates of community transmission.

These results are robust across multiple empirical strategies, including an interaction analysis for the fifth pandemic wave, a block-weekly dataset capturing weekly fluctuations in infection dynamics, controlling for building prototype fixed effects, and incorporating a post-SARS dummy along with a pre-SARS subsample analysis. We further explore the heterogeneity in the association between green buildings and infection risk. The infection-reducing benefits are more pronounced in buildings with higher levels of green certification (e.g., BEAM Plus Gold or Platinum), in districts more severely affected by the pandemic, with higher population density, and lower household income.

Our study contributes to the expanding body of literature on the health co-benefits of green buildings by offering empirical evidence of their social value during public health crises. By combining block-level compulsory testing records and green certification data in Hong Kong's public housing system, we provide new insights that green buildings could enhance residents' health resilience during infectious disease outbreaks, particularly as a form of passive defense in high-density urban environments. The findings provide empirical guidance for policymakers and urban planners, suggesting the necessity of incorporating public health considerations into future green building standards and public housing policies.

Our findings also present certain limitations that may point directions for future research. First, regarding the causal mechanism, our work relies on infection outcomes as a proxy for health resilience. Due to data availability, we lack direct physical measurements of IEQ (e.g., real-time air change rates, drainage stack performance, or viral loads) within these blocks. Therefore, while the link between green design features (such as enhanced ventilation) and reduced transmission is theoretically grounded in the BEAM Plus standards, the specific channels remain inferential rather than directly observed. Second, although we control building age, the strong correlation between green certification and modern building prototypes (e.g., post-SARS designs) presents an identification challenge. Although we incorporated building prototype fixed effects, post-SARS indicators, and pre-SARS subsample analyses to identify a green premium in infection rates, completely isolating the impact of certification from the structural advantages of newer housing typologies remains difficult. Moreover, we acknowledge that unobservable confounders, such as differences in resident behavior (such as mask-wearing practices or social interaction patterns), variations in property management quality across estates, and heterogeneous enforcement of infection control measures may still exist. Finally, as this study focuses exclusively on public housing with centralized allocation, the findings may not be fully generalizable to the private sector or other cities with different allocation systems, where resident self-selection, heterogeneous management practices, and local institutional contexts could introduce residual confounding factors. Future research could benefit from integrating big data of real-time environmental sensing or high-resolution fluid dynamics simulations to empirically trace the mechanisms. Additionally, it is worth further investigating whether these associations hold in the private sector. Comparative analyses between public and private residential developments could reveal how different maintenance standards and property management levels moderate the health benefits associated with green certification.

CRediT authorship contribution statement

Liya Zhang: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Xin Lin:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Eddie Chi-man Hui:** Writing – review & editing, Writing – original draft, Supervision, Funding acquisition, Conceptualization. **Jianfu Shen:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization.

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Declaration of competing interest

None.

Appendix A. Variable definitions

Variables abbreviations	Variables full form	Definition
CASERATIO	Covid case ratio	The number of confirmed cases in a block / the number of flat in a block.
GB	Green building dummy	Equal to one if a block is a green building and zero if not.
GB_RATING	Green building rating	0 for non-green buildings, 1 for bronze / unrated green buildings, 2 for gold, and 3 for platinum.
LNFLTATNO	Flat number	Log of the number of flats in a block.
LNAGE	Flat age	Log of the age of a block +1.
LNMINSIZE	Min flat area	Log of the minimum flat area in a block.
LNMAXSIZE	Max flat area	Log of the maximum flat area in a block.
LNHH_SIZE	Household size	Log of district average household size.
POSTEDU_RATIO (%)	Post-secondary ratio	Percentage of post-secondary education in the district.
LNPOP_DENSITY	Population density	Log of district population density.
POST_SARS	Post-SARS building dummy	Equal to 1 if a building was completed in 2004 or later.

Data availability

The authors do not have permission to share data.

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