

Economics of Vertical Growth of Slums: Floors, Rents and Vertical Sorting in Mumbai*

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October 2026

Abstract

In response to rising population densities in land-scarce developing country cities, slum settlements are increasingly growing vertically. This paper is, to our knowledge, the first to study the determinants of slum building heights and estimate its relationship with rents. Using satellite-derived building heights for Mumbai's slums, we first show that informal building heights display a bid-rent gradient as height falls with distance from the city's main business districts and rises with residential land values. We then ask how height is priced within a building. We conduct a survey of tenant households across slum buildings experiencing high vertical growth and show that rents fall by 3.2–3.4% for every additional floor. We test for mechanisms that explain this penalty and find a statistically significant impact of recorded temperature, roof leakage perception, and roof material. We also find patterns of vertical sorting where poorer households are more likely to occupy upper floors, with each additional floor associated with a 0.21 lower household asset index.

Keywords: Informal housing, vertical densification, household sorting, slum settlements, India

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1. Introduction

Around 1.16 billion people, or nearly one in four urban residents, live in slums or informal settlements worldwide (United Nations 2026). As cities grow and land becomes scarce, many of these settlements are building upward. Slum structures often begin as single-storey units. As urban land becomes more expensive, land is used more intensively, and owners expand structures vertically, often renting out the newer units. As one landlord we interviewed put it, rising commercial activity nearby raised demand for rental housing, prompting them to add floors to their one-storey structure. Figure 1 (Panels A and B) show many slum structures in Mumbai that appear to have been extended vertically over time, indicated by differences in materials used across floors. Yet, little is known about the economics of vertical growth of slums.

The relationship between building heights and land values in formal housing markets has been extensively studied. As urban land values increase, the optimal formal building height increases (Ahlfeldt and McMillen 2018). Residents in formal buildings prefer living on a higher floor, which offer better views, more light, and better privacy (see Danton and Himbert 2018). However, we do not know whether informal housing markets respond to underlying land values in the same manner and whether floor level is priced as an amenity or a disamenity within a slum building. We answer two questions. Is vertical growth of slum buildings driven by distance to business districts and urban land prices? Is living on a higher floor an amenity or a disamenity?

Our paper overcomes two challenges. First, slum heights are harder to measure than formal building heights, since informal structures are not officially recorded the way formal buildings are. Existing spatial datasets on building stock cover the formal settlements in the city but do not reliably extend to informal settlements. We address this challenge by building a panel of 100m grid cells across Mumbai and measuring slum building height in each cell for 2016 and 2023. We use 3m-resolution SPOT 6/7 stereo imagery for both years and follow the methodology of Tripathy et al. (2022) to construct heights. We then merge these heights with the slum layer.

The second challenge is that no existing dataset links rents to floor level within the same slum building, which is necessary to isolate the effect of floor net of location, tenure and landlord characteristics. We conducted a survey of 227 tenant households across slum buildings of at least two storeys in three parts of Mumbai. By surveying tenants within the same building, we can compare rents across floors of that building. We also collect data on household characteristics and asset ownership. To understand what drives the relationship between floors and rents, we collect structural characteristics, roof and wall type, and environmental perceptions. We also record temperature and air pollution levels on every floor.

We use two empirical strategies. First, we test for a bid-rent gradient in slum heights, regressing height on distance to business districts and residential land values. Second, we use our household survey to compare rents across floors of the same building. Building fixed



A. North of the city



B. Near a business district

Figure 1. Tall slums in Mumbai

Note: Both panels show slum structures in Mumbai that have been extended vertically over time.

effects absorb location, neighbourhood, and building characteristics, so identification comes from variation across floors of the same structure alone. We also test candidate mechanisms behind this penalty. We apply this same comparison to the physical conditions of the dwelling, temperature, air pollution, flooding perception, roof leakage perception, roof material and water supply, to see which of them vary with floor. Finally, applying the same estimation strategy to the household asset index, we test for vertical sorting by wealth.

We find that slum heights are lower farther from the business districts, and grew most, between 2016 and 2023, in grid cells with the highest residential values, consistent with the same land-value pressures that shape formal densification also operating in slums. Within buildings, we find that higher floors rent for significantly less than lower floors of the same structure. Rent falls by 3.2–3.4% for each additional floor. However, this decline is non-linear: it is concentrated upwards of the fourth floor, where units rent for around INR 3,137 less per month than ground-floor units in the same building. Indoor temperature and roof leakage rise with each floor, and roofs shift toward worse materials. We also find evidence of vertical sorting where poorer households, as measured by an asset index, are more likely to occupy the upper floors of the same building, with each additional floor associated with a decline of 0.21 in the household asset index. Vertical growth in slums, in other words, appears to follow the same economic logic as in the formal sector. However, height itself functions as a disamenity for the tenants, and disproportionately the poorer tenants end up living on the top floors.

This paper contributes to four literatures, discussed in detail in Section 2. Section 3 describes our data, Section 4 our empirical strategy, Section 5 presents results. In Section 6 we discuss mechanism and Section 7 we show our results on vertical sorting. Section 8 concludes with a discussion of policy implications.

2. Literature Review

We contribute to four types of literature. Our first contribution is to the literature on the economics of building heights in cities. This literature predicts a negative relationship between distance to the city centre, where land values are highest, and building heights, as developers utilise land more intensively and substitute it for capital. Ahlfeldt and McMillen (2018) estimate height and construction-cost elasticities in Chicago and Ahlfeldt and Barr (2022) estimate a -0.25 elasticity estimate of building height with respect to distance from the city centre, confirming this relationship between urban land prices and building heights. Henderson, Regan, and Venables (2021) extend this framework to a developing-country setting and find a negative relationship between building height and distance to the city centre for the formal sector but a flat distance-height gradient for the informal sector in Nairobi. But whether these same land-value forces drive vertical intensification in informal settlements over time, rather than just a cross-sectional height gradient, remains unexamined. We answer this question for land-scarce cities in developing countries. We show that slum heights in Mumbai are greater, and grew more between 2016 and 2023, in grid cells closer to the city’s business districts and with higher residential land values. Thus, the forces that shape formal-sector densification also operate in land-scarce informal settlements.

Within a building, taller structures are found to command a vertical rent premium. Danton and Himbert (2018) show that rents in formal residential buildings rise with floor level, a premium attributed to better views, more light, and greater privacy on higher floors. However, Hwang and Ma (2023) find the opposite in top-floor units in South Korean apartment buildings: these sell at a discount due to greater exposure to heat and cold near the roof, implying that the relationship between height and prices is non-monotonic even in formal markets. None of this literature, to our knowledge, has examined whether the vertical rent gradient in formal buildings extends to informal ones, or what drives it. We show that the vertical rent premium runs in the opposite direction from the formal-sector premium: rents fall, not rise, with floor level, and we trace this discount to physical disamenities — rising indoor temperature and deteriorating roof quality — that worsen with height.

Our second contribution is to the literature on incremental building of rental housing supply in informal settlements in cities in developing countries. The existence of a private rental sector in informal settlements, created through incrementally constructing and leasing out dwelling units has been widely documented (Amis 1984; Andreassen et al. 2021; Kumar 1996; Scheba and Turok 2020). But the phenomenon of vertical growth of informal rental housing has only been recently studied and the literature on this remains sparse. Visagie and Turok (2020) argue that building upwards is often the only way for crowded African informal settlements to accommodate population growth without consuming more land. Harish et al. (2024) show, in the Indian context, that landlords retrofit older structures through vertical extensions in areas

with historically high demand in order to maximise rental incomes. Mwau and Sverdlík (2020) document how landlords in Mathare Valley, Nairobi, have added floors to existing structures to expand the rental housing stock, producing multi-storey slum buildings rented out by the room. This literature has not connected this vertical growth quantitatively to underlying land values in the way the formal building-heights literature has, nor has it examined how rental units on higher floors are priced. We show both: we link vertical growth to land values, and show that higher floors rent for less within the same building.

Our third contribution is to the literature on determinants of rents in informal settlements. Gulyani, Bassett, and Talukdar (2012) and Gulyani and Talukdar (2008) show that rents are determined by size and quality of the dwelling unit, together with access to electricity and water supply. In the Indian context, Gupta and Gupta (2017) study demand for rental housing in Delhi's slum settlements, linking rents to dwelling and household characteristics. We add to this literature by estimating, for the first time to our knowledge, the within-building floor-level rent gradient in informal settlements.

Our fourth contribution is to the literature on residential sorting and segregation in cities. Households of different incomes and social groups are not randomly distributed within a city but sort themselves based on amenities and disamenities associated with any location. Brueckner, Thisse, and Zenou (1999) posit that because the marginal valuation of amenities rises with income, the spatial configuration of amenities determines where richer and poorer households locate. Rivera-Padilla (2021) examines sorting between informal and formal settlements in developing cities, modelling how lower-income, lower-skilled households sort into slums rather than formal housing. But sorting into informal tenements can also result from disamenities in the tall buildings that the formal sector provides. In his fieldwork in a vertical resettlement colony, Burte (2024) documents that many households rehoused from slums could not bear the costs of vertical living, which ranged from electricity for lifts to pumping water to upper floors, and moved back to nearby informal settlements. While not explicitly testing for sorting, Asher et al. (2026) document how segregation within Indian cities is associated with poorer access to basic services for socioeconomically weaker groups. Finally, studies have hypothesised that segregation itself may be partly attributed to vertical growth in cities (Graham 2015; Harris 2015). In each of these studies, sorting is treated as a process that happens across space. We add to this literature by showing that sorting also takes place within a single structure; poorer households, measured by asset holdings, occupy the higher floors of the same slum building. This is the vertical equivalent of amenity-based income sorting, with the distribution of disamenities inside a building playing the role that amenities play across a city.

3. Data

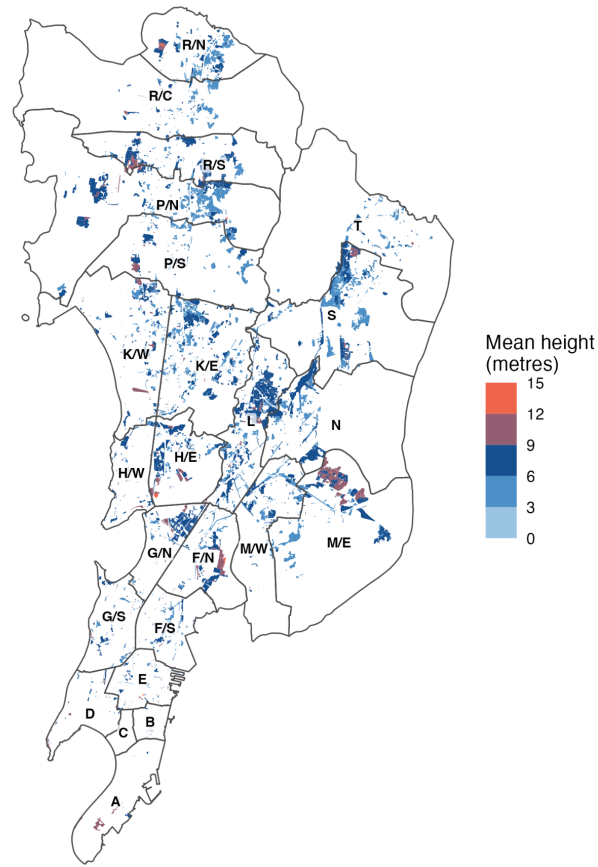
We make use of four data sets.

Our first data set is the geospatial layer of slum settlements in Mumbai. We build it from official slum maps provided by the Municipal Corporation of Greater Mumbai in their Development Plan, supplemented with maps of slum settlements in areas under special planning authorities.

Our second data set is slum building heights. We divide Mumbai into $100\text{ m} \times 100\text{ m}$ cells, clipped at the city boundary, and assign each cell to the municipal ward with which it has the largest area of overlap. We construct heights of informal settlements using 3m-resolution SPOT 6/7 stereo imagery for 2016 and 2023. SPOT 6/7 photographs the same location from two viewing angles on a single pass, which lets us construct elevation measures following Tripathy et al. (2022). We clip and mask both rasters to the mapped slum boundaries, so the resulting height measures describe buildings within slum areas rather than all buildings in a cell. We drop raster pixels with heights below 1.5 metres or above 15 metres, to exclude formal slum redevelopment buildings that may have come up within slum areas and structures shorter than a single floor (one floor is approximately three meters). For each grid cell, we average the height of the pixels in that cell to get the mean slum-building height for 2016 and 2023, and define the change in height as the difference between the two years.

Our third data set is on residential values. We use Mumbai's Ready Reckoner data, which gives government-assessed property values for geographically defined valuation zones annually. These rates represent the official benchmark value per square metre for different property types, including residential property. We overlay the Ready Reckoner zone boundaries and residential rates with the slum polygons and 100m grid cells for each year. A cell located entirely within one valuation zone is assigned that zone's residential rate, while a cell spanning multiple zones takes an area-weighted average, using each zone's share of the cell as the weight. Because a single slum can span several grid cells and valuation zones, different parts of the same slum can carry different residential values.

Our fourth data set is a primary survey of tenant households in select slum settlements within Mumbai. Figure 2 depicts slum settlements and their mean heights. We first identify wards with large shares of multi-storey slum area: M/East and P/North wards had the highest shares of slum area built two floors or more (19.7% and 13.7% respectively, see Appendix Table A1). We additionally selected H/E ward (7.2%) for its proximity to the central business district. Within these wards, we select specific sites based on clusters of vertically built dwellings, as seen in the SPOT 6/7 imagery viz. Malad West, Bandra East, and Chembur.



Mean height is calculated from valid 3 m raster pixels within each mapped slum settlement.

Figure 2. Mean Slum-Building Height, 2023

Source: Authors' own creation using SPOT 6/7 data and slum layer acquired from MCGM.

We targeted 40 slum buildings in each area, for roughly 240 households across 120 buildings. In each area, we randomly select buildings with at least two floors and survey all tenants who were available and willing to participate. We restricted the surveys to buildings in residential use only, to avoid a commercial rent premium on ground-floor units. The final dataset has 227 households surveyed, 84 each in Bandra and Chembur and 59 in Malad.

The survey covered five broad areas. First, questions on household demographics and composition included the number of people living in the unit, number of children, religion, and caste. Data on ownership of durable goods (TV, fridge, AC, washing machine, laptop, desktop, car, motorbike, auto, bicycle) was also collected. Second, characteristics of the dwelling unit covered floor level, number of rooms, wall and roof type and material, and plinth/foundation status. Third, we collected data on the monthly rent, security deposit, and how tenants found the unit. Fourth, environmental conditions and amenities were measured through questions

on roof leakage, flooding, light pollution, and noise pollution, trash outside the home, main water source, hours of water supply and cost, hours of power supply and cost, presence of an in-unit toilet; and how households cope with heat, air pollution, and flooding, including whether the upper floors felt hotter and how they adapt to temperature. Finally, we record on-site PM_{2.5}, indoor temperature, and GPS location of the building using handheld monitoring devices. In Bandra and Malad, we also interviewed five landlords for qualitative information on the rationale and process of building vertically and on how rents are set.

4. Methodology

We test for the bid-rent curve in slum heights in two ways. First, we estimate the relationship between slum height and distance to Mumbai’s two main employment centres (Central Business Districts) of Bandra and Nariman Point, and between slum height and government-assessed residential values. Second, we re-estimate the same relationship using the change in mean slum-building height between 2016 and 2023 as the dependent variable, to test whether these same forces also determine the pace of vertical growth. Equation (1) estimates this relationship in both the level and growth specifications:

$$\text{BlgHt}_c = \beta_1 \text{DistCBD}_c + \beta_2 \text{ResPr}_c + \varepsilon_c \quad (1)$$

Where BlgHt_c is the mean building height in grid c in 2023, or its 2016–2023 change in the growth specification. DistCBD_c is the distance in kilometers between the centroids of cell c and its nearest central business district. ResPr_c is the residential land value in c . In the level specification, a negative β_1 and a positive β_2 are the signature of a bid-rent gradient. Slum heights fall with distance from the business district and rise with residential land value, the same pattern formal building markets show.

Using the household surveys, we then test whether rent varies with floors within the same informal structure. We estimate the following model, where i indexes dwellings and b indexes slum structure:

$$\begin{aligned} \text{Rent}_{ib} = & \beta_1 \text{Floor}_{ib} + \beta_2 \text{Deposit}_{ib} + \beta_3 \text{Rooms}_{ib} \\ & + Z'_{ib}\theta + \sum_k \psi_k \mathbf{1}[\text{Reason}_{ib} = k] + \mu_b + \varepsilon_{ib} \end{aligned} \quad (2)$$

In equation (2) the dependent variable Rent_{ib} is monthly rent. The coefficient of interest is β_1 on Floor_{ib} , the vertical location of the dwelling, which measures the change in rent per floor. Deposit_{ib} is the security deposit paid at move-in, which is included since landlords we interviewed described adjusting the rent amount according to this deposit amount. Rooms_{ib} is the number of rooms, capturing dwelling size. The vector Z_{ib} includes additional household controls — household size and number of children — in our augmented specifications. The

terms $\mathbf{1}[\text{Reason}_{ib} = k]$ are dummies for the household's stated reason for staying in the location, absorbing differences in attachment and outside options that may affect the negotiated rent. Finally, μ_b is a slum-building fixed effect and ε_{ib} is the error term. The slum-building fixed effect is central to identification because μ_b absorbs everything constant within a structure — its location, neighbourhood, structural quality, tenure status, and landlord. Hence, β_1 is identified from within-building variation alone, comparing otherwise-similar units on different floors of the same building and isolating the price of vertical location from building-level confounders. We report both heteroskedasticity-robust standard errors and standard errors clustered at the area level, i.e. the level at which unobserved local shocks to the rental market are most plausibly correlated.

To allow for flexibility in the rent–floor relationship, we replace the linear floor term, Floor_{ib} , with floor-level dummies $\mathbf{1}[\text{Floor}_{ib} = j]$, each equal to one when a dwelling is located on floor j . Equation (3) estimates this flexible specification:

$$\begin{aligned} \text{Rent}_{ib} = & \sum_j \beta_j \mathbf{1}[\text{Floor}_{ib} = j] + \gamma \text{Deposit}_{ib} + \delta \text{Rooms}_{ib} \\ & + Z'_{ib}\theta + \sum_k \psi_k \mathbf{1}[\text{Reason}_{ib} = k] + \mu_b + \varepsilon_{ib} \end{aligned} \quad (3)$$

Each β_j measures the rent difference between floor j and the ground floor in the same slum building. It imposes no functional form on how rent evolves with height, and can capture any non-linear changes in rents with respect to floor-level.

5. Results

5.1. Slum Building Heights, Distance to CBD and Land Values

Table 1 presents the estimates for the relationship between slum heights and distance to business districts and residential values.

We find that slum-building height declines with distance from the business district (column 1, Table 1). Each additional kilometre from the nearest CBD is associated with a 0.049-metre reduction in mean height. Residential values are also positively associated with slum height: an INR 1 million increase in residential value is associated with a 1.15-metre increase in mean height (column 2, Table 1). When both variables are estimated together, however, the coefficient on residential value is no longer statistically significant, while the coefficient on distance remains unchanged (column 3, Table 1). This suggests that the association between residential values and slum height arises because higher-value locations cluster closer to Mumbai's business districts. The densification of slums closer to CBD reflects two forces: more intensive use of scarce land in high-valued locations and the premium lower-income households place on living closer to employment centres.

Table 1. Slum Height, Distance to CBD and Residential Values

	Slum height in 2023			Change in slum height 2016–23		
	(1)	(2)	(3)	(4)	(5)	(6)
Dis. to CBD (kms)	−0.0488*** (0.00418)		−0.0493*** (0.00422)	−0.0184*** (0.00239)		−0.00725*** (0.00240)
Res. value (INR mil.)		1.154*** (0.333)	0.415 (0.337)		3.654*** (0.196)	3.545*** (0.197)
Constant	6.843*** (0.0435)	6.229*** (0.0534)	6.770*** (0.0701)	0.941*** (0.0256)	0.229*** (0.0295)	0.308*** (0.0384)
Observations	10,007	9,873	9,873	9,765	9,631	9,631
R-squared	0.013	0.002	0.015	0.006	0.049	0.05

Notes: The dependent variable in columns 1–3 is mean slum-building height in metres in each 100 m grid cell in 2023. The dependent variable in columns 4–6 is the difference in slum-building height between 2016 and 2023. Distance to CBD is measured in kilometres from the centre of each grid cell to the nearer of Mumbai’s two principal business districts. Residential value is the 2023 residential rate applicable to the grid cell, expressed in INR millions. Columns 2, 3, 5, and 6 drop observations with residential value recorded as 0. Heteroskedasticity-robust standard errors are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 1 also shows how changes in slum heights relate to distance to employment districts and residential prices (columns 4–6). Slums closer to a CBD experienced greater vertical growth: each additional kilometre away from the nearest CBD is associated with 0.018 metres less growth in height. Slums in higher-value locations experienced substantially greater height growth (column 5, Table 1). An INR 1 million higher residential value is associated with a 3.65-metre greater increase in mean slum height between 2016 and 2023. When distance and residential value are included jointly (column 6, Table 1), the residential-value coefficient remains large and statistically significant, at 3.55 metres, while the magnitude of the distance coefficient falls from -0.018 to -0.007 metres but remains statistically significant. Taken together, the estimates suggest that while proximity to Mumbai’s employment centres is strongly associated with the level of slum-building height, both higher residential values and proximity to the CBD are associated with vertical growth.

This pattern fits the classic monocentric-city model. Land closer to the city centre commands a higher price because it saves commuting costs, and developers respond by building taller near the centre. The same reasoning generates the bid-rent gradient in the informal housing market. Landlords and owners of informal housing appear to be substituting capital — additional floors — for increasingly scarce and expensive land. Interviews with landlords confirm this. One landlord described building a single-story structure on a plot of unoccupied land in the 1990s in what was then a low populated area in the far north of the city. Rising commercial activity and population growth in the following decades raised demand for housing in the area, motivating him to add floors to the structure and rent out the new units.

Our findings stand in contrast with the flat bid-rent gradient for informal housing in Hender-

Table 2. Monthly Rent by Floor Level

Dependent variable	(1)	(2)	(3)	(4)
	Rent (per month)			
Floor	−223.3** (107.1)	−241.3** (103.7)	−223.3* (86.17)	−241.3** (57.87)
Deposit	−0.00971*** (0.00192)	−0.00983*** (0.00189)	−0.00971*** (0.00135)	−0.00983*** (0.00138)
Constant	5,817*** (942.6)	5,080*** (1,188)	5,817*** (867.4)	5,080* (1,799)
Observations	226	226	226	226
R-squared	0.847	0.851	0.847	0.851
Building FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
SE type	Robust	Robust	Clustered at Area	Clustered at Area

Notes: The dependent variable is rent per month. Columns 1 and 3 have the number of rooms and reasons to stay in this location as controls. Columns 2 and 4 have additional controls which are household size and number of children. Columns 1 and 2 have robust standard errors and columns 3 and 4 have standard errors clustered by area the slum household is located within. Significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

son, Regan, and Venables (2021). A potential reason could be that topographical features shape patterns of slum growth. When demand in topographically constrained cities like Mumbai cannot be accommodated through horizontal expansion, vertical intensification emerges as an important margin of adjustment. Thus, it is important to consider absolute levels of land scarcity in understanding how informal settlements respond to increases in land values and population pressure.

5.2. Higher Floors — Amenity or Disamenity?

Having established that slum heights respond to land values, we now ask whether higher floors are priced as an amenity or a disamenity, using our household survey data to test whether the floor-rent relationship reveals a penalty or a premium.

Table 2 estimates the linear floor gradient using the household survey, regressing monthly rent on the dwelling's floor level, the deposit, and building fixed effects. The identification comes from variation across floors within the same slum structure. We find that moving up one floor within the same building is associated with a reduction of monthly rent of around INR 223–241 (columns 1–2). These estimates are robust to clustering standard errors at the area level (columns 3–4 in Table 2). Relative to the average ground-floor rent of Rs. 7,054 per month, our preferred estimates (columns 1–2) imply a 3.2–3.4% decline in rent for each additional floor. These results are in line with landlords' own accounts of earning lower rents on higher floors.

Taken together, Table 2 documents a robust within-building rent penalty for height — in contrast to the vertical rent premium Danton and Himbert (2018) find in formal housing markets.

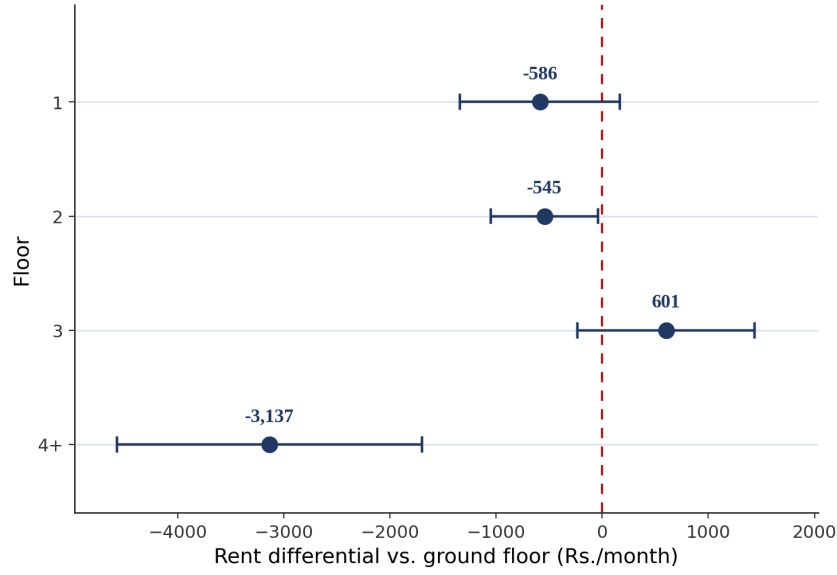


Figure 3. Rent Differential by Floor

Figure 3 plots the coefficients β_j from the floor-dummy specification in equation (3), each measuring the rent difference between floor j and the ground floor within the same building. We provide evidence of a non-linear relationship between floors and penalty on rents. From the fourth floor upward a clear and statistically significant rent penalty emerges. Dwellings on the fourth floor and above rent for around INR 3,137 less per month than ground-floor units in the same building. This pattern suggests that the rent discount with respect to the vertical height in slum buildings is concentrated beyond the third floor rather than accruing smoothly with each additional floor.

The floor penalty documented in Table 2 and Figure 3 therefore appears to reflect a bundle of disamenities associated with vertical location — which may include heat exposure, absence of a lift, reduced water pressure, or lower structural quality.

6. Mechanisms

We now ask what drives the non-linear relationship between floors and rents. Table 3 shows separate regressions of six candidate mechanisms on floor level, using the same within-building comparison as before — indoor temperature, air pollution, flooding and roof leakage, roof material, and hours of water supply. Factors that change with floor levels are plausible channels through which height affects rent.

We find that temperature rises with floor (0.180°C per floor), consistent with heat accumulating at height in buildings without insulation or cross-ventilation. $\text{PM}_{2.5}$ readings decline with floor ($-5.2 \mu\text{g}/\text{m}^3$ per floor) but the relationship is not statistically significant. Roof material shifts toward cheaper tin sheeting at higher floors, consistent with upper floors being more

Table 3. Candidate Mechanisms by Floor Level

Mechanism	Floor coef.	SE	R^2	N
Temperature ($^{\circ}\text{C}$)	0.180**	(0.081)	0.626	227
PM _{2.5}	-5.196	(3.348)	0.519	226
Flooding	0.027	(0.051)	0.517	227
Roof leakage	0.093*	(0.056)	0.581	227
Tin roof (vs. cement)	0.051***	(0.019)	0.464	181
Water supply hours	0.233	(0.182)	0.668	224

Notes: Each row is a separate regression of the named mechanism variable. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Temperature and PM_{2.5} are objective physical readings, taken with a handheld sensor at each dwelling at the time of the survey visit. One observation having an implausible large PM_{2.5} value was dropped in the PM_{2.5} regression. Flooding and roof leakage are self-reported on a 1–5 scale where higher values indicate the respondent reports a more severe problem. Tin roof (vs. cement) is a binary indicator equal to 1 if the respondent’s roof is tin sheet and 0 if cement (the omitted/base category). Respondents who did not answer the roof-material question are excluded, which is why this row’s N is lower. Water supply hours is self-reported hours of piped water supply received per day. Fewer observations are on account of non-responses.

recent, informally added construction rather than part of the original structure. Roof leakage reports rise with floor, while flooding and water supply hours show no significant relationship with floor at all.

These results point to disamenities that worsen gradually with height. Temperature rises and roof quality worsens gradually with height. At lower floors, the accumulated disamenities are modest enough that there is no net, statistically detectable rent penalty on floor 3. From the fourth floor upward, however, a large and significant discount emerges, suggesting the accumulating disamenities cross a threshold beyond which tenants are no longer willing to pay comparable rents. While we are able to test the role of some mechanisms, there may be other contributing factors which also explain the rent penalty on higher floors. These include the absence of elevators and increasing effort of climbing stairs to upper floors, concerns about structural stability, and difficulty in emergency evacuations.

7. Vertical Sorting

The preceding sections establish that upper floors rent for less and that this discount reflects a bundle of disamenities. If the rent discount compensates for these disamenities, poorer tenants may be most willing to accept the disamenities for lower rents and occupy higher floors.

We test for vertical sorting by examining the correlation between household wealth and floor level within the same building. We proxy wealth with an asset index, Asset Count, constructed as the sum of ten binary ownership indicators (television, refrigerator, air conditioner, washing

Table 4. Household Assets by Floor Level

	(1)	(2)
Dependent variable: Asset Count		
Floor	−0.206*** (0.0634)	−0.206*** (0.0609)
Constant	1.573*** (0.1145)	0.410 (0.418)
Observations	227	226
R-squared	0.664	0.695
Building FE	Yes	Yes
Controls	No	Yes
SE type	Robust	Robust

Notes: The dependent variable is Asset Count, a household asset index built as the sum of ten binary ownership indicators (television, refrigerator, air conditioner, washing machine, laptop, desktop computer, car, motorbike, auto-rickshaw, bicycle). Floor is treated as continuous in both columns. Column (1) includes no controls. Column (2) controls for number of rooms, household size, and number of children. Both columns include building fixed effects and report heteroskedasticity-robust standard errors. Significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

machine, laptop, desktop computer, car, motorbike, auto-rickshaw, and bicycle). Mean asset ownership falls from 1.58 for tenant households on the ground floor to 0.77 on the fourth floor and above, against an overall mean of 1.29 (see Appendix Table A2).

We regress this index on floor level, retaining the slum-building fixed effect and the household controls (number of rooms, household size, and number of children):

$$\text{AssetCount}_{ib} = \beta_1 \text{Floor}_{ib} + X'_{ib}\theta + \mu_b + \varepsilon_{ib} \quad (4)$$

As in the rent regressions, the building fixed effects μ_b allow us to compare the asset holdings of households living on different floors of the same structure, so any relationship between wealth and height is identified from within-building sorting. We estimate the relationship in two forms: a continuous specification in which floor enters linearly and a flexible specification with floor dummies and the ground floor as the omitted category, and the fourth and fifth floors combined into a single 4+ group.

Table 4 shows that each additional floor is associated with 0.206 fewer assets owned, statistically significant at the 1% level. The floor-bin specification (Figure 4) shows that relative to ground-floor households in the same building, second-floor households own 0.388 fewer assets and households on the 4+ floor own 1.20 fewer assets. The first and third floor estimates, while also negative, are not statistically significant. These descriptive results indicate that the tenants absorbing the disamenities of higher locations i.e. hotter, harder-to-reach dwellings with poor roof quality, are also the least well-off.

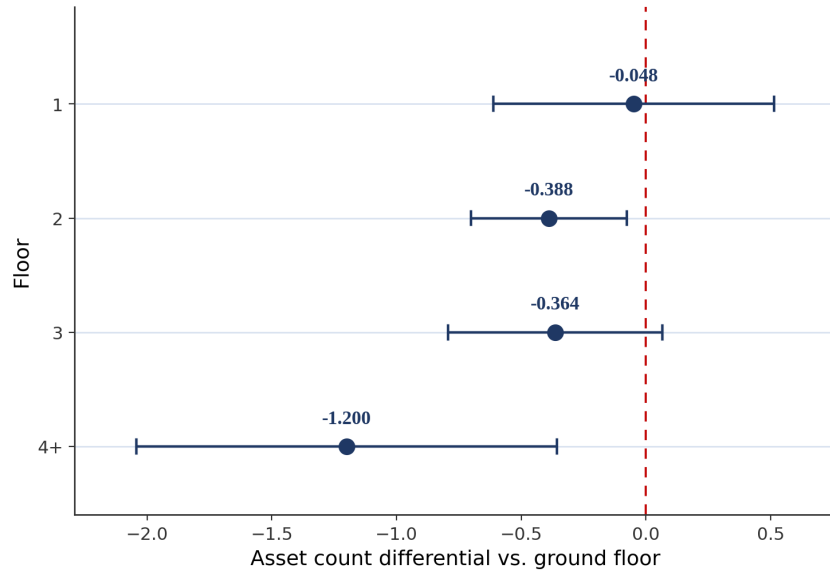


Figure 4. Asset Count Differential by Floor

Note: The figure plots the coefficients on floor dummies with floor 0 (ground) as the omitted/base category and floors 4 and 5 combined into a single 4+ category. The regression controls for number of rooms, household size, and number of children, includes building fixed effects, and reports heteroskedasticity-robust standard errors.

Amenity-based sorting has long been documented across neighbourhoods within cities (Brueckner, Thisse, and Zenou 1999). Our results suggest it also operates vertically within a single slum building. Households with fewer assets are systematically more likely to occupy the upper floors of the same structure, accepting a lower rent relative to their ground-floor neighbours as compensation for living with height-related disamenities.

8. Conclusion

The economics of vertical slum growth is understudied. This paper takes a first step toward filling that gap. We find slum heights fall with distance to business districts and rise with residential land values. This is consistent with a bid-rent gradient in formal housing. To understand if living on higher floors in slums is an amenity or a disamenity, we conduct a survey of tenant households to estimate the relationship between floors and rents. We use within-building variation across floors of the same structure and find that rents fall by 3.2–3.4% per additional floor, on average. However, this decline is strongest at four floors and above. We find evidence for higher temperature, roof leakage, and poor quality roof material on the higher floors potentially driving the rental discount. Finally, each floor is associated with 0.21 fewer assets owned by tenant households providing evidence of vertical sorting by wealth.

This paper extends several theories of urban land markets to informal housing. Bid-rent theory has long explained formal building heights near city centers. We show slum heights respond to the same underlying land-price gradient in land-scarce cities. Yet, the floor-rent relationship inside slum buildings diverges from formal buildings. Upper floors in formal high-rises command a premium for view and light. Instead, upper floors in slum buildings face a discount for disamenities. Amenity-based sorting theory has mostly examined sorting across neighborhoods within cities. We extend this theory to sorting within a single building. Poorer households sort onto higher floors just as they sort into worse neighborhoods. Vertical sorting is therefore the within-building analogue of horizontal amenity sorting. While this study provides an initial step toward understanding vertical pricing in informal housing, and an understanding of mechanisms driving floor-level rental discounts, more research is needed on the economics of slum growth. One research avenue is using direct measures of water pressure, quality of stairwells, and presence or absence of elevators to pin down the channels behind the floor penalty.

Our findings provide policy directions for addressing the downsides of vertical densities in slums. Incremental housing schemes that encourage the building of additional floors must consider the potential costs in terms of absence of lifts, stairwells built to a reasonable standard, and greater exposure to inclement weather and provide support for roof insulation and weatherproofing, safe stairways, and assessments of structural capacity. Rental subsidy or tenure-security programmes targeted at slum tenants need to consider higher floor level as a marker of vulnerability since tenants residing there may belong to socioeconomically weaker sections relative to those living on the ground floor.

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Table A1. Slum Area Built Two Floors or Higher, Selected Wards

Ward	Area sqm	% of total area	Rank
M/E	2,769,587	19.71%	1
P/N	1,923,326	13.69%	2
H/E	1,013,203	7.21%	6

Table A2. Asset Count by Floor: Descriptive Statistics

Floor	Mean	SD	Min	Max
0	1.58	1.44	0	6
1	1.24	1.30	0	4
2	1.03	1.19	0	4
3	1.33	1.32	0	4
4+	0.77	0.73	0	2
Overall	1.29	1.32	0	6

Notes: Asset count is a household asset index constructed as the sum of ten binary ownership indicators: television, refrigerator, air conditioner, washing machine, laptop, desktop computer, car, motorbike, auto-rickshaw, and bicycle. Smart phones and simple/feature phones are excluded from the count because ownership of at least one is nearly universal (over 85% of households own a smart phone), leaving little variation to distinguish households by wealth. Floor 0 is the ground floor. Floor 4+ combines floors 4 and 5 into a single top-floor category, consistent with the 4+ category in Figure 4.