Housing market discrimination in the Mumbai Metropolitan Region - a spatial analysis of caste-based and religious segregation

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1. Introduction

Mumbai, India's financial and commercial capital, is both its wealthiest city and its most diverse. The former headquarters of the Bombay Presidency during British rule, the city had long been home to large minority communities from around the province, but was always dominated by Maharashtrians and Gujaratis, the ethnic natives of the region. Post-independence, however, the city was (and continues to be) shaped by waves of immigration from across the state and the country, exponentially growing its population and consequently its urbanized area to accommodate these new residents. Large swathes of land to the north of the city, previously independent towns or villages, were annexed by administration. Mumbai is no stranger to expansion - indeed, the original island city owes its mere existence to land reclamation by the British - but its scale and scope in the past few decades has been unprecedented. In 1951, the city covered 231.5 km^2 and housed 2.3 million people. By 2011, the city's metropolitan region (henceforth shortened as MMR) spanned 6,328 km^2 with 22.8 million people, with the city proper housing 12.2 million over a mere 603 km^2. Today, Maharashtrians and Gujaratis only make up 42% and 19% of the city's population.

These rapid changes in demography have brought with them a significant rise in ethnic, religious, and caste tension. Combined with rising real estate prices - the highest in India and in the top 20 globally - these have manifested in *severe* social segregation in the housing market. Despite recent laws that have attempted to curb the practice (Koppikar 2023), many apartment buildings have been found outright barring Muslims, lower caste individuals, and specific ethnicities; failing that, they ban "non-vegetarians" in order to circumvent the law, as lower/middle caste Hindus and religious minorities alike are more likely to be non-vegetarian (T. Staff, n.d.). From Gujarati "colonies" in suburban neighborhoods like Vile Parle and Ghatkopar to the ghettoization of Muslims in Mumbra, many in the city live segregated lives.

When not motivated by self-preservation as a social minority, the common thread uniting these blatantly discriminatory acts is likely a strong **casteist** sentiment. With housing societies going as far as having separate elevators for residents and "servants" (I. Staff 2020), we see a strong revulsion of living in, or even sharing any space, as people with perceived undesirable characteristics, linked to the idea of the "impurity" of lower castes. Even when ethnic solidarity has been observed amidst rising tensions, caste fractures

have run high in Mumbai; for example, the Shiv Sena, a right-wing, pro-nativist political party that came into power rallying under preferential treatment for Maharashtrians, covertly opposed affirmative action for lower caste Maharashtrians (see Worli riots, opposition to Mandal Commission). This discrimination can extend to "natives" of the region as well, with numerous stories having emerged in recent years (M. Staff 2021) of Maharshtrians being denied housing by Gujaratis (on average, local Gujarati communities are wealthier and of higher caste than Maharashtrians).

This project hence aims to explore to what extent Dalits, Adivasis, and other lower caste/class groups have been pushed to the margins of the city, as well as how current demographics of the region reflect characteristics of migrating populations. The primary objective of the project is descriptive rather than inferential or predictive, and aims to obtain a spatially-informed understanding of segregation both within Mumbai's exurbs and between the city and its fringes. Spatial segregation in Mumbai's housing market has been well-established in the literature (Shaban and Aboli 2021); however, little analysis has been conducted on segregation in the wider metropolitan region, outside the boundaries of the city proper. In a city with limited land space, segregation effectively incentivizes those shut out of its restrictive market to either live in slum-like informal tenements or to seek housing in the MMR's far-flung satellite cities. Real estate prices also tend to decrease as one moves northwards and eastwards from the old city, further pushing lower-income individuals (who are disproportionately lower-caste and/or Muslim) outwards. This has the potential for severe business impacts (Bharathi, Malghan, and Rahman 2023) - daily commutes of three hours or more are not uncommon in the region, as a majority of employment tends to be concentrated in industrial areas and business districts in the city proper, even today. There is also evidence that these exurbs are less developed and have reduced access to public services (see pre-print from Asher et al. 2023), further underlining the necessity of this study.

2. Data

The data used in this study comes from The Socioeconomic High-resolution Rural-Urban Geographic Platform for India Project (abbrv. SHRUG). SHRUG is an open access repository that links hundreds of Indian datasets comprising socio-economic surveys, censuses, and environmental studies with common geographic identifiers. Owing to the nation's size and diversity, Indian record-keeping is notoriously inconsistent, with formats, naming conventions, and even languages often differing within the same state. SHRUG obtains a level of standardization and geographic granularity that cannot be found in any single government dataset - by splitting the nation into 576,153 uniform areal units termed "shrids" and reaggregating all variables to these, it provides a largely consistent framework facilitating analysis at a deeper level than states, districts and sub-districts. For these reasons, this project utilizes the **2011 Population Census Abstract (PCA) and Economic Census (EC)** datasets in SHRUG (Registrar General and Census Commissioner 2011; Ministry of Rural Development 2011; Asher et al. 2021).

The 2011 PCA and EC datasets are the most recent census data available for India. As stored at the shrid and subdistrict level in SHRUG, they contain a multitude of variables on employment, occupation, literacy, and consumption, as well as demographic information like gender, caste, and educational status. Key variables of interest were the Scheduled Caste/Scheduled Tribe (SC/ST) population percentages, home/land ownership shares, and employment/business ownership by different classes (including OBCs). Note that

SC/ST are government designations for Dalits and Adivasis, while OBCs refer to a range of lower and middle classes considered socio-economically "backward". Surprisingly missing from the dataset was a breakdown of religions and ethnicities in each shrid. This could have provided additional nuance to our analysis, especially when looking at how they intersect with caste; many non-Hindu Indians also have caste distinctions, while an ethnic breakdown could contextualize discrimination with regards to how familiar individuals may be with specific sub-castes not present in their native regions.

2.1 Data Cleaning

As SHRUG has no linking variables between district/sub-district data and shrid-level data, finding the specific shrids that comprised the MMR outside of the city proper proved a challenge. This was compounded by the fact that the MMR is defined by the Municipal Corporations and Councils that comprise it, the exact boundaries for which occasionally span multiple state-level sub-districts. To rectify this problem as much as possible, the spatial intersection between the most relevant sub-districts of the MMR and all shrids in the PCA data was computed. This, however, missed out on a few areas of interest, most notably the majority of the municipal council of Khopoli, while including a few parcels of rural land that were not relevant. The cleaned dataset contained 1273 shrids with a population totaling roughly 22.1 million - this was deemed an acceptable enough difference from the true population of 22.8 million.

Another issue encountered was that the city proper was only comprised of two shrids, each spanning the Mumbai City and Mumbai Suburban districts respectively. The authors of SHRUG note this as an issue in their documentation - specifically, that breaking up census data into shrids was challenging in and around major cities given census issues - and this hampered some of the comparative analysis that was planned with regards to segregation in the city vs. the rest of the MMR.

Finally, there were 102 missing shrids in the EC dataset. As a result, only PCA variables are available for those vs. the full set of PCA and EC variables for the rest.

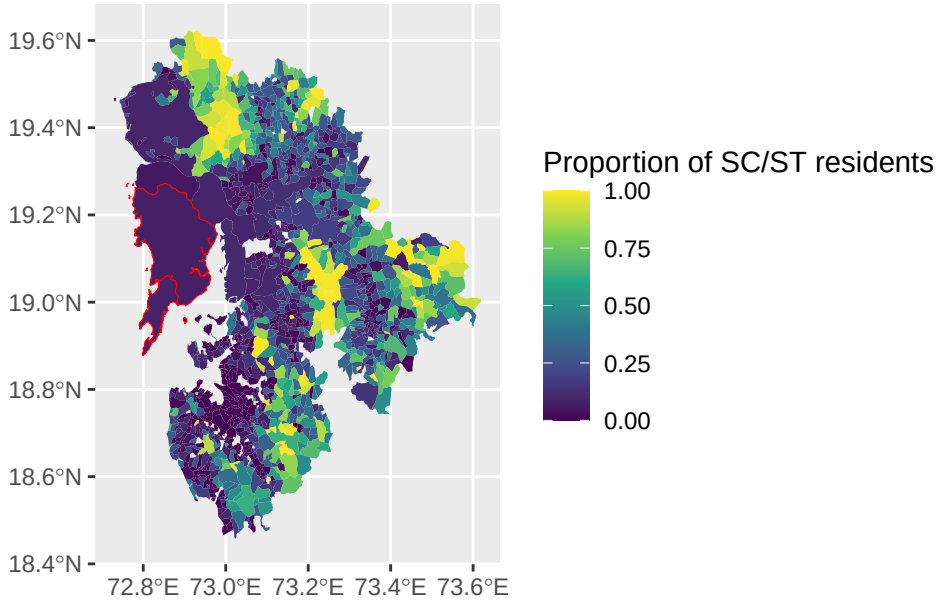
2.2 Exploration

Table 1: Caste demography of the MMR vs. India

	Region	SC Population (% of total)	ST Population (% of total)	Combined SC/ST Population (% of total)
1	Mumbai (city proper)	6.46	1.04	7.50
2	MMR (excluding city proper)	7.12	5.56	12.68
3	Maharashtra	11.81	9.35	21.17
4	India	16.60	8.60	25.20

Table 1 demonstrates that migration to Mumbai and the MMR has not been reflective of the broader caste population of India or of the state. This is not particularly surprising for the ST population, who primarily inhabit forested regions, but a marked difference must be noted in the SC population, who theoretically should be more evenly spread out. What is notable for STs is the stark difference in population percentages between the city proper and the rest of the urban region, indicating their exclusion from the city.

Figure 1: Shrid−wise map of SC/ST populations



This finding is confirmed by Figure 1. As before, note that all of the city proper is two large shrids, outlined in red on the map. We observe a pattern of increasing SC/ST percentages as we move northwards from the original island city, with higher percentages observed in the Kalyan and Bhiwandi sub-districts as well as parts of Vasai/Virar (see Figure 2 in Appendix for a subdistrict-wise map). A particuarly high percentage is observed in the easternmost sub-district of Karjat, as well as the southermost parts of Alibag/Pen sub-districts in the south. This reinforces initial speculation as to the pricing out of these minorities towards northern and eastern parts of the MMR. Computing Geary's C yielded a value of 0.543 ($p < 0.001$), suggesting positive spatial autocorrelation and indicating that a shrid with a high SC/ST proportion is likely to neighbor a shrid with a very similar proportion. These set the guiding context within which we will conduct our analysis and provide additional evidence for claims made in the introduction.

Table 2: Firm ownership by caste/class in the MMR

	Region	SC (% of total firms)	ST (% of total firms)	OBC (% of total firms)
1	Mumbai (city proper)	7.18	2.10	5.41
2	MMR (excluding city proper)	6.84	2.86	17.36
3	India	9.82	4.17	34.17

Table 2 shows us that lower and middle caste groups, especially OBCs, have a drastically lower ownership of firms in the city as compared to India, with a sharp difference even between Mumbai and the exurbs. This is less pronounced for SCs, but note that SCs and STs are far more disenfranchised as populations and have much lower capital ownership in general, so this may not the best metric to evaluate.

3. Spatial Analysis

3.1 Methodology

3.1.1 Primary Outcome

The primary outcome of this study is a set of segregation statistics to spatially describe caste/tribe-based segregation in the MMR at a shrid level. These will comprise of the aspatial global dissimilarity index, Reardon and O'Sullivan's set of surface-based spatial dissimilarity indices (Reardon and O'Sullivan 2004), and Morrill's areal-based, spatially-adjusted dissimilarity index (Morrill 1992), comparing SC and ST population percentages vs. all other individuals as well as firm ownership for SC, ST, and OBC populations vs. all others. These statistics are theoretically bounded between 0 and 1, with 1 being some measure of perfect segregation/no diversity and 0 being no segregation/perfect diversity (elaborated upon in Results). OBC statistics will be used as a proxy for religious discrimination - high percentages of religious minorities fall in this class.

The conventional aspatial global dissimilarity index, although still widely used, has long been considered insufficient to accurately capture the effects of spatial correlation. This is primarily due to the so-called "checkerboard problem" (Reardon and O'Sullivan 2004), where high exposure (i.e. at small distances from each other and easily able to interact), but non-clustered distributions of two groups can appear more segregated than they are. In a city like Mumbai, where expansions of its territory and local geography have been shaped significantly by different waves of immigration, this could greatly affect our estimates. The specific choice of Reardon and O'Sullivan's (henceforth abbrv. RS) measures was because similar kernel-based spatial indices have been previously used in the Indian context to some success (see Haque et al. 2021). However, neither the aspatial index nor the RS global dissimilarity index fully satisfy the compositional invariance criterion (Barron et al. 2023; Reardon and O'Sullivan 2004) - the implications of this for the analysis of the region are debated in further detail in the Discussion section. RS also requires tuning of the kernel/smoothing algorithm, which I was unfamiliar with and had to rely on the software's best guess. Therefore, I also included Morrill's measure, which is a more easily intepretable, direct modification of the aspatial index, but suffers from the MAUP (see Secondary Outcome for details).

These metrics were calculated using the *seg* package in R, developed in part by O'Sullivan. As *seg* has been temporarily unavailable on CRAN since Feb 2024 due to dependency issues, I used an older version of the package available on the archive, for which the tar.gz can be found in the project repo. I also had to update some code in the package itself, as some lines were outdated given changes in syntax for some R functions; these changes are described in the Appendix.

Significance will be tested using a pseudo-significance "p-value" measure, computed on a Monte Carlo simulation of dissimilarity using random spatial arrangements vs. the population data (using a procedure

similar to Feitosa et al. 2007, 309–10). This will be conducted using the *OasisR* package - as this package depended on *seg*, it is also no longer available on CRAN, so an archived version from Dec 2023 was used.

3.1.2 Secondary Outcome

The secondary outcome of this study is the same set of spatial statistics, but computed at the census' sub-district level. This is primarily to account for potential variability in results resulting from the modifiable areal unit problem (MAUP), also known as the "grid" problem (Feitosa et al. 2007). Most spatial data is stored in an areal format - indeed, so was the data for this study - but the exact choice of area unit, including its shape and its size, can have large impacts on how one estimates segregation. This is especially true for data when we can only compute a simple spatial weight matrix to quantify interactions between areal units, as is the case here, rather than an intensity of interaction function. For example, smaller units are likely to be more homogeneous so could show a smaller segregation effect than larger ones. Neither the aspatial index or Morrill's measure avoid this issue, and although RS largely avoids it through kernel-based population estimates, it may still be informative to see how estimates differ.

3.2. Results

Table 3: Primary Outcome Results - Shrid-level Indices

Comparison Type	Aspatial D Index	Morrill's D Index	Reard/O'Sull D Index	Reard/O'Sull R Index	Reard/O'Sull H Index
SC residents vs. all	0.137	0.099	0.026	-0.025	-0.019
ST residents vs. all	0.496	0.287	0.067	0.114	0.090
SC/ST firm ownership vs. all	0.143	0.031	0.007	-0.008	-0.006
OBC firm ownership vs. all	0.368	0.126	0.046	0.051	0.040

First, we can note that the spatial indices are uniformly lower in value than the aspatial index, underlining the importance of considering spatial correlation when examining segregation. The aspatial index seems to display clear segregation for all comparisons. Glancing at our results, however, we see generally inconsistent results with RS's *R* and *H* indices, with some negative values as well. *R* refers to how much less diverse an individual's local environment is, on average, as opposed to the global environment; *H* is an entropy-based measure of the same. While a value of 1 would imply a mono-caste/class/tribe shrid, a negative value for either implies that shrids are more diverse than the global environment, on average. This is certainly an unintuitive finding for both SC residential and SC/ST firm ownership discrimination and will be dissected further in the Discussion Section.

With these caveats in mind, we still observe a value of approximately 0.1 for Morrill's Dissimilarity index for the SC population ($p = 0.01$), indicating that roughly 10% of the MMR's SC population would have to

move to achieve a perfectly even distribution (i.e. be well-integrated). However, the strongest evidence is undoubtedly that for Scheduled Tribes, who have the highest levels of segregation in the MMR across all metrics. Using RS's *R* index, relatively easier to interpret, we see that STs neighborhoods will be roughly 11.4% less diverse/have a 11.4% higher concentration of STs than average for the MMR. Similarly, Morrill's D Index indicates that 28.4% of the MMR's ST population would have to move to be well-integrated, a staggering number. There statistics were also statistically significant by our permutation test (all p-values can be found in Table 6 in the appendix).

Finally, when examining OBC firm ownership statistics, we see a sharp drop-off between the aspatial dissimilarity value vs. Morrill's dissimilarity. Intuitively, this makes sense - a large proportion of native Maharashtrians and Gujaratis fall under the OBC designation, and their longer history in the city may have led to more distinct enclaves and spatial arrangements. Interestingly, OBC's segregation, at least when examined on a firm ownership basis, seems roughly equal to or slightly higher than SC segregation, with RS measures more consistent as well. However, it is unclear how valid this comparison is, given the conceptual differences between population concentration and capital ownership and the fact that OBCs own capital at a far higher rate, as previously mentioned; this utility of this segregation measure is examined further in the Discussion section.

Table 4: Secondary Outcome Results - Subdistrict-level Indices

Comparison Type	Aspatial D Index	Morrill's D Index
SC residents vs. all	0.102	0.069
ST residents vs. all	0.428	0.376
SC/ST firm ownership vs. all	0.089	0.061
OBC firm ownership vs. all	0.323	0.233

On repeated efforts, RS measures failed to compute for any of our desired secondary comparisons. This may owe to the number of subdistricts simply being too small to obtain an accurate kernel estimation of the population density function. However, examining the remaining indices, very similar results are seen to the primary outcome, and no conclusions are majorly affected, showing that this analysis is fairly robust to the MAUP. A smaller Morrill's D value for SC residents at the subdistrict level as well as generally lower aspatial index values indicate that at a more granular level, population compositions may actually be more heterogeneous, potentially signaling the necessity of an even smaller unit of analysis than shrids for the most accurate results.

4. Conclusion and Discussion

This project's analysis showed less segregation for SC individuals than initially may have been expected, but still displayed convincing evidence for the segregation of STs. In a city where deforestation has accelerated significantly due to infrastructure development and new construction (Pathak 2019; Singh 2022), this is a particular meaningful finding, as Mumbai's affected mangrove forest areas are historically home to Kolis, many subgroups of whom are STs. As Figure 1 and 2 display, a higher concentration of SC/ST is found

outside Mumbai, particularly evident in the exurban centres of Badlapur/Ambarnath (far east of the city) and non-mangrove forest areas, indicating possible displacement from their traditional dwelling near the coast.

Although clear OBC segregation in percentages of firm ownership was seen, this was admittedly a somewhat arbitrary measure to use to analyze housing discrimination, speaking more to asset ownership patterns. Conflating OBC membership with lower/middle castes may also be a shaky assumption to make - the definition of the class has been increasingly diluted due to upper-middle Hindu castes lobbying governments for their inclusion in it (e.g. to receive affirmative action benefits), such that up to 30-40% of Hindu communities fall in the class today. As such, the observed result may speak more to class-based rather than caste/religious-based segregation, somewhat outside the initial scope of the study but still a notable finding. It serves best as a standalone measure of OBC segregation compared to all other castes, especially Forward castes, and has less utility to as a direct comparison to SCs or STs.

Many of the limitations of this study arose from data availability and quality. The fact that the city proper only consisted of two shrids affected the ability to make accurate intra-city and city/exurb comparisons. For example, if we did have more granularity, we might have observed conglomerations of STs in areas of the city that are heavily forested like Aarey Colony, Gorai, etc. Further, with the bulk of the MMRs population in the city, more clear cut segregation of SCs may have been observed as well. An explicit comparison of segregation indices within the city and outside would have been conducted if this were the case. Methodologically, we must also acknowledge that many of these measures are, relatively speaking, new in the literature and each suffers from limitations unique to them. Specifically, for the set of RS measures, compositional invariance - the idea that a segregation index should return the same value regardless of the actual composition of a population by subgroup - is not met, which means that they require a uniform population distribution across space, an assumption that certainly does not hold for the MMR. This may be why we observed such low RS values at the shrid-level, compounded by the asymmetry in distribution from the 2-shrid problem,

In the future, this study could be conducted at the census' *ward* level; wards correspond directly to specific neighborhoods in the region that have sociological and historical value (rather than the more arbitrary geography of shrids), yielding more meaningful conclusions. However, ward-level data is not readily available in SHRUG, so cleaning it appropriately (i.e. implementing SHRUG's rigorous standardization process) would be a months/years long affair more suitable for a thesis project. With newer, more granular datasets, it may be interesting to examine specific religions and ethnic breakdowns for a fuller picture, or better still, look at specific sub-castes and their segregation, especially with the recent groundbreaking caste surveys conducted by states like Bihar. This could also solve the 2-shrid problem, possibly allowing us to re-compute RS measures and obtain a clearer sense of discrimination against SCs.

Regardless of these limitations, however, the practical implications of this study are significant. For one, it demonstrates the tendency of urban centers to marginalize the already disenfranchised, failing to serve them with the same quality of public services, access to employment, or quality of life as the privileged. From an equity standpoint, it underscores the need for MMRDA (the MMR's urban planning authority) to focus on exurban development, as well as build better transit connections to the city to equalize these developmental differences. In recent years, MMRDA seems to have taken the opposite approach, focusing on car-centric infrastructure to connect the richer, southern parts of the city through projects like the Coastal Road; like

deforestation, this has the largest impacts on the ST Koli community by harming fishing yield along the coast (Desai 2024). This study hence reinforces the intersection of urban and economic inequity with caste, tribe and religion in India, even in progressive cities like Mumbai, and asks policy-makers to consider how new development could exacerbate existing disparities. Finally, this study can serve as a model to examine the metropolitan regions of other major Indian cities, with their own complex histories of immigration, diversity, and discrimination.

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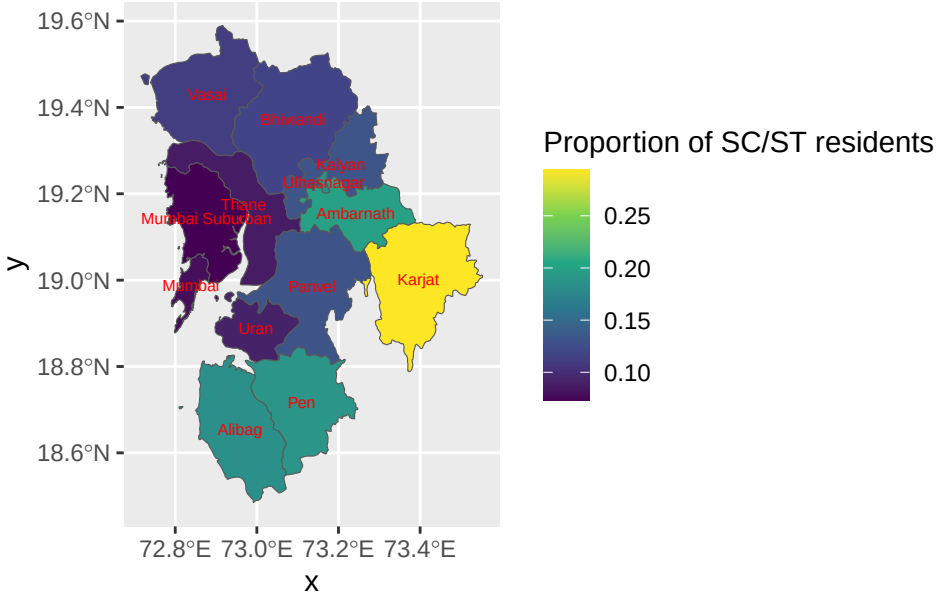
Appendix

Figure 2: Subdistrict−wise map of SC/ST populations

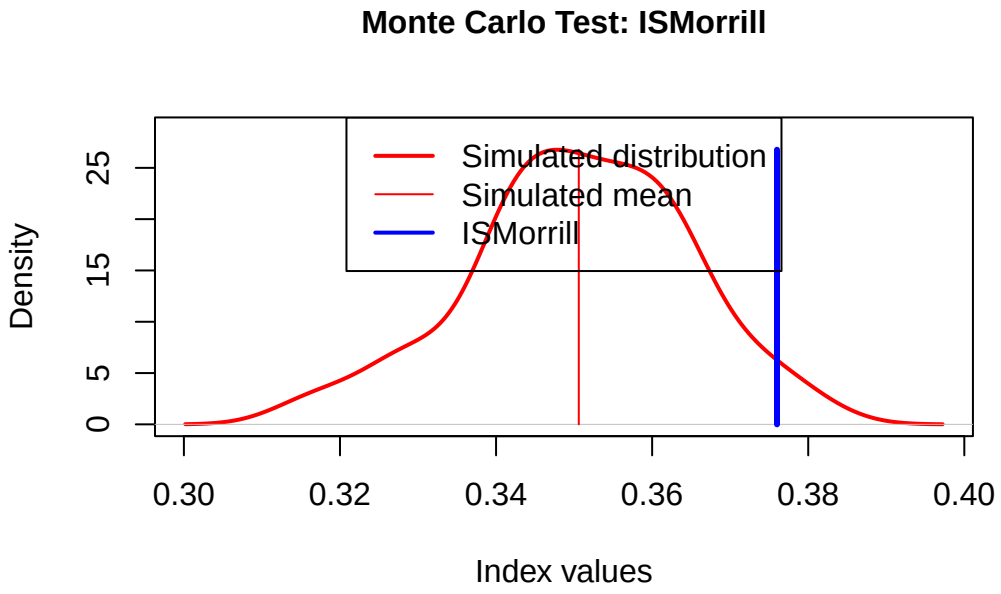


Modifications to seg: In dissim.internals, all do.call function calls called their functions with their names in quotes (i.e. "spdep::poly2nb" instead of spdep::poly2nb), which prevented dissim from working correctly. I changed this to the non-quoted version, which made the package work.

Table 5: P-values for spatial statistics (only evaluable for Morrill's D)

Comparison	P-value
SC population vs. all - shrid level	0.01
ST population vs. all - shrid level	0.01
SC/ST firm ownership vs. all - subdist level	0.01
ST population vs. all - subdist level	0.02
SC/ST firm ownership vs. all - shrid level	0.01
SC/ST firm ownership vs. all - subdist level	0.61
OBC firm ownership vs. all - shrid level	0.01
OBC firm ownership vs. all - shrid level	0.01

An example of the permutation test for which p-values were computed can be found below. This is for the ST vs. all comparison at the subdist level:


Monte Carlo Test: ISMorrill
Simulated distribution
Simulated mean
ISMorrill
Density
0
5
15
25
0.30
0.32
0.34
0.36
0.38
0.40
Index values