Do Ethnic Integration Policies also Improve Socioeconomic Integration? A Study of Residential Segregation in Singapore

ABSTRACT

Concerns over the negative impact of residential segregation have motivated de-segregation policies around the world. Singapore's Ethnic Integration Policy (EIP) is a de-segregation policy perceived to be effective in reducing ethnic segregation. However, there is little clarity about how the EIP might affect socioeconomic segregation, another important dimension of segregation. This study explores Singapore's socioeconomic and ethnic residential segregation patterns from 1990 until 2020, focusing on three scales of analysis: national, city district-level (subzone) and building-level. Ethnic and socioeconomic segregation, which were generally low, fluctuated in opposite directions over the years. While public housing flats were exposed to less ethnic and socioeconomic segregation than private housing, findings suggest a negative relationship between ethnic and socioeconomic segregation for majority public housing subzones. This inverse relationship between socioeconomic and ethnic segregation might be due to EIP's distortionary effect on flat resale prices. These findings highlight the need for greater attentiveness to residential integration policies' impact on both socioeconomic and ethnic integration, and not to assume that policies aimed at improving one would be sufficient to address the other.

Keywords: Racial segregation, Ethnic segregation, Socioeconomic segregation, Asia, property transaction

INTRODUCTION

Residential segregation refers to the physical separation of individuals in residential space based on their membership in socially constructed categories such as race, ethnicity, gender, class, or religion (Kramer, 2018; Massey and Denton, 1988). High levels of residential segregation can be very problematic as they often coincide with unequal spatial access to important spatial goods and amenities like jobs and good schools, such that access is disproportionately reserved for the powerful while marginalized groups are forced to live in less-well served areas with more negative environmental exposures (Brulle and Pellow, 2006; Gobillon et al., 2007; Williams and Collins, 2001). Such inequitable distribution of goods, services, and resources exacerbates existing inequalities in economic and health outcomes. Furthermore, neighborhoods are a good avenue for the cultivation of 'bridging' social ties important for obtaining jobs and other opportunities (Granovetter, 1983; Henning and Lieberg, 1996). As socioeconomic segregation ensures that social ties formed in neighborhoods are largely between people of similar socioeconomic status (Krivo et al., 2013) and insofar as ethnic/racial categories overlap with socioeconomic status, residential segregation can disadvantage both low-income groups and racial/ethnic minorities (Small, 2007). The spatial segregation of different groups might also have a negative effect on social harmony by reducing the chance for intergroup contact needed to reduce prejudice (Enos and Celaya, 2018)–although others have also argued that increased contact might increase intergroup antagonism and distrust (Bazzi et al., 2019).

Concerns about the negative implications of residential segregation have bolstered calls for policies to create more integrated neighborhoods (Arbaci, 2019). Desegregation policies generally target either ethnic/racial or socioeconomic integration. In the United States, anti-segregation housing programs tend to focus on income-based mixing. These include rental subsidy programs to help low-income households access more well-resourced neighbourhoods; urban redevelopment efforts to replace distressed low-income public housing projects with mixed-income housing; as well as other inclusionary housing policies where private developers are required or incentivized to offer affordable units within their developments (Clampet-Lundquist, 2004; Ellen and Steil, 2019). Similar income or housing tenure-focused inclusionary housing policies can be found in the U.K (Li and Guo, 2020), Netherlands, Sweden (Bolt, 2009), Brazil, Colombia (Santoro, 2019) as well as South Africa (Klug et al., 2013). Other jurisdictions like Berlin, Frankfurt and Rotterdam have experimented with desegregation policies that focus on ethnic/racial or nationality-based mixing, such foreign household quotas in housing estates (Bolt, 2009), though these proved controversial and were eventually removed (Hanhörster and Ramos Lobato, 2021; van der Wal and van Zijl, 2020).

Socioeconomic and ethnic/racial segregation tend to be tightly intertwined because race/ethnic identities and socioeconomic class often overlap. One explanation for this inter-relationship is that of 'spatial assimilation theory', which hypothesizes that socioeconomic-based neighborhood sorting drives ethnic/racial segregation. Alternatively, 'place-stratification' theory posits that institutional and inter-personal discrimination drive both the clustering of ethnic/racial minorities and socioeconomic disadvantage among said population (Costa and de Valk, 2018; Sager, 2012) . As policies and social forces are likely to affect both ethnic/racial and socioeconomic segregation

(Reardon et al., 2015), it is important to consider how desegregation housing policies, whether ethnic/racial or socioeconomic, might impact both forms of segregation jointly. A singular focus on either form of segregation can be problematic as policies to tackle one aspect of segregation may not adequately reduce the other. (Bolt and Kempen, 2010; Khare et al., 2015; Quillian, 2012)

Singapore, a densely-populated multi-ethnic country of 5.7 million located in South East Asia, has implemented a housing policy that targets exclusively one dimension of residential segregation: the ethnic integration policy (EIP) Since 1989, the EIP imposes quotas on the ethnic composition of public housing estates, which are developed and sold by the Housing Development Board of Singapore (HDB), and which are where over 80 percent of the country's population lived. The EIP is one of the few examples of a consistently and robustly implemented anti-segregation housing policy, and has thus been touted by international observers as a successful approach to avoid entrenched spatial segregation (di Mauro, 2018; Fischer, 2021). Singapore's experiences thus provide an important reference for on-going dialogues around social and spatial integration. However, while there have been some empirical studies documenting how Singapore's EIP policy reduced ethnic residential segregation in Singapore, none have focused on socioeconomic segregation.

This study addresses the current knowledge gap around how Singapore's EIP policy relates to both ethnic and socioeconomic segregation, by exploring the following research questions:

1. Has there been a reduction in national-level estimates of both ethnic and socioeconomic segregation since the implementation of the EIP in 1989?
2. Do subzones with more ethnic segregation also have more socioeconomic segregation?

3. Given that only public housing blocks are subject to the EIP, are public housing residents therefore exposed to less ethnic and socioeconomic segregation than private housing residents?

To answer these questions, I analyze levels of ethnic and SES segregation in Singapore from 1990 to 2020, at three scales: national, subzone and building. Given that segregation is a multi-scale phenomenon, where different features of segregation might be visible only at certain scales of analysis, scholars have advocated for multi-scalar approaches to analyzing segregation patterns (Chodrow 2017, Lan et al 2020, Reardon 2009). This study's three scales have been chosen for their immediate relevance to Singapore's urban planning and housing policy. If the same relationship between socioeconomic and ethnic segregation is consistently observed throughout all three analysis scales, one could infer that desegregation policies can be applied without too much concern about implementation scale. On the other hand, divergent findings between scales would suggest the need to pinpoint the appropriate scale at which to target de-segregation measures.

OVERVIEW OF SINGAPORE'S SOCIAL AND HOUSING POLICY LANDSCAPE

Ethnic and Socioeconomic Segregation in Singapore

Singapore's largest ethnic group is the Chinese (74.3% of the resident population), followed by Malays (13.5%) and Indians (9.0%) (Department of Statistics, Singapore, 2021). National statistics indicate that Singapore's minority Malay population is less socioeconomically well-off than the rest of the population, across various domains (Brassard, 2020; Mutalib, 2012). While

published studies on why these ethnic disparities exist are few, some highlight ethnic discrimination as an important contributor (Chew et al., 2019; Lee, 2004).

Ethnic identity, which is often interchangeably referred to as 'race' in Singapore, is deeply embedded into the country's institutional and cultural landscapes (Chua, 2003). At the same time, discussions of race/ethnicity are carefully managed by the state ostensibly seeking to reduce societal conflict (Velayutham, 2017), an approach rationalized by the spectre of serious race riots that occurred in 1964, just before Singapore became an independent state (Chua, 2003).

The initial stated policy rationale for the EIP was the prevention of ethnic enclaves that might threaten 'racial tolerance and harmony' (Lim et al., 2019). Over time, EIP policy justifications shifted beyond the maintenance of social order towards extolling the benefits of integration of, and interaction between, different ethnic groups; providing good access to jobs and education opportunities; and allowing appreciation in home equity to be reaped by all ethnic groups (Ong, 2021; Tharman Shanmugaratnam, 2015).

The EIP imposes constraints on housing allocations and re-sale transactions based on owners and buyers' ethnicity, to ensure that housing block would broadly reflect national ethnic proportions, with an allowance for some variation in each block and neighbourhood. For example, non-Chinese residents in a block that is at the Chinese quota cap are disallowed from selling their units to a Chinese family (Sin, 2002b). HDB does however allow a small number of waivers of the EIP, assessed on a case-by-case basis (Ng, 2021).

Scholars whostudied the EIP in its earlier years of implementation over the 1990s concluded that it kept ethnic segregation low (Sim et al., 2003; Sin, 2002a). Since the early 2000s, however, little

work has been done to examine Singapore's ethnic segregation patterns—with the notable exception of Leong et al (2020), who gathered data on which of the existing public housing blocks, as of 2016, had reached one or more ethnic quotas. The authors then assessed if such blocks were spatially clustered by the type of ethnicity quota reached and found that areas with a higher concentration of Chinese had higher housing resale prices whereas areas with higher concentration of Malay residents had lower housing resale prices. Their findings suggested an overlap between ethnic clusters and socioeconomic distributions (Leong et al., 2020). This study however only examines a snapshot of ethnic segregation patterns, not how it might have changed over time. Scholars have also documented the EIP's distortionary effects on HDB housing resale prices, particularly in estates that have reached the ethnic quotas and where sellers face a smaller set of potential buyers than in an unconstrained estate. These distortions negatively affect the economically disadvantaged sellers, particularly ethnic minorities. While the EIP's impact on housing resale prices have been hypothesized to affect patterns of residential segregation, this link has not been empirically established (Wong 2012, 2014, Leong et al 2020).

Singaporean government leaders have also articulated a commitment to socioeconomic spatial integration, in the form of planning a mix of different housing types to cater for a different income groups within each neighborhood (Ho, 2013; Tharman Shanmugaratnam, 2015). However, unlike the EIP, there have been no explicit quotas governing the actual income mix in residential estates, nor empirical studies estimating socioeconomic segregation, despite concerns over the rise of socioeconomic and spatial polarization in Singapore (Peng, 2020; Tan and Low, 2019).

Data availability and alternative sources of spatial information

Hindering the study of Singapore's socioeconomic residential segregation is a lack of fine-grained census data. For example, the most up-to-date granular public geographic data on income distribution of residents available as of 2022 was collected during the 2020 Census, aggregated by 'Planning Area' (PA). There are currently 55 PAs in Singapore, each with an average population of about 150,000 (data.gov.sg). Such coarse aggregation of data makes it impossible to analyze ocioeconomic segregation at the scales which people actually interact with other residents.

Instead of using coarsely aggregated census data, an alternative approach is to examine changes in built environment that might signal similar shifts in population. Housing transactions records are readily available,frequently updated (Rabiei-Dastjerdi and McArdle, 2021), and allows for analyses that are far more spatially granular than possible using coarsely aggregated census statistics, being available at the unit-level. While housing sale prices do not directly measure residents' wealth, it has been used as a measure of socioeconomic status (e.g. (Coffee et al., 2013; Sohn, 2013) since households hold a substantial amount of their wealth in their homes (Agarwal and Qian, 2017). A 2018 study, using Singapore data, compared survey-collected monthly income data against housing prices aggregated at planning area and concluded that housing price was indeed a strong indicator of residents' SES (Xu et al., 2018). To estimate socioeconomic segregation this study thus utilizes housing resale transaction records (see 'Methods' section for elaboration).

MATERIALS AND METHODS

One data source for this study is the decennial national census data from 1990, 2000, 2010 and 2020, which are representative surveys conducted by Singapore's Department of Statistics

(Singstat). The spatial units available for analysis differ by year and data category. For the 1990 census, Singstat reported ethnic group and income group distributions by electoral boundaries (n=81). For subsequent years, they utilized administrative boundaries drawn up by the Urban Redevelopment Authority of Singapore (URA) to facilitate planning work. The most fine-grained spatial units of ethnic population data are subzones (n=332, as of 2019), which are areas centred around a focal point such as neighbourhood centre or activity node (data.gov.sg), have an average population of about 14,000 residents, and can broadly be understood as a city district. Income group census data is available by planning area, as mentioned above

The second data source is housing resale transactions. Singapore has a dual housing market—one for public housing and one for private housing. Public housing, which are residential apartments built by the government, makes up over 80% of Singapore's housing stock. New units are typically sold with 99-year leases to citizens and permanent residents. Public housing owners are allowed to re-sell their units, subject to restrictions such as buyers' citizenship status and ethnicity as described previously. The rest of Singapore's housing market consists of units developed, bought and sold by private entities and individuals on a relatively less restricted market. While public housing units commonly available for sale are relatively similar in design, span a limited range of sizes and a narrower range of sale prices, private housing units are much more varied in terms of design, price point, types of development control policies applicable to them, and, to a certain extent, purchasing eligibility criteria (Phang, 2018; Urban Redevelopment Authority, 2022).
Between 2000 to 2020, HDB resale transactions ranged from an average yearly minimum of 140,0000 Singapore Dollars (SGD) to a maximum of 1.14million, while private housing resale transactions ranged from 210,000 to over 67 million SGD (prices standardized to 4Q2017).

In order of increasing average unit sale price, the categories of private housing types are: Condominiums/ Apartments (which make up 17% of buildings that had resale transactions between 2015 up to 2020) , Terrace houses (15%) , Semi-Detached houses (7%) , and Detached houses (3%). Of the condominiums/apartments, about 1% of the 17% transacted are 'Executive Condominiums' built by private developers but sold by HDB, and which are thus still subject to eligibility requirements similar to HDB flats.

The housing resale transactions are categorized as 'low', 'mid-low', 'mid-high' and 'high' priced, corresponding to 25%, 25-50%, 50-75%, and above 75 percentile of the net sale prices of all transactions during their year of transaction. These categorized transactions are aggregated by five year rolling batches, such that each five year batch of transactions is analyzed as one consolidated sample. Doing so smooths out short-term perturbations in housing prices, as does the categorization by relative sale prices during each year of transaction. As people move into housing units after sales transactions have been completed, housing transactions are likely to be a 'leading' indicator of resident mix. Thus, when calculating the socioeconomic segregation for a given year, I include transactions five years leading up to said year. Table 1 below provides details of data sources.

Tests of the level of agreement between the census-based estimates of socioeconomic segregation and the housing resale transactions-based measure suggest sizeable concurrence between the two measures, which provides reasonable confidence that housing resale transactions are a valid proxy for income group distribution (see **Appendix A**)

Please insert Table 1

Measure of Spatial Segregation

This study utilizes the '**Spatial Information Theory Index' (H̃)** to measure spatial evenness/ clustering (Reardon and O'Sullivan, 2004). **H̃** is a single summary measure of the extent to which the local environments of individuals differ in their group composition compared to the overall group composition of the city or region of study. A **H̃** value of 1 indicates maximum segregation, where the local environments of all individuals consist of only one type of population group, whereas a **H̃** value of 0 indicates that local environments have exactly the same diversity as the city overall and thus arguably no segregation. A negative **H̃** value suggests 'hyperintegration', where there is greater diversity in the local environments than the diversity of the population (Iceland, 2004; Reardon et al., 2009; Reardon and O'Sullivan, 2004).

While **H̃** is typically analyzed as a summary measure for the entire region/city, it can be decomposed into localized subcomponents to provide a fine-grained view of how areas differ from each other. I estimate ethnic and socioeconomic segregation for each subzone, using census data for the former, and housing transaction data aggregated by subzones for the latter. I also calculate socioeconomic segregation for each residential building and its immediate neighborhood, by analyzing residential sale transactions within a 2km radius of each building, and weighting nearby transactions more highly than those further away. Details of the calculation of **H̃** are in **Appendix B**.

Analytical Methods

To understand how overall levels of socioeconomic and ethnic segregation in Singapore changed over the years, I calculate national levels of **H̃** for 1990, 2000, 2010, and 2020).

To identify what types of subzones have higher levels of ethnic and/or socioeconomic segregation, and whether public housing components might modify this relationship, I fitted two sets of ordinary least squares regression models, with time fixed effects to account for variation specific to the different periods of analysis, such as economic recessions or booms. The first set of models analyzes the outcome of subzone socioeconomic H̃, transformed by taking a natural logarithm to reduce the right-skew of the variable's distribution. The base model includes ethnic H̃, mean-centered, as the main predictor variable (Model 1.1).

The second set of models includes a binary variable indicating whether over 50% of subzone residents were living in public housing ('Majority in Public Housing"), and the interaction between H̃ and the 'Majority in Public Housing' variable, to explore whether having more public housing component within a subzone modifies the relationship between socioeconomic and ethnic H̃ (Model 1.2). About 38% of subzones have less than 50% of their residents in public housing (n=85), as of 2020[1].

The third set of models icontrols for other subzone characteristics, such as the subzone's percentage of housing resale transactions within the analysis period that were considered 'Low' priced, and the square of this variable to account for potential non-linear effects between % low priced transactions and socioeconomic H̃; the percentage of residents over 65 years old, and the

[1] Additional robustness checks of the regression models using an alternative threshold of 80% residents living in public housing yielded similar results, though with a poorer model fit. These alternative model findings can be made available upon request from the author.

overall subzone population density (Model 1.3). Standard errors robust to heteroscedasticity was calculated and reported for all models.

Models 2.1 to 2.3 repeat the above, but focus on the outcome of subzone ethnic H̃, with mean-centered, logged socioeconomic H̃ as the predictor variable.

The third set of analyses examines localized segregation measures of the immediate area around each residential building, for the periods 1995 up to 2000, 2005 up to 2010, 2015 up to 2020. I fitted two linear regression models, with time fixed effects to account for variation specific to the different periods of analysis, to examine how building-level characteristics associated with different levels of localized socioeconomic segregation. The first model includes a variable coding for two categories of housing types: public housing and private, while the second model examines a more detailed split of private housing types into the five categories described earlier in this paper. .. Unpacking the differences in social segregation between the private housing development types could provide more insights about the finer-grain patterns of socioeconomic segregation than if all private housing types were examined as a monolithic housing type, given the wide variation in price and characteristics between private housing types, and could help local urban planners formulate more targeted strategies to improve social mixing.

The second variable is the period in which the building was completed

Analyses were carried out using R version 3.6.2. Spatial segregation measures were calculated using ‘seg’ version 0.5-7; fixed effects models used ‘plm’ v 2.2; and robust standard errors

calculated using 'lmtest' version 0.9-37 and 'sandwich' version 25-1. Concordance between census data derived and housing transaction derived socioeconomic measures of segregation were calculated using 'epi*R*' v2.0.26.

RESULTS

National Estimates of Segregation

Ethnic-based residential segregation dropped from 0.034 in 1990 to 0.027 in 2000 and 0.025 in 2010. It then increased slightly between 2010 and 2020, to 0.027. In contrast, socioeconomic segregation doubled from 0.081 in 2000 to 0.163 in 2010, before dropping to 0.155 in 2020.

Subzone Analysis

Subzones with majority of their residents living in public housing were more likely to have less socioeconomic and ethnic H̃ (Table 2, Models 1.2,1.3, 2.2, 2.3). A 'majority public housing' subzone has an estimated socioeconomic H̃ about $e^{(-0.68)}$ =0.51 times that of a 'majority private housing' subzone, assuming both subzones are of the national-average levels of ethnic H̃ (Table 2, Model 1.3). The difference in ethnic H̃ between a 'majority public housing' subzone and a 'majority private housing' subzone, again assuming national average levels of socioeconomic H, is 0.065, which is sizeable given ethnic H̃'s maximum range of 0.8 (Table 2, Model 2.3).

Regressing subzone socioeconomic H̃ against ethnic H̃, with year fixed effects suggests an inverse relationship between the two forms of segregation (Table 2, Models 1.1. and 2.1). This inverse relationship holds for 'majority public housing' subzones only, as evident from the significantly negative interaction terms between 'majority public housing', and ethnic H̃ and socioeconomic H̃

respectively (Models 1,2 and 2.2). These observed relationships are robust to the inclusion of other subzone-level controls (Models 1.3 and 2.3). A 'majority public housing' subzone with a socioeconomic $\tilde{H}$ score double that of another similar subzone would have an ethnic $\tilde{H}$ that is 0.048(log2) = 0.03 units less than the latter (Model 2.3). A 'majority public housing' subzone with an ethnic $\tilde{H}$ that is 0.25 units more (about one-third of the range of ethnic $\tilde{H}$) than that of another similar subzone would have a socioeconomic $\tilde{H}$ that is $e^{(-2.491*0.25)}$, or about half, of the latter's (Model 1.3).

Please insert Table 2

Looking at the five subzones with the highest combined levels of ethnic and socioeconomic segregation as of 2020 reveals that all had zero public housing residents; mostly 'High' priced transactions, and a low percentage of Malay residents. In contrast, characteristics of the subzones with the lowest combined ethnic and socioeconomic segregation were much more varied, with a good mix of housing types and ethnic group splits. Details are in **Appendix C**.

Building-level analysis

Regression results (Table 3, Model 3.1) suggest that, compared to public housing, private housing developmentswere more spatially segregated. Model 3.2 further suggests that private detached housing units and apartments/condominiums were the most segregated types of developments, while terrace houses were the only private housing type that was less segregated than public housing blocks. Developments built between 2000-2009 seemed to be the most highly segregated

Please insert Table 3

DISCUSSION

Changes in Ethnic and Socioeconomic Segregation Over Time

This study suggest that levels of ethnic and socioeconomic segregation in Singapore were generally low from 1990 to 2020. As a rough benchmark, Iceland (2004) estimated that the ethnic $\tilde{H}$ of metropolitan areas in the U.S. in 2000 to be about 0.25--almost 10 times higher than Singapore's 2000 estimates. An important caveat is that Iceland's calculations relied on census data aggregated by census tract, which approximates a neighborhood of about 2,500 to 8,000 residents whereas this study's calculations were based on census data aggregated at subzone, with an average of 14,000 residents. Nevertheless, the fact that estimates of Singapore's spatial segregation hovered close to minimum of the theoretical range of $\tilde{H}$ suggests Singapore has a spatially mixed residential landscape.

As the EIP was introduced in 1989, we hypothesized that overall levels of ethnic segregation would drop from 1990 onwards—that hypothesis was verified by our analysis, though there was an slight increase between 2010 to 2020 from 0.025 to 0.027. However, while we expected levels of ethnic and socioeconomic segregation to move in tandem, we instead observe the increase in socioeconomic segregation between 2000 to 2010 coincided with a reduction in ethnic segregation, and vice-versa.

The building-level analyses further suggest that newer residential developments built after 1990, particularly those built between 2000 and 2010, were exposed to more socioeconomic segregation

than older developments. Residential buildings built after 2010 were comparatively less exposed to segregation than those built between 2000 to 2010,a pattern similar to overall national changes in socioeconomic segregation, even though the former is unlikely to be a result of the EIP policy, which applies to public housing blocks regardless of year built. To definitively conclude why residential buildings built between 2000 to 2010 were exposed to higher levels of socioeconomic spatial segregation, additional research is needed. For instance, national income inequality rose in Singapore substantially during this period, before stabilizing and dropping from 2012 onwards (Peng, 2020). An interesting hypothesis for future research could thus be whether income inequality and its drivers contributed to residential building construction patterns during this period.

In sum, this study's findings suggest that introduction of the EIP in 1989 was insufficient to dampen increases in socioeconomic segregation over time. There may thus be a need for more spatially targeted policies to monitor and prevent spatial clustering by socioeconomic groups—in Singapore's case, this could be including more diverse housing types into areas with housing stock predominantly built between 1990 to 2010.

Public Housing and Segregation

This study's hypothesis that public housing residents would be less exposed to both ethnic and socioeconomic segregation is supported by both subzone regression models and building level models. The subzone models find that subzones with more public housing tended to have lower levels of both forms of segregation, while the qualitative inspection of the five most highly segregated subzones confirmed that these had zero public housing component. In contrast, the subzones with the lowest combination of ethnic and socioeconomic segregation all had at least 58%

of their residents living in public housing. The building level analyses further confirm that the immediate neighbourhood of public housing developments tended to be less socioeconomically segregated than those around most types of private housing developments, with the exception of terrace houses.

A 2017 survey on social ties in Singapore, found that private housing residents had a more insular social circle than public housing residents (Chua et al., 2020). This phenomenon could conceivably be bolstered by private housing developments being more socioeconomically segregated than public housing. Policy-makers could thus study the socioeconomic spatial mix within and around private housing estates, particularly detached housing and condominiums/apartments, and consider introducing other residential types in these locations to increase socioeconomic diversity.

Relationship between Ethnic Segregation and Socioeconomic Segregation

While this study's findings suggest that public housing supports lower levels of ethnic and socioeconomic segregation, we also find a negative correlation between ethnic and socioeconomic segregation within subzones with a large proportion of public housing. A possible explanation for this inverse relationship that the EIP'sdistortionary effects on housing resale prices, generated by imposing arbitrage limits on sale transactions, especially since Singapore's housing markets are 'thin' and housing preferences are inelastic (Wong, 2013, 2014). For HDB block or neighborhoods that have reached the Chinese quota, the majority of Chinese-owned flats can be sold without restrictions and thus enjoy unrestricted buyer demand, whereas Chinese buyers unable to purchase from minority sellers in that block/neighborhood face a more restricted supply. This combination

exerts upward pressure on prices of Chinese-owned flats within a Chinese-constrained block. In contrast, the relatively small proportion of minority-owned flats face a highly constrained market and may have to lower sale prices to attract minority households otherwise reluctant to purchase flats in this location. This dynamic suppresses the prices of these minority flats. These distortions result in a divergence in prices of minority-owned versus Chinese-owned flats, and create a wider spread of housing resale prices within a block than would otherwise be without EIP restrictions. In contrast, in HDB neighborhoods that have reached Indian or Malay quotas, Chinese sellers face a restricted market because they cannot sell to the minority buyers, which imposes downwards pressure on their housing prices in order to attract Chinese buyers who otherwise might not prefer to live there. The lack of constraints for minority sellers in these estates arguably raises the resale prices of their flats. In these HDB neighborhoods therefore, the EIP restrictions might thus narrow and suppress the range of housing resale prices and thus add to greater socioeconomic homogeneity. By comparing the price differences between EIP-constrained and unconstrained blocks close to the limits, Wong (2014) provides empirical support for these hypothesized mechanisms, and also demonstrates that the EIP generated price distortions that disproportionately burdened minority sellers. My analyses highlight an additional concern that these market distortions introduced by the EIP might exacerbate socioeconomic segregation in subzones that might otherwise might have had a better socioeconomic mix.

Chua et al.'s (2020) study of social network ties highlighted that there was a "fair amount of ethnic variety in networks" compared to low levels of socioeconomic class diversity (pg 78). The authors thus suggest that while Singapore's policies around ethnic mixing have supported inter-ethnic relationships, "new inequalities have now emerged with class" (pg 85). This study's findings

reiterate the call for greater attentiveness to socioeconomic integration in Singapore, in addition to ethnic integration.

Limitations

As this study utilizes on census data aggregated at the subzone level, there are inherent limitations of such spatially aggregated geographic data. Administrative subzone boundaries may not always delineate meaningful 'neighborhoods' as perceived and experienced by residents. There is thus a potential mismatch between estimates of spatial segregation based on administrative boundaries and experienced levels of spatial segregation--a source of bias known as the 'modifiable areal unit problem' (Openshaw, 1984). Furthermore, as census data covers only Singapore's resident population, non-residents (1.64 out of 5.69 million as of 2020) are excluded from this analysis.

Property data, being more fine-grained, does not suffer from similar biases around spatial aggregation but face other limitations. For instance, an expensive home may not always house a high-income resident, as it might be shared among many lower-income individuals rather than one wealthy individual.

Furthermore this study does not examine the actual effects of residential segregation in Singapore. While the problems associated with residential segregation have been well-documented in the U.S and elsewhere, one should be wary about assuming the same set of outcomes occur in Singapore, given contextual differences. Without additional research establishing how different levels of ethnic and/or socioeconomic residential segregation in Singapore affect social, economic and

health outcomes, it is difficult to conclude how substantively meaningful estimated levels of segregation might actually be.

As this study utilizes data collected only after the 1989 implementation of the EIP, its findings cannot, and are not intended to, definitively prove that the EIP is the primary cause of the observed segregation patterns, as there is no ability to compare a 'pre' EIP state to a 'post' EIP state. Thus, this study's findings should be interpreted as an exploratory effort to map the contours of segregation in Singapore rather than a definitive accounting of the effects of the EIP. Additional analyses using more granular population data, especially if combined with data on health and social outcomes, could build a richer understanding of Singapore's spatial segregation.

Conclusion

Singapore provides an internationally well-known, example of an ethnic desegregation housing policy. This study suggests that, while the EIP might have kept segregation levels in Singapore low, it might not have been sufficient to completely suppress increases in socioeconomic segregation. Furthermore, the EIP, through its distortionary effects on housing prices, might have created an unexpected inverse relationship between socioeconomic and ethnic segregation in subzones with majority public housing. These exploratory findings reiterates calls for greater attentiveness to both socioeconomic and racial/ethnic integration, and to avoid assuming policies tackling one or the other might suffice.

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Table 1: Details of Data, by Year

	Census Data		**Resale Transactions**	
	Geographic Distribution of Population by Ethnic groups		**Geographic Distribution of Housing by Resale Prices**	
Year	Population	Spatial Unit (n)	Population Measured	Spatial Unit (n)
1990	Resident[1] population, classified into 'Chinese,' 'Malay', 'Indian' and 'Others' categories.	Census Division, 1988 electoral boundaries (81)	N.A	N.A
2000	As above	Subzone, URA's 1998 Master Plan (135)	Resale transactions of public and private housing units[2] were classified into four price categories, based on percentile thresholds of each year's transacted prices: ● Low (under 25th percentile) ● Mid-low (25th to 50th percentile)	Housing Unit (986,176 transactions between 1995 up to 2020; ~40,000 transactions per year)
2010	As above	Subzone, URA's 2008 Master Plan (192)		
2020	As above	Subzone, URA's 2019 Master Plan (234)		

			• Mid-high(50th to 75th percentile) • High (above 75th percentile) The categorized transactions are aggregated five years leading up to the year in question (e.g. 1995 up to 2000 for year 2000)	

According to the 2020 Census report "Singapore citizens and permanent residents are classified as Singapore residents or the resident population. Singapore permanent residents refer to non-citizens who have been granted permanent residence in Singapore. The non-resident population comprised foreigners who were working, studying or living in Singapore but not granted permanent residence, excluding tourists and short-term visitors"

[2] Socioeconomic segregation analyses utilizing housing resale transactions go back only to 2000, as resale data is only available from 1995 onwards. Public housing resale transaction information was downloaded from a public government data repository, data.gov.sg, and geocoded using the Singapore Land Authority's OneMap API. For private housing resale transactions, records were downloaded from REALIS, an online repository of real estate data, including records of the caveats lodged at the Singapore Land Registry since 1995. While lodging of caveats is usually done voluntarily, caveated transaction records cover a large proportion of the market, accounting for an estimated 80 to 90% of all sub-sale and resale transactions (data.gov.sg).

Table 2: Regression Analysis of Association between Subzone Characteristics and Segregation

	Dependent variable:					
	Socioeconomic H (Log)			Ethnic H		
	(1.1)	(1.2)	(1.3)	(2.1)	(2.2)	(2.3)
Socioeconomic H (Log),mean-centered				-0.027***	-0.007	-0.006
				(0.006)	(0.008)	(0.008)
Ethnic H, mean-centered	-1.604***	-0.309	-0.284			
	(0.334)	(0.656)	(0.656)			
Majority Residents in Public Housing		-0.946***	-0.679***		-0.067***	-0.065***
		(0.092)	(0.131)		(0.013)	(0.017)
Socioeconomic H (Log), mean-centered :Majority in Public Housing					-0.056***	-0.048***
					(0.011)	(0.010)
Ethnic H, mean-centered : Majority in Public Housing		-2.575***	-2.491***			
		(0.722)	(0.715)			
% Transactions Low Price			-3.703***			-0.216***

			(0.487)			(0.066)
(% Transactions Low Price)²			4.514***			0.125
			(0.605)			(0.090)
Percent Residents Over 65			0.034			1.073***
			(0.864)			(0.126)
Population Density ('000 per sqkm)			0.008**			0.002***
			(0.004)			(0.001)
Year 2010	0.749***	0.634***	0.574***	0.016	0.025*	-0.006
	(0.118)	(0.109)	(0.106)	(0.016)	(0.015)	(0.014)
Year 2020	0.876***	0.676***	0.611***	0.026*	0.027*	-0.073***
	(0.115)	(0.106)	(0.130)	(0.016)	(0.015)	(0.018)
Constant	-3.056***	-2.293***	-2.242***	0.049***	0.081***	0.009
	(0.094)	(0.121)	(0.128)	(0.013)	(0.016)	(0.016)
Observations	546	546	546	546	546	546
R^2	0.144	0.333	0.389	0.044	0.156	0.318
Adjusted R^2	0.140	0.327	0.379	0.038	0.148	0.306
Note:	*p<0.1; **p<0.05; ***p<0.01					
	Baseline: Year 2000					

Table 3: Regression Analysis of Building Characteristics and Socioeconomic Segregation

	Dependent Variable: Socioeconomic H̃ (Log)	
	(Model 3.1)	(Model 3.2)
Private Housing Type	0.052*** (0.007)	
Executive Condominium		0.119*** (0.027)
Apartment/Condominium		0.320*** (0.011)
Terrace House		-0.301*** (0.010)
Semi-Detached House		0.084*** (0.013)
Detached House		0.550*** (0.019)
Building Completion Date		
1980-1989	-0.005 (0.010)	-0.061*** (0.010)
1990-1999	0.243*** (0.010)	0.210*** (0.010)
2000-2009	0.498*** (0.011)	0.413*** (0.012)
2010-2019	0.420*** (0.020)	0.253*** (0.020)
Years Of Analysis		
2000 up to 2005	0.457*** (0.015)	0.450*** (0.015)
2005 up to 2010	0.589*** (0.014)	0.598*** (0.014)
2010 up to 2015	0.650*** (0.014)	0.665*** (0.014)
2015 up to 2020	0.500*** (0.013)	0.509*** (0.013)
Constant	-3.107*** (0.014)	-3.067*** (0.014)
Observations	106,491	106,491
R^2	0.06	0.10

Adjusted R^2	0.06	0.10

*Note: *p<0.1; **p<0.05; ***p<0.01,*

Baseline: Public Housing HDB flats, built before 1980, Years of analysis 1995 up to 2000

Appendix A: Testing concurrence of census-based measure of socioeconomic segregation and the property transaction based estimates

To test the level of agreement between the census-based estimates of socioeconomic segregation and the housing resale transactions-based measure, I calculated the localized spatial segregation scores for each planning area for the years 2000, 2010 and 2020, using census data and housing resale prices, as described in Appendix B. Table A.1 summarizes the data sources for the census-based estimates.

Table A.1: Census Data		
	Geographic Distribution of Population by Income groups	
Year	Population Measured	Spatial Unit (n)
2000	Resident Households, Monthly Household Income from Work, classified roughly into the following four categories[1] ● Low (~25th percentile, less than 2,000SGD) ● Low-mid (25th to 50th percentile, 2,000 to 4000SGD) ● Mid-high (50th to 75th percentile, 4000 to 7000SGD) ● High(above 75th percentile, above 7000SGD)	Planning Area, URA's 1998 Master Plan (32)
2010	Resident Households, Monthly Household Income from Work, classified roughly into the following four categories ● Low (~21st percentile, less than 2000SGD) ● Low-mid(~21st to 45th percentile, 2000 to 5000SGD) ● Mid-high(~45th – 75th percentile, 5000 to 10,000SGD)	Planning Area URA's 2008 Master Plan (35)

	• High(above 75th percentile, over 10,000SGD)	
2020	Resident Households, Monthly Household Income from Work, classified roughly into the following four categories • Low (~25th percentile, up to 3000SGD) • Low-mid(25th - 45th percentile, 3000 to 7,000SGD) • Mid-high (45th percentile – 75th percentile, 7,000 to 14,000 SGD) • High(above 75th percentile, over 14,000SGD)	Planning Area, URA's 2019 Master Plan (30)

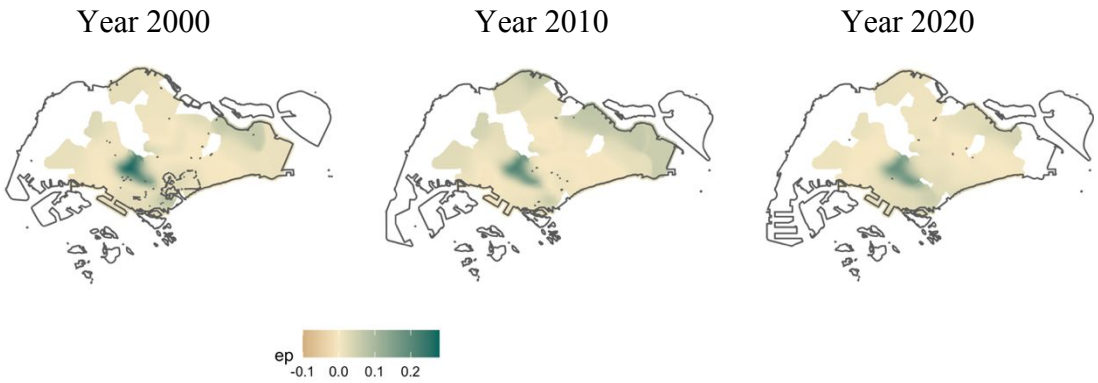
1. The household income categories differ between the various years, because the censuses collected data according to categorical bands in increments of 1,000 SGD without accounting for changes in income levels and inflation. To better compare 'like-for-like', I translated the income bands roughly into income percentiles.

I calculated the rank-transformed average localized spatial segregation scores for the planning areas for the years 2000, 2010 and 2020, such that the least segregated planning area within its respective year of analysis would be ranked first, and the most segregated last. I then calculated the concordance correlation coefficient for agreement (Lin, 1989) between both measures' ranked scores, across all three periods of analyses. This yielded a moderate CCC estimate of 0.75 (95th percent confidence interval of 0.65 to 0.83). Other measures of correlation (Pearson and Spearman's Rho) both yield similar magnitudes of correlation (0.75) that were statistically significant at $p<0.05$.

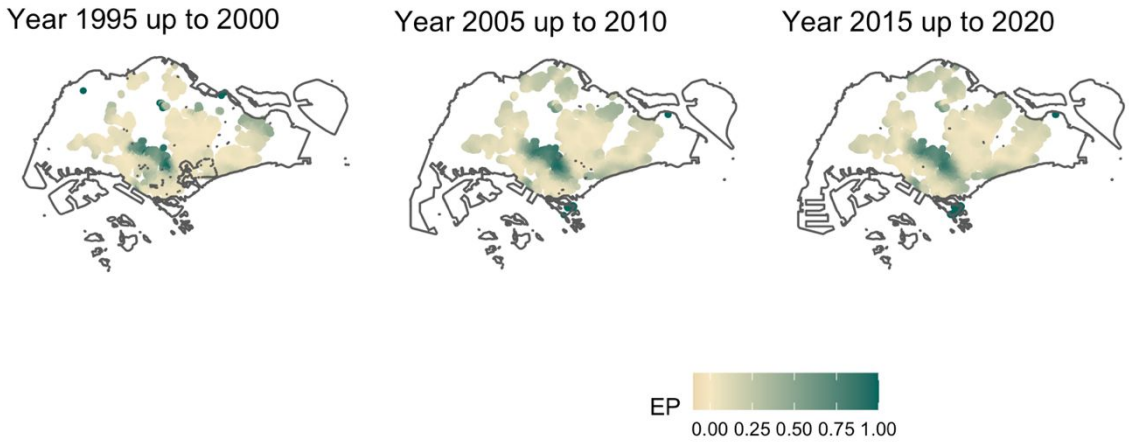
Localized estimates of socioeconomic $\tilde{\mathbf{H}}$ derived from both the census data and property data revealed similar spatial distributions (Fig B.1)

Figure B.1: Spatial distribution of H̃ estimates

Census-based



Property Transaction-based



Appendix B : Details about H

Calculating $\tilde{H}$ requires the calculation of a 'surface' of population information, which gives at each location of analysis the weighted proportion of the population within its local neighborhood who are members of each defined group of interest. The influence of units within each localized environment is spatially weighted using a negative exponential function to represent a distance-decay effect. The weight given to these listings was defined as $w(d) = e^{-\beta d}$, where d is the Euclidean distance in km between the listings' locations, and $\boldsymbol{\beta}$ is a distance-decay factor.

Assuming that walking is a mode of travel that provides more opportunities for chance encounters, social interactions and thus build a sense of community(Middleton, 2018, Wood et al., 2010), I examined empirical studies that modelled the distribution of walking trips. This study adopted a rate of decay $\boldsymbol{\beta} = 1.0$., which is validated as a suitable distance-decay measure for shopping trips in Singapore (Sevtsuk and Kalvo 2018). The analysis also capped the 'search' distance at 2km.

Calculating National Levels of Ethnic and Socioeconomic Segregation

To calculate $\tilde{H}$ using the census data, I divide the island into a 200x200 grid cells. The total population for each subzone/planning area is split equally among the grid cells that make up this subzone/planning area. I then calculated a spatially weighted group composition of the localized environment of each grid cell centroid, according to the above distance-decay weighting formula. This spatially weighted group composition is then used to calculate a spatially weighted entropy score ($\tilde{E}_p$) for each grid centroid (p), as follows:

$$\tilde{E}_p = -\sum_{m=1}^{M} \tilde{\pi}_{p_m} \times \log_M (\tilde{\pi}_{p_m})$$

where:

m = Group category (e.g. ethnic group, or household income group)

$\tilde{\pi}_{p_m}$ = Weighted proportion of m units in the local environment of p

M = Total Number of group categories

Each localized environment was then compared against the overall group composition of the entire city, to calculate a 'Spatial Information Theory Index' ($\tilde{H}$) for the whole city

$$\tilde{H} = 1 - \sum_{i=1}^{N} \frac{P_{total} \times \tilde{E}_p}{city_{total} \times E}$$

where:

E is the overall city entropy of the total population given by:

$$E = -\sum_{m=1}^{M} (\textit{proportion of m persons in city}) \times \log_M (\textit{proportion of m persons in city}$$

p_{total} = total number of people at point p;

$city_{total}$ = total number of people in city

N = total number of p locations

For the calculation of national-level socioeconomic segregation using resale transaction data, I repeated the analyses but calculating p for each residential building location, and looking at total units transacted for each building location, within each five-year period of analysis, such that p_{total} refers to total number of units at point p, and $city_{total}$ refers to total number of units within the city.

Calculating Localized Levels of Ethnic Segregation and Socioeconomic Segregation

For the localized subzone measure of ethnic segregation, I calculate the average $\tilde{E}_p$ scores for the grid cell centroids by subzones, to produce a single localized estimate of $\tilde{E}_p$ for each subzone. I then take 1-($\tilde{E}_p$/ E) to generate a localized estimate of $\tilde{H}$. I calculate the localized measure subzone measure of socioeconomic segregation $\tilde{H}$ similarly, but using building-level transaction data aggregated to subzone level first before calculating localized estimates in a similar manner to the aggregated census data .

For the localized planning area measure of socioeconomic segregation based on census data which I test against the housing-price based estimate (Appendix A), I do the same, but aggregate average $\tilde{E}_p$ scores (calculated using census data as well as housing prices) for the grid cell centroids by planning areas instead.

For the building level measure, I calculate a localized estimate of $\tilde{H}$ for each building, based on its localized $\tilde{E}_p$.

APPENDIX C: Characteristics of Subzones with the highest and lowest levels of ethnic and socioeconomic segregation combined.

Figure C.1. shows the distribution of subzones by combined levels of ethnic and socioeconomic segregation. The five subzones with the highest levels of segregation are edged in black while those with the lowest combined levels of segregation are edged in white. Table C.2 summarizes subzone characteristics.

Figure C.1: Map showing subzones' sum of percentile ranks of ethnic H̃ and Income H̃, 2020

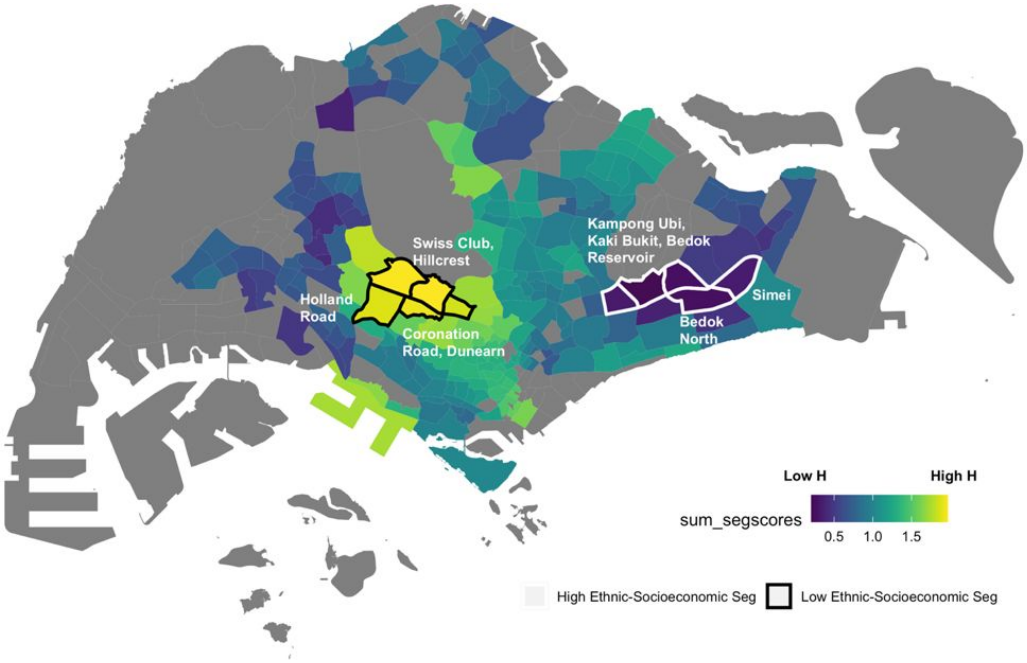


Table C.3 Subzones with High or Low Levels of Socioeconomic Segregation & Ethnic Segregation

	Percentile Rank for ethnic segregation (raw score)	Percentile Rank for socioeconomic segregation (raw score)	Ethnic group composition	%residents in public housing	Housing transaction type (2015 up to 2020)
Low Socioeconomic Segregation & Ethnic Segregation					
Kaki Bukit	15th (-0.09)	5th (0.02)	More Malay (23.5%), fewer Chinese (65%), with a representative proportion of Indian (9%)	95%	Few 'High' priced transactions (3.5%), fairly equally split between the other three categories
Bedok North	23rd (-0.05)	3rd (0.02)	Close to national proportions, with more Malay (19.0%), and slightly fewer Chinese	87%	Most 'Low' priced transactions 49.7%), and relatively little High (10.9%). 'Mid-high' and 'Mid-low'

			(70.2%) and Indians (7.6%),		transactions are around 20%.
Bedok Reservoir	20th (-0.07)	7th (0.02)	Close to national proportions: Chinese (75%), Malay (13%), Indian (9%)	68%	Fairly equally split among the categories
Kampong Ubi	30th(-0.01)	2nd(0.01)	Close to national proportions, with more Malay (19.8%), and slightly fewer Chinese (68.7%) and Indians (8.7%),	99%	Most transactions split between 'Mid-Low' (43.8%) and 'Low'(47.2%)

Simei	11th (-0.1)	22nd (0.04)	More Indian (12.2%), slightly fewer Chinese (72.2%) and Malay (11.5%)	58%	High (26.7%), Mid-high (49.1%), Mid-low (22.7%), Low(1.6%)
High Socioeconomic Segregation & Ethnic Segregation					
Hillcrest	98th(0.30)	98th(0.73)	More Chinese (83.2%), and 'Others' (10.0%), Fewer Malay (0.6%)	0%	Mostly 'High' priced transaction (89%) and 'Mid-high' (10.5%)
Swiss Club	99th(0.35)	96th (0.65)	More Chinese (85.0%), and 'Others' (9.2%), Fewer Malay (0.9%) and Indian (4.9%)	0%	Mostly 'High' priced transaction (88%) and 'Mid-high' (10.3%)

Holland Road	98th(0.30)	90th (0.41)	More Chinese (86.3%), and 'Others' (8.5%), Fewer Malay (0.6%) and Indian (4.7%)	0%	Mostly 'High' priced transaction (94%) and rest 'Mid-high' (6%)
Coronation Road	97th (0.29)	96th (0.62)	More Chinese (87.8%), and 'Others' (7.6%), Fewer Malay (0.4%) and Indian (4.2%)	0%	Mostly 'High' priced transaction (90%) and some 'Mid-high' (8%)
Dunean	86th (0.23)	99th (0.76)	More Chinese (81.6%), and 'Others' (9.8%), Fewer Malay (0.5%) and Indian (8.1%)	0%	Mostly 'High' priced transaction (98.5%)