Jens Kandt, Shu-Sen Chang, Paul Yip and Ricky Burdett

The spatial pattern of premature mortality in Hong Kong: how does it relate to public housing?

Article (Accepted version) (Refereed)

Original citation:
Kandt, Jens, Chang, Shu-Sen, Yip, Paul and Burdett, Ricky (2017) *The spatial pattern of premature mortality in Hong Kong: how does it relate to public housing?* Urban Studies, 54 (5). pp. 1211-1234. ISSN 0042-0980

DOI: 10.1177/0042098015620341

The spatial pattern of premature mortality in Hong Kong: How does it relate to public housing?

Abstract

Research into the relationship between access to housing, health and well-being has yielded mixed evidence to date and has been limited to cities in Western countries. Many studies appear to highlight the negative role of public housing in influencing health. In Asian cities, too, current trends on urban housing markets as well as debates on the government's role in providing housing confirm that the need for research into housing and health is pressing. In this paper, we seek to bring Hong Kong as an example of a thriving Asian city into the debate by exploring and comparing the intra-urban geographies of premature mortality and public housing provision in the city. Using a fully Bayesian spatial structural model, we investigate associations between public housing provision and different types of premature mortality in small areas. We found significant geographic variations in premature mortality within Hong Kong in 2005-2009, while public housing and premature mortality risk were positively related. But the association attenuated or even reversed for pre-mature mortality of injuries and non-communicable diseases after controlling for local deprivation, housing instability, access to local amenities and other neighbourhood characteristics. The results indicate that public housing may have a protective effect on community health, which contradicts similar studies carried out in Western cities. We suggest reasons why the association between public housing and health differs in Hong Kong and discuss the implications for housing policy in Hong Kong and other thriving Asian cities.

Keywords

urban health disparities | public housing | spatial analysis | global cities | premature mortality

1. Background

Recent reports by the World Health Organization (WHO & UN-HABITAT 2010) and the Global Research Network of Urban Health Equity (GRNUHE 2010) confirm that pronounced health inequalities persist in cities all over the world. The reports resonate with calls by scholars to address the social determinants of health in cities (Stephens 2011; Marmot 2005, 2010; Corburn 2009), including socio-economic and physical neighbourhood conditions as well as access to housing, which are thought to modify material, behavioural and psycho-social pathways of health (Kawachi & Berkman 2003; Brunner & Marmot 2006). Secure access to housing is identified as a key policy arena (GRNUHE 2010, 17), which seems particularly critical in cities whose economies strongly interconnect with the global economy. Such cities have been found to generate advanced forms of inequality and polarised geographies of disadvantage (Corburn 2009, Sassen 2001, Gusmano et al 2010), and hence public housing appears to be a valuable policy tool to address the social determinants of health (Doran et al 2013). But studies investigating connections between housing and community health have been predominantly conducted in Western cities, and while there is some evidence for a protective effect of housing stability on disadvantaged residents (Baker et al. 2013; Pollack et al. 2012; Burgard et al. 2012), results have been mixed overall. In this paper, we seek to bring Hong Kong into the debate by comparing the spatial pattern of health disadvantage - measured as premature mortality risk (PMR) - to the spatial distribution

of public housing in the city. We do this to investigate whether in Hong Kong's context of housing and land shortage, neighbourhoods with high level of social housing coincide with reduced levels of PMR, if area deprivation, access to services, and aspects of the built environment and housing instability are taken into consideration.

Public housing and health - empirical evidence

Researchers who investigated the relationship between housing and health have primarily focussed on environmental or physical aspects of housing (building conditions, exposure to noise, crowding) (Jacobs 2011; Krieger & Higgins 2002; Dunn & Hayes 2000), the role of housing tenure (Baker et al 2013; Dalstra et al. 2006; Hartig & Fransson 2006; Leech 2010) or the relationship between both alongside neighbourhood characteristics (Hiscock et al 2003; Macintyre et al 2003; Ellaway & Macintyre 1998; Windle et al 2006). Except perhaps the investigation by Baker et al (2013), the studies highlight the negative health effects of rented accommodation - including social housing - vis-a-vis owned properties. Yet, ascertaining a health effect of housing over and above physical and neighbourhood conditions is complicated, since social housing is often of inferior quality compared to private accommodation and is located in deprived and socially disorganised neighbourhoods. The conflation of housing and neighbourhood stressors may confound correlations between social housing and poor health (Anthony & Robins 2012; Gibson et al 2011; Mueller & Tighe 2007).

A very recent study by Lawder et al (2014), for example, finds that Scottish residents show poorer health in neighbourhoods with more social housing. This finding matches those of other, similar studies, while it contradicts the expectation that, in guaranteeing access to secure accommodation, public housing should exert some positive health effects for those who would be unable to afford private housing compared to residents with a similar socio-economic profile actually living in private housing. This

expectation, logically following from the social determinants of health approach, seems particularly pertinent in urban environments where housing is scarce; in global cities or Asia's rapidly growing cities, we may well expect that public housing emerges as a critical determinant of health and well-being.

In an ecological analysis of health and social mixing in UK wards, Graham et al (2009), too, observe a positive association between social housing and health disadvantage. This association, however, becomes weaker if not insignificant, when the authors control for housing stressors, such as overcrowding or lack of physical facilities (e.g. heating). The authors note that "… there is no reason to assume that the owners will necessarily be 'better off' than the social renters." (ibid., 161), a conclusion that resembles findings by Burgard et al. (2012), who, in their study, could identify heterogeneous associations between different kinds of housing instability, types of tenures and poor health. For instance, individuals who are behind in mortgage payment rate their health more poorly and are more likely to report anxiety attacks than other types of occupiers (ibid, 2221); this questions common assumptions on the health advantage of home ownership relative to social renting. The relationship between tenure, access to housing and health seems therefore more complex and contingent than is often hypothesised, and frequently suggests a positive effect of social housing in certain contexts (also see Taylor et al 2006; Burrows 2003).

Public housing in Hong Kong

The vast majority of inquiries into the relationship between housing and health has been carried out in the UK, other European countries and North America. Hong Kong offers an interesting Asian case study, since the city is highly connected to the global economy and shows similar trends with regard to housing scarcity and urban inequality as those ascertained in other global cities (Lee et al 2007; Tai 2006). Some basic figures confirm

this: Hong Kong has a relatively high GDP per capita of 38,800 US-Dollar and a high GINI coefficient of inequality of .537, where 0 indicates full equality and 1 maximum inequality. In addition, Hong Kong has unique characteristics that create further pressures on housing, health and well-being. Located on more than 200 islands and surrounded by protected mountain ranges, the city is topographically highly structured. The resulting limits to space and possibilities of land development are manifest in hyper-dense urban form with high-rise residential buildings of dozens of storeys being the norm (Lai and Baker 2014, 223; Yip et al. 2009; Lai 1993), although the government's strict regulation of land supply may also play a role on the housing pressure (Peng and Wheaton 1993). Hong Kong's population of just over 7 million people live on less than 10 per cent of the city's area (Yip et al 2009). As a consequence, the functioning of Hong Kong highly relies on the public transportation system: the MTR (Mass Transit Railway) bus and minibus services, all of which are considered to be efficient and affordable, connect dense housing estates with the city`s major business districts.

Public housing played a central role in Hong Kong's urban development, often having been a driver in government-led urban expansion and construction of New Towns. Since the 1950s, the government has been committing itself to developing a large-scale public housing programme due to an influx of immigrants from Mainland China. This programme has had a major impact on Hong Kong's urban morphology and the "geography of housing opportunities" (Forrest et al 2004), by moderating the impact of income deprivation in Hong Kong's highly unequal society. Scholars investigating housing in Hong Kong point out that the city's success and position in the global economy is partly owed to the extensive public housing programme, which contrasts

sharply with the *laissez-faire* policy regime Hong Kong is often associated with (Delang 2010; Forrest & Yip 2014).

Lee and Yip's (2006) detailed, qualitative investigation of the social impacts of public housing in Hong Kong prior to 1990,offers some explanations on the question of how social renting and the long-term socio-economic development of families and households are causally connected, whereby public housing offers security and acts as a quasi-material resource to increase life chances and disposable income. Unlike in Western contexts, the authors conclude, public housing constitutes a stepping stone towards upward social mobility.

Public housing in Hong Kong comprises different kinds of benefits which individuals can access based on a number of eligibility criteria, notably annually reviewed maximum incomes (HKHA 2014). Public rental-housing are managed by the Hong Kong Housing Authority and the Hong Kong Housing Society and are rented at reduced rates with a maximum admissible rent of 10% of the household income (Govt. HK 2012). In addition there are two subsidized home ownership schemes: the “Home Ownership Scheme”, which allows low-income households to purchase housing units at substantially discounted house prices, and the “Tenants Purchase Scheme”, which provides public rental-housing tenants to purchase their apartments. Public rental-housing constitutes the largest part of Hong Kong's public housing programme; in 2011, just over 2 million Hong Kong residents (30 per cent of the population) lived in public rental-housing and nearly 1.4 million (17 per cent) lived in subsidized home ownership flats (C&SD 2011b). With altogether almost half of the population in public housing schemes – if subsidised sale flats are included – Hong Kong currently operates the largest public housing system among cities of the capitalist world (Forrest & Yip 2014). Single public housing estates can be large with often more than 5,000 units

accommodating up to 15,000 residents (HKHA 2015a). The geographic distribution of public housing in Hong Kong is uneven: whereas central and well-served areas of Hong Kong Island are virtually free of public housing, the central areas of Kowloon, Tsuen Wan, Kwai Chung, Wong Tai Sin or Kwun Tong and other New Towns in the New Territories can have more than 60% of the population living in public housing (figure 1).

Figure 1. Hong Kong – urban context and public housing.

The Government estimates that its large-scale public housing programme has reduced poverty in Hong Kong by approximately one fifth in 2012 if one particular estimation technique is adopted (Govt. HK 2012). While the Hong Kong government has investigated the potential impact of public housing on poverty reduction, the health effect of public housing has not been investigated. Potential health benefits of access to public housing schemes may have important implications for the status of public housing in Hong Kong and other prospering Asian cities with increasing linkages to the global economy.

Linking public housing to health in Hong Kong

While there are studies on housing and neighbourhood conditions in Hong Kong, they tend to focus on the social and economic impact on households and residents (e.g. Delang 2010; La Grange 2010; Lui 2007). Associations of public housing with health and well-being have not been investigated systematically. But considering the special role of public housing in Hong Kong's political economy and historic urban development, an inquiry into health effects may provide lessons for other Asian cities, and add insight to inconclusive evidence from studies conducted in Western countries. More specifically, it may be expected that public housing contributes to better health

and well-being of individuals relative to residents in different types of housing, if it can be disentangled from correlating aspects of different housing types, income, housing instability and neighbourhood resources.

2. Data and methods

To test the relationship between health disadvantage and public housing, we carried out a small area study of pre-mature mortality due to all and certain groups of causes, and estimated their associations with public rental housing provision adjusted for other neighbourhood characteristics thought to influence health.

,In this to date first comprehensive small area study of health in Hong Kong, we drew on a variety of data sources to measure premature mortality and neighbourhood context.

Mortality data

Premature mortality has been identified as an effective measure of health disadvantage, because it is thought to reflect the cumulative effect of exposure to stressors, including potential neighbourhood or housing influences (Kawachi & Berkman 2003). Mortality data were obtained from the Hong Kong Census and Statistics Department. We pooled data for 2005-2009 to estimate five-year small-area Standardised Mortality Ratio (SMR) for premature mortality. This time period included the 2006 by-census year; it was the most recent period that allowed access to the complete mortality data at the time of the study. In England, premature mortality is defined as mortality before the age of 75 years (PHE 2014). Given an average life expectancy in England and Wales of 79 for males and 83 for females in 2010 (ONS 2012), this definition appeared appropriate for Hong Kong, too, where in the same year, life expectancy at birth was 80 and 86 years for men and women respectively (CHP 2014). Since we were interested in the long-term effects of public housing and residential environments, we focused on Hong Kong residents

and therefore excluded all death records of visitors (people without a Hong Kong residence).

In Hong Kong, the death register holds information on the date of death, sex, age, cause of death, residential area, length of stay in the city as well as previous country of residence. Information on individual socioeconomic background is not collected, so that the analysis of pre-mature mortality could not be carried out in a multi-level model. Multi-level models have the advantage of disentangling individual effects from area effects (Meijer et al 2012; Subramanian & Kawachi 2004), but since we were primarily interested in health as a community level outcome, we would argue that a full ecological analysis of premature mortality still reveals overall tendencies as evidence for the existence of health effects by public housing at the aggregate level.

The register codes causes of death according to the International Classification of Diseases, 10th revision (ICD-10) (WHO 2012). This information is useful to explore different patterns for distinct groups of diseases. Previous research on health trends in Hong Kong suggest that different disease groups relate to the social environment in different ways (Lau et al 2012; Schooling et al 2010). We therefore found it necessary to disaggregate all-cause mortality by at least the first level logic adopted by the WHO Global Burden of Disease Study (WHO 2008), which grouped deaths into three cause categories: infectious, maternal, perinatal and nutritional conditions (type I), non-communicable conditions (type II), and injuries (type III).

Reference to planning units is included in each death record based on residential address, allowing the calculation of area-based mortality risk. Data at a higher spatial resolution are currently not released due to confidentiality concerns.

Spatial units and area characteristics

The Hong Kong Census Department provided population census counts at the level of Small Tertiary Planning Unit Groups. In 2006, there were 204 of these units with a median population size of 16,000 residents or 5,500 households. **T**he variables extracted from the 2006 Hong Kong by-census included income, economic activity, education, demographic and household information, rooms per person or housing tenure (see table 2 below for a full list of variables). Socio-economic variables were so selected as to capture aspects that have been shown to correlate with health and well-being at the neighbourhood level (Congdon 2010, 2013; Hiscock et al 2003). We standardised selected variables to relative frequencies using the Location Quotient (LQ), which forms a ratio between counts of a particular category relative to the expected frequency in each planning unit, thus centring area values at the Hong Kong wide average:

$$LQ_i = \frac{(n_i + 1)/(p_i + 1)}{\sum_i n_i / \sum_i p_i} \qquad [1]$$

where n_i is the frequency of observed counts in area i and p_i is the population of area i, with 1 added to the denominator in order to avoid LQs of 0. The area LQs were then transformed to *z* scores to further standardise variables to comparable units (where 0 represents the mean and 1 the value of 1 standard deviation). This procedure was applied to all census variables, except income, where the z score of median income was used, and a few other variables including public housing, whose LQ values were log-transformed to meet distributional requirements. We only included public rental flats in our definition of public housing, since both the Home Ownership Scheme flats and Tenant Purchase Scheme were grouped together under subsidised sale flats in small area Census tables. Though less numerous, the Tenant Purchase Scheme is a special form of

privatisation by which tenants own their property and although they are subject to sale restrictions, they pay back a proportion of the reduced land premium when they sell their property in the open market.[1]

In addition, we considered access to local amenities and services. Only few studies take into account supply-side determinants of health, although they constitute an important aspect of community deprivation (McLennan et al 2011). We used geographic point coordinates available for clinics, hospitals, parks, supermarkets and sports grounds, which were obtained from the Hong Kong Lands Department. For each planning unit, we calculated population-weighted road network distances to each amenity.

In addition, we measured an urban design aspect, which we found specifically relevant in Hong Kong's dense urban context: land use intensity. Based on building footprint data obtained from the Hong Kong Lands Department, we calculated surface area ratio, open space ratio, surface coverage and net population density (census population on built-up land) as recommended by Berghauser-Pont and Haupt (2005).

Spatial structural model

For each small area we determined the observed number of death, based on the death register data, and calculated the expected number of death, which was derived by multiplying the whole Hong Kong sex- and age-specific mortality rate by the corresponding small-area population data (in 5-year age bands) extracted from the 2006 Hong Kong By-Census. We then derived small-area age-standardised mortality ratios (SMRs) by dividing the observed number of death by the expected number of death.

[1] It should be noted that Home Ownership Scheme flats are typically in direct proximity if not part of public rental housing estates; thus the location quotient of public rental housing is very similar to the one that includes subsidised sale flats (correlation r=.93) and lead to nearly identical results in the subsequent analysis.

Small area estimates are prone to statistical uncertainty due to small counts and are also subject to spatial autocorrelation: rates in geographically close areas are likely to be related (Congdon 2012; Best et al 2005; Elliott & Wakefield 2001). A widely-used model in spatial epidemiology that accounts for these properties is the so-called BYM model, a Bayesian hierarchical model proposed by Besag et al. (1991; applications in e.g. Chang et al 2011; Cheung et al 2012; Congdon 2013). The model estimates area relative risk based on a Poisson regression as follows:

$$Y_i \sim \text{Pois}(e_i \theta_i) \quad [2]$$

$$\log \theta = \mu_i + \mathbf{x}_i \boldsymbol{\beta} + v_i + u_i \quad [3]$$

where θ_i is the relative risk of area i, μ_i the intercept of area i, $\mathbf{x}_i$ a vector of covariates, $\boldsymbol{\beta}$ a vector of regression coefficients, v_i an unstructured, normally distributed error component, which accounts for global variability in risk across the whole territory, and u_i, a spatially structured component, which accounts for local variability and correlation between neighbouring areas.

Smoothed estimates of small area SMRs could be calculated using this model, when no covariates are included. Smoothed SMRs can be understood as a weighted average of the observed area SMR, the global mean, and the SMR in neighbouring areas, with weights based on estimated levels of global and local variability. Hong Kong's fragmented urban form, located on hundreds of islands with dispersed, topographically separated settlements, challenges basic spatial conceptualisations of neighbour-relations. In order to overcome false adjacency based on area boundaries, manual adjustments with ancillary data (road network and ferry connections) were necessary to

connect all areas to a single component and permit Bayesian estimation with correct neighbour-relations.

We estimated premature mortality risk ratios for all, male and female residents through a series of models: first, a null model of smoothed SMR with no covariates; second, univariable models with each of the covariates studied; third, a full multivariable model including all variables. Since area covariates typically correlate, we ran factor analyses to derive latent variables representing different aspects of area characteristics. We used the Deviance Information Criterion (DIC) and the effective number of parameters (pD) to assess model fit and calculated the additional variance the full models accounted for, compared to the null models with no covariates. In order to test evidence for global spatial patterning of mortality risk, we used the Moran's I test of spatial autocorrelation.[2]

The Bayesian estimation was implemented using Integrated Nested Laplace Approximation (INLA), a deterministic alternative to the computationally intensive Multiple Chain Monte Carlo (MCMC) sampling methods (see Rue et al 2009, R Development Core Team 2011). We used the Open Source R-INLA package (www.r-inla.org) to estimate the models but back-checked these INLA-based models by estimating the same model using the software package WinBUGS (Spiegelhalter et al. 1999), which uses the conventional MCMC sampling methods. Results were nearly identical.

[2] A Moran's I of 0 indicates little or no autocorrelation, while a value of +1 indicates strong positive autocorrelation, suggesting that high rate areas tend to be proximal to other high rate areas and low rate areas to others low rate areas.

3. Results

Between 2005 and 2009, there were 198,734 mortality cases in Hong Kong; among them 80,770 (41%) were premature, excluding 1,768 cases for whom information of residence of mortality cause were missing. 83% of premature deaths occurred due to non-communicable conditions (type II),[3] and 8% due to communicable, maternal, perinatal and nutritional conditions (type I) and 9% due to injuries (type III) (table 1). In all types of premature deaths, men outnumbered women by more than twice, which indicates a considerably higher pre-mature mortality risk (PMR) among men.

Table 1. Premature deaths in Hong Kong 2005-2009.

Spatial pattern of premature mortality in Hong Kong

Figure 2. Health disparities in Hong Kong

Overall, there were significant geographical disparities of PMR in Hong Kong. Two corridors of increased emerged in Hong Kong's geography of all-cause PMR (figure 2): one running across the Northern New Territories, from Sai Sang Tsuen eastward to Fanling, and another one along central Kowloon, from Sham Shui Po n to Jordan. The former high risk corridor indicates a general health disadvantage in Hong Kong's northern New Towns. Some of them are directly linked through common development and transport infrastructure: the MTR West Rail Line as well as light rail links serve Tuen Mun, Tin Shui Wai (for Sai Sang Tsuen) and Yuen Long. Fanling and Hang Tau are physically separated from Yuen Long and form their own cluster of high risk areas. The corridor in central Kowloon stretches along the city's busy Nathan Road which is

[3] For definition of 'types', see WHO 2008.

characterised by high commercial activity and mixed residential land use. Population and building density are high in these areas with limited access to open space.

Sham Shui Po and some of the northern New Towns had a PMR of more than 1.5 the Hong Kong average. West Kowloon and most planning units of Hong Kong and Lantau Island were below the Hong Kong average. Most of the high risk areas showed a risk ratio that were significantly above the Hong Kong average: in the new towns Tuen Mun, Yuen Long and Fanling, the Kowloon neighbourhoods around Sham Shui Po, as well as the areas on Hong Kong Island, the probability that type I PMR risk exceeded 1 was above .95. This indicator represents a way of measuring statistical confidence within the spatial structural model.

In order to obtain a more robust estimate of the magnitude of difference, we calculated the risk difference between the 5^{th} and 95^{th} risk percentile of areas. For all-cause premature mortality, disparities in risk were wide: they ranged from 0.13 to 6.06 (crude) and from 0.31 to 5.44 (smoothed) with a 3.47-fold relative risk difference between the 95^{th} and the 5^{th} percentiles. This difference reflects an absolute risk difference of 259 cases (364 minus 105) per 100,000 person-years of residents younger than 75 years.

The geography and magnitude of health disparities differed by type of mortality cause considered (see Appendix for cause-wise maps). Crude risk ratios for type I causes (communicable, maternal, perinatal and nutritional diseases) ranged from 0.10 to 11.1 in their extremes (excluding observed counts of 0). This difference in magnitude reduced to 0.40 and 5.13 after smoothing. For type I causes, the absolute risk difference was 23 (34 minus 11) cases per 100,000 person-years or 3.04 in relative terms: between the 5^{th}

and 95th risk percentile of areas, we found a more than three-fold difference in type I PMR.

There was statistical evidence for weak spatial autocorrelation in mortality risk for type I causes with a Moran's I of .0.95 (p = .011). Areas with high risk were concentrated in some areas in north, east, and south coast of Hong Kong Island, Kowloon, and central areas in the North Territories. In contrast, areas with low risk were located in Nam Cheong, West Kowloon, Sha Tin and on Lantau Island.

PMR due to non-communicable conditions (type II) ranged from 0.14 to 6.18 (crude relative risk) or 0.33 to 5.33 (smoothed relative risk) between planning units in Hong Kong. The 95th versus 5th percentile ratio was 3.2 for the smoothed values, reflecting an absolute risk difference of 203 (295 minus 92) premature deaths per 100,000 residents after smoothing. Type II PMR mirrored closely the geography of all-cause PMR, since, as shown above, the type II premature mortality cases constitute 83 per cent of all cases. With no statistical evidence of clustering, areas with high risk were scattered across the whole territory: in central parts of the city Kowloon, as well as Yuen Long, Tai Po and Sai Kung Town in the New Territories. Areas of low risk were located across Northern Hong Kong Island, West Kowloon and some parts in the New Territories. Yuen Long and San Sang Tsuen in the New Territories, Sham Shui Po in North West Kowloon emerged as areas of increased risk with risk ratios between 1.6 and 1.9. On Hong Kong Island, too, we found a few areas where residents are more likely to die prematurely due to non-communicable conditions. The high risk areas covered larger housing estates in Aberdeen and Chai Wan and again dense and high-activity neighbourhoods adjacent to Hong Kong's business district.

PMR due to injuries (type III) also ranged widely from 0.12 to 3.45 in crude terms; this difference narrowed to 0.32 and 2.04 after smoothing. The observed 95^{th} versus 5^{th} percentile ratio of 2.79 corresponds to an absolute risk difference of 21 (32 minus 11) premature deaths per 100,000 person-years.

While overall spatial clustering of type III PMR was insignificant, a low degree of spatial concentration could be observed around the new towns of Tuen Mun, Yuen Long and certain northern neighbourhoods in Kowloon. The high risk corridor starting from Kowloon's Sham Shui Po and in the Western New Territories around Tuen Mun appeared again for type III PMR. Here, all types of health disadvantage coincided. Among the northern New Towns, only Tuen Mun showed increased risk, while the remaining ones did not indicate high type III PMR risk.

The findings suggest that the spatial patterns are not random and open up the question of causality as well as urban policy interventions to address health disparities. Often, higher risk areas are surrounded by low risk in close proximity resulting in a contrasting geography of risk, for example between West Kowloon and the immediately adjacent corridor running from Sham Shui Po to Jordan. This pattern reflects Hong Kong's high built-up density with its resulting fine-grained socio-spatial neighbourhood differentiation that locates affluent areas proximate to more deprived areas in substitution to macro-scale segregation. Contextualising risk by measuring associations with area characteristics, in particular public housing, may provide further evidence as to how risk varies with social and urban characteristics and how it may be addressed strategically in urban and town planning policy.

Associations of PMR and public housing

As explained in more detail earlier, social and urban characteristics were derived from a variety of data sources and combined by means of factor analysis. Table 2 shows all factors that were derived from the data. The four factors that could be derived from the census were interpreted as neighbourhood affluence, housing instability, elderly residents and social fragmentation based on the loadings of individual variables. Road distance to a variety of services correlated very strongly and formed a single factor that can be interpreted – in reversed form – as centrality of areas. Similarly, the variables measuring land-use intensity correlated and formed another single factor; the higher the value, the greater the intensity of land use.

Table 2. Factors describing small area characteristics, used as control variables in models

An additional variable describing neighbourhood context – neighbourhood daily fluctuation – did not load significantly in factor solutions with other census variables and the variable was therefore separated from factor analysis. All factors and derived variables along with public housing as exposure of interest were included in Bayesian models. We first ran univariable (unadjusted) models for each covariate and compared them with the fully adjusted multivariable models of all-cause PMR and cause-specific PMRs. We did this for the whole population as well as the female and male subpopulations. Table 3 shows the unadjusted and adjusted results for cause-specific PMRs among women and men.

Table 3. Contextualisation of premature mortality in Hong Kong (2005-2009)

The correlation of area characteristics with PMR differed by type of PMR and between women and men. We identified significant associations as those which excluded 0 from

the coefficients' lower and upper limits – known as credible intervals – which is measured as the range between the 2.5th and 97.5th percentile of the distribution of coefficient values.

As expected, neighbourhood affluence was inversely associated with PMR in all models, i.e. the higher the affluence of a neighbourhood, the lower the risk to die prematurely regardless of mortality cause. The intensity of the association as measured by the regression coefficient increased after all other variables were accounted for. For instance, the mean correlation coefficient in type I PMR for women is .14, which indicates that if we were to increase neighbourhood affluence by one standard deviation, we would observe a reduction of PMR by 13 per cent. After model adjustment, this crude effect increased to 21 per cent.[4] These associations in all PMR were stronger for men than for women, which may reflect the higher life expectancy of women. In 2014, there was a five-year difference in life expectancy between men and women, 81 and 86 years respectively. It should be noted, however, that increasing neighbourhood affluence is an abstract idea, since it is measured in terms of factor scores. In reality, it entails addressing associated neighbourhood characteristics that loaded as variables on this factor.

As for cause-specific models for type I (communicable) PMR, the older age composition of neighbourhoods were associated with increased risk for women. Centrality, that is the proximity to services including hospitals, was positively associated with type I PMR for both women and men, although the credible intervals for women just included 0. Public housing was not significantly associated with type I

[4] This can be calculated in the following way: One standard deviation above the Hong Kong mean would signify a factor score of 1. Hence the exponent of the covariate would be -.234 x 1, which results in a risk ratio of .791.

PMR. Yet, the direction switched from a positive association to a negative one after model adjustment. The association was almost significant for men, i.e. the credible interval stretched very little across 0.

As for type II (non-communicable) PMR, housing instability, which included crowding, emerged as a significantly positive covariate. Akin to the behaviour of neighbourhood affluence, the association intensified after model adjustment. For public housing, we again observed a switch in directions: the presence public housing was as such associated with increased type II PMR, but after controlling for all other area characteristics, notably neighbourhood affluence and housing instability, the association reversed. For men, both of these associations were significant, for women they seemed more moderate yet nearly significant. As with type I PMR, confidence intervals for women might be wider because the female subpopulation is only half as big as the male one. The negative association between public housing and type II PMR in the entire population – i.e. women and men combined – reached a value of .085 (not shown in table).

We further found that neighbourhood daily fluctuation was correlated with type II PMR among women: the higher the share of residents working outside the neighbourhood, the higher type II PMR. Land use intensity showed the opposite trend of centrality: the higher land use the lower type II PMR. We will comment on this finding further in the discussion below.

Type III (injuries) PMR, too, was higher in less affluent and more central areas. Injury risk was increased in areas with more elderly residents. Among men, there was a higher type III PMR in more socially fragmented areas. Again, public housing was inversely correlated with risk only after adjustment. This time, the inverse relationship turned out to be significant for women but not for men, while the reverse applies for the unadjusted

association. The small number of premature mortality cases may not allow for definitive conclusions, but the general trends observed with other types of PMR can still be identified. This becomes evident when combining men and women and looking at the entire population: here, both the unadjusted, positive association and the adjusted inverse association are significant (not shown in table).

When all mortality cases regardless of cause are considered, the observed associations re-appeared and followed closely the pattern for type II cases, since these cases constituted 83% of the cases. In general, it could be observed that public housing was significantly, positively associated with most types of PMR for both women and men in the unadjusted models, and inversely associated with PMR after full adjustment. This indicates that, after controlling for neighbourhood affluence, housing instability, centrality and other area covariates, PMR was lower in neighbourhoods with higher public housing stocks. The coefficient for public housing for type II PMR in the entire population was .085.

4. Discussion

Overall, the spatial analysis revealed significant geographic variations in premature mortality in Hong Kong. Geographical differences could be observed for separate risk categories, with different degrees of spatial clustering and sometimes very close proximity of high risk and low risk, reflecting a fine-grained geography of social differentiation in Hong Kong. In unadjusted models, public housing was positively associated with premature mortality. However, this relationship consistently reversed in most adjusted models: local levels of public housing provision were associated with reduced risk of premature mortality after accounting for other area characteristics.

Public housing as social determinant in Hong Kong and beyond

In our assessment of geographic health disparities, we could identify clusters of small areas that experience increased premature mortality risk across different categories of causes. Paradoxically – at least, on the surface – some of these areas have a high share of public housing and even were developed with public housing as central planning element. But disentangling the typical conflation of deprivation, poor housing conditions and the instance of social renting, as we did, suggests different undercurrents in the relationship between public housing and health. The thus apparent positive association between public housing and risk in unadjusted models may offer some explanations of inconsistent findings in the literature.

While our findings support the hypothesis that public housing contributes to health, our study also provides empirical support at an aggregate level for Lee and Yip's (2006) continued asset role of public housing ascertained at the individual level. Drawing on our findings and research by others on housing in Hong Kong, we suggest four potential pathways linking public housing and health that may be specific to the city. First, it is possible to view access to public housing as in-kind benefit that represents a transfer from market-level rents to subsidised rents (Lui 2007). This indirectly increases households' disposable income and potentially expands material assets relevant to health and well-being. Indeed, in Hong Kong, private renters have been subjected to rent increases in the past decade: while public housing tenants never pay more than 10 per cent of the income, in private housing it can be up to 50 per cent (C&SD 2011a). The disposable incomes among low income groups not living in public housing has therefore diminished relative to those of living in public housing. The income disadvantage of private tenants increases even more when considering that the Government waives the rents of public housing tenants for up to three months. In

addition, as Yip et al (2009) note, the public-assisted home ownership scheme has enabled households to directly accumulate capital within the public housing sector. Although we did not explicitly include subsidised sale flats, Home Ownership Scheme flats are indirectly included in our analysis through their co-varying location quotient. Households who own their property under the Home Ownership Scheme can re-sell their properties to households that are eligible for public housing or they can pay the land premium cost in selling the flat in an open market. The logic of the more common Home Ownership Scheme differs from that in the UK, for example, where the 'right to buy' effectively privatises public-rental homes.

Second, in Hong Kong, public housing estates are usually maintained and managed by the Housing Authority to high functional and sanitary standards, particularly in newly developed estates in suburban areas, such as the northern districts in the New Territories. Inferior quality of the low-end private rental market may trigger material pathways between housing conditions and health disadvantage, which may appear as health advantage among public housing tenants in the models. The positive associations between public housing and health disadvantage found in Western studies may indeed result from poorer conditions of public housing estates. Our evidence from Hong Kong suggests that it is not sufficient to only provide public housing, but also maintain and improve the public housing stock; a clear imperative to rethink current debates on public housing in some Western global cities (Doran et al 2013; Fenton et al 2013; Hamnett 2010).

Third, the size and wide presence of public housing in central and high-quality locations, including targeted upgrading initiatives in older stocks, does away with stigma that social tenants typically experience in Western contexts (Forrest & Yip 2014; Delang 2010; Li 2005). Housing and location-related stigma may limit life chances and

may activate psycho-social pathways in health (Anthony & Robbins 2012). In Hong Kong, these pathways are likely to be attenuated if they materialise at all. The additional psychological sense of guaranteed access to public housing may further reinforce the ability of households to cope with social stress.

Fourth, there is evidence that social cohesion is higher in public housing estates in Hong Kong (La Grange 2010), which again contrasts with experience in the West. The public housing policy`s focus on the family, i.e. applicants living with their families are given priority in conclusion of tenancies, may contribute to greater social cohesion. Hence living in public housing offers possibilities for improved well-being familial and social support and poses a significant advantage over the low-end private renting sector. The high number of applicants often from diverse social backgrounds also demonstrates that living in the public sector is considered to be desirable (HKHA 2015b).

Overall, in the context of strongly competing interests on scarce land and high housing demand in global and rapidly growing cities, the relative weight of secure access to housing in shaping social well-being and improving life chances may be larger than elsewhere. As in other global cities, access to housing and transport are likely to be the crucial determinants of health in Hong Kong, and a stable, strategic public housing programme may be an important policy mechanism to guarantee higher levels of physical and mental well-being for a significant part of the population . Testing whether this association can be further substantiated in Hong Kong can provide important lessons for similarly striving cities both in Asia and in Western countries.

The role of urban context

While neighbourhood affluence and housing instability show patterns of associations with premature mortality that would be expected, there are a few unexpected results that

deserve further discussions and indeed inquiries in future studies. Our results indicate that land use intensity is associated with lower premature mortality risk due to non-communicable diseases. Land use intensity is high in the central and commercial areas in both Hong Kong Island and Kowloon. While those areas have a better supply with services that are not included in the centrality factor (such as primary health care), the result is difficult to explain and intriguing. High density is often associated with higher deprivation and lack of open space, but also better access to services and transport. Since other factors reflect some of these aspects, there seems to be an independent association of density with better health. At this point, we can only speculate that living in more urban environments attracts healthier people with active and diversified lifestyles in the long-run.

The centrality factor, on the other hand, is consistently and significantly associated with higher premature mortality risk. Because centrality implies better access to a range of services, including supermarkets, hospitals and clinics, open space and leisure facilities, this may be at first surprising. Yet, it is likely that there is a selection effect at work: less healthy people at later life stages move to central areas in order to be closer to the services they require for easier and independent living. Depending on their material circumstances, they may need to live in small and crowded accommodation or in wealthier areas, such as Hong Kong Island. This pattern would explain the independent contribution of centrality in fully adjusted models.

The pattern observed with neighbourhood daily fluctuation suggests that neighbourhoods with a high proportion of commuters are associated with health disadvantage. Those areas can be found throughout the urban region, often in the outskirts, New Territories but also in central areas of Hong Kong Island. Reduced time budgets due to commuting may reflect lacking opportunities for relaxation, sleep and

sleep and recovery, which in turn compromises on mental and physical well-being. Yet, since the pattern observed applies predominantly to women, the impact of commuting on time budgets cannot be the only explanation. While the work participation rate of women has risen in the last decade, women have a range of additional tasks in relation to household, family and child-raising. The difficult task of balancing private and work commitment may translate into lifestyle aspects that have a particular health impact on women. A highly fluctuating neighbourhood would then be a quasi-biographical indicator of lifestyle aspects, if premature cases have occurred during economic activity or if they have remained in their neighbourhood after retirement. While this may be a plausible explanation in the Hong Kong context, this is a rather speculative point with some risk of ecological fallacy. Yet future exploration of this point may be highly relevant for questions about Hong Kong's working culture, gender roles and their impact on health and well-being.

5. Conclusions

Study limitations and avenues for future research

Although one may be tempted to attribute causality to observed associations, it should be remembered that this ecological analysis represents a contextualisation rather than explanation of risk. The cross-sectional design of our study further challenges our ability to identify causal relationships with certainty. With regards to public housing, it is possible that we also observe what is known as health selection or reversed causality: people already in poor health may 'drift' into public housing. This, however, is unlikely given the size of the public housing sector (30% of the total households). In addition, since mortality rates are age-sex-standardised and the age of residents adjusted for, the effect of health selection should have largely been controlled for. As with any ecological, cross-sectional analysis, there may be a risk of residual confounding, that is

the observed associations may be caused by unobserved covariates that are directly or indirectly associated with public housing. For this reason, we have drawn on a multitude of data from diverse data sources to include a wide range of area characteristics. By means of factor analysis, we sought to avoid colinearity among intercorrelated variables and reveal small area characteristics that are specific to Hong Kong and yet speak to neighbourhood studies by others. This study is based on aggregated small area data, while health is an outomce at individual level. Approaches such as multi-level models are useful in disentangling individual characteristics from contextual information (Kawachi & Berkman 2004). But since the Hong Kong mortality register does not provide much detail about individual cases beyond age, sex and residential area, a purely ecological study seemed appropriate at this stage. The lack of access to full address data means that we are unable to determine exactly whether an individual has resided in a public housing estate; the information would still have to be approximated through the neighbourhood instance of public housing. Yet, since many public housing estates are large, they often accommodate the majority of the population of a spatial unit, and this thus reduces the risk for ecological fallacy with respect to public housing. Finally, in estimating cumulative health disadvantage as pre-mature mortality, we are lacking information on morbidity. Morbidity adds information about healthy life expectancy and may thus describe health disadvantage more comprehensively. Comprehensive data on morbidity is currently emerging in Hong Kong and will offer research opportunities to further examine the association between health and public housing in the future.

We nevertheless deem this study successful in highlighting - for the first time in Hong Kong - markers of evidence as starting point for more focussed, aetiological research of housing, neighbourhoods and health, considering the four potential pathways we

surmised. As an example of a possible application that can build on this study, a geographically focussed evaluation of Hong Kong's housing policies, akin to the studies by Lee and Yip (2006) or La Grange (2010), may shed some light on the questions such as whether state-subsidized housing would contribute higher availability of assets that are relevant to health and well-being, fosters a higher level of social cohesion or moderate the health consequences of occupying lower social positions.

Future research should therefore not only comprise studies that draw on a wider range of data at a higher spatial resolution as they emerge but also targeted neighbourhood studies applying a mix of quantitative and qualitative methods to further investigate history and trends of residents' health and well-being in high-risk areas and instigate joint community and government interventions, such as those proposed by Corburn (2009). In this sense, in addition to informing urban policy substantively, our study highlights geographically varying challenges and localised information needs that can be addressed effectively at a strategic level.

Final remarks

Despite the known limitations of cross-sectional analysis, our study has proved revealing in characterising the intra-urban geography of health disadvantage for the first time in Hong Kong and discussing the role of a central instrument of urban policy: public housing. We therefore hope to contribute to the current literature on housing and health, not least by expanding the geographical reach of this field of inquiry. The locally specific guise of pathways linking public housing and health in Hong Kong may be manifest in a larger group of Asian cities, where living in public housing becomes a crucial determinant to urban health and well-being in the context of increasing urban inequalities, strain on public services, and globalised housing markets.

References

Anthony, E. & Robbins, D., 2012. A latent class analysis of resilient development among early adolescents living in public housing. *Children and Youth Services Review*, 35(1), 82–90.

Baker, E., Bentley, R. & Mason, K., 2013. The Mental Health Effects of Housing Tenure: Causal or Compositional? *Urban Studies*, 50(2), 426–442.

Berghauser-Pont, I. & Haupt, I., 2007. The Spacemate: density and the typomorphology of the urban fabric. *U-lab*, 55–68.

Besag, J., York, J. & Mollié, A., 1991. Bayesian image restoration with two applications in spatial statistics. *Annals of the Institute of Statistics and Mathematics* 43, 1-20.

Best, N., Richardson, S. & Thomson, A., 2005. A comparison of Bayesian spatial models for disease mapping. *Statistical Methods in Medical Research*, 14(1), 35–59.

Brunner, E. & Marmot, M. 2006. Social organization, stress, and health". In: *Social determinants of health*. Ed. by M. Marmot & R. G. Wilkinson. Oxford: Oxford University Press.

Burgard, S.A., Seefeldt, K.S. & Zelner, S., 2012. Housing instability and health: findings from the Michigan Recession and Recovery Study. *Social Science & Medicine*, 75(12), 2215–2224.

Burrows, R., 2003. Poverty and home ownership in contemporary Britain, Bristol: The Policy Press.

C&SD, Census and Statistics Department, 2011a, *2009/10 Household Expenditure Survey and the Rebasing of the Consumer Price Indices*. Census and Statistics Department, Hong Kong Special Administrative Region, People's Republic of China.

C&SD, Census and Statistics Department, 2011b. *2011 Population Census: Key Statistics*. Census and Statistics Department, Hong Kong Special Administrative Region, People's Republic of China.

Chang, S.S., Sterne, J.A., Wheeler, B.W., Lu, T.H., Lin, J.J. & Gunnell, D. 2011. Geography of suicide in Taiwan: Spatial patterning and socioeconomic correlates. *Health & Place* 17, 641-650.

Cheung YT, Spittal MJ, Pirkis J, Yip PS 2012. Spatial analysis of suicide mortality in Australia: investigation of metropolitan-rural-remote differentials of suicide risk across states/territories. *Social Science and Medicine* 75(8), 1480-1488.

CHP, Centre for Health Protection, Department of Health, Hong Kong 2014. *Life expectancy at birth (female and male), 1971-2012*. online http://www.chp.gov.hk/en/data/4/10/27/111.html, January 2014.

Congdon, P. 2013. Assessing the impact of socioeconomic variables on small area variations in suicide outcomes in England. *International Journal of Environmental Research and Public Health* 10, 158-177.

Congdon, P. 2012. Modelling small-area inequality in premature mortality using years of life lost rates. *Journal of Geographical Systems* 15(2), 149-167.

Congdon, P., 2010. The Spatial Pattern of Suicide in the US in Relation to Deprivation, Fragmentation and Rurality. *Urban Studies*, 48(10), pp.2101–2122.

Corburn, J. 2009. *Toward the Healthy City.* Cambridge, US, London, UK: The MIT Press.

Dalstra, J.A.A., Kunst, A.E. & Mackenbach, J.P., 2006. A comparative appraisal of the relationship of education, income and housing tenure with less than good health among the elderly in Europe. *Social Science & Medicine*, 62(8),2046–60.

Delang, C. O., & Ho Cheuk Lung. (2010). Public Housing and Poverty Concentration in Urban Neighbourhoods: The Case of Hong Kong in the 1990s. *Urban Studies*, 47(7), 1391–1413.

Doran, K.M., Misa, E.J. & Sha, N.R., 2013. Housing as Health Care — New York's Boundary-Crossing Experiment. *The New England journal of medicine*, 369(25), pp.2374–2377.

Dunn, J.R. & Hayes, M. V, 2000. Social inequality, population health, and housing: a study of two Vancouver neighborhoods. *Social Science & Medicine*, 51(4), 563–87.

Ellaway, A. & Macintyre, S., 1998. Does housing tenure predict health in the UK because it exposes people to different levels of housing related hazards in the home or its surroundings? *Health & Place*, 4(2), 141–50.

Elliott, P. & Wakefield, J.C., 2001. Bias and confounding in spatial epidemiology. In: Elliott, P., Wakefield, J., Best, N., Briggs, D. (ed.). *Spatial Epidemiology*. Oxford: Oxford University Press.

Fenton, A. et al., 2013. Public housing, commodification, and rights to the city: The US and England compared. *Cities*, 35, 373–378.

Forrest, R., La Grange, A. & Yip, N., 2004. Hong Kong as a global city? Social distance and spatial differentiation. *Urban Studies*, 41(1), 207–228.

Forrest, R., & Yip, N.-M. 2014. The Future for Reluctant Intervention: The Prospects for Hong Kong's Public Rental Sector. *Housing Studies* 29, 551–565.

Gibson, M., Petticrew M, Bambra C, Sowden AJ, Wright KE, Whitehead M., 2011. Housing and health inequalities: a synthesis of systematic reviews of interventions aimed at different pathways linking housing and health. *Health & Place*, 17(1), 175–84.

Govt. HK (2012). *Hong Kong Poverty Situation Report 2012*. Hong Kong: Government of the Hong Kong Special Administrative Region.

Graham, E., Manley, D., Hiscock, R., Boyle, P. & Doherty, J., 2009. Mixing Housing Tenures: Is it Good for Social Well-being? *Urban Studies*, 46(1), 139–165.

GRNUHE Global Research Network for Urban Health Equity 2010. *Improving urban health equity through action on the social and environmental determinants of health*. Final report of the Global Research Network on Urban Health Equity, London.

Gusmano, M.K., Rodwin, V.G., Weisz, D. 2010. *Health care in world cities*. Baltimore: The Johns Hopkins University Press.

Hamnett, C., 2010. Moving the poor out of central London? The implications of the coalition government 2010 cuts to Housing Benefits. *Environment and Planning A*, 42(12), 2809–2819.

Hartig, T. & Fransson, U., 2006. Housing tenure and early retirement for health reasons in Sweden. *Scandinavian Journal of Public Health*, 34(5), 472–9.

Hiscock, R., Macintyre, S., Kearns, A. & Ellaway, A., 2003. Residents and Residence: Factors Predicting the Health Disadvantage of Social Renters Compared to Owner-Occupiers. *Journal of Social Issues*, 59(3), 527–546.

HKHA, Hong Kong Housing Authority. (2014). *Annual report 2013/14*. Hong Kong: The Hong Kong Housing Authority.

HKHA, Hong Kong Housing Authority. (2015a). *Complete list of PRH/TPS estates*. The Hong Kong Housing Authority, online: housingauthority.gov.hk/en/global-elements/estate-locator/completeList.html (1/2015).

Govt. HK (2015b). *Number of Applications and Average Waiting Time for Public Rental Housing*. The Hong Kong Housing Authority, online: housingauthority.gov.hk/en/about-us/publications-and-statistics/prh-applications-average-waiting-time (3/2015).

Jacobs, D.E., 2011. Environmental health disparities in housing. *American journal of public health*, 101 Suppl 1, S115–22.

Kawachi, I. & Berkman, F., 2003. *Neighborhoods and Health.*Oxford, New York: Oxford University Press.

Krieger, J. & Higgins, D.L., 2002. Housing and health: time again for public health action. *American Journal of Public Health*, 92(5), 758–68.

La Grange, A., 2010. Neighbourhood and Class: A Study of Three Neighbourhoods in Hong Kong. *Urban Studies*, 48(6), 1181–1200.

Lai, L.W.C. & Baker, M., 2014. The final colonial regional plan that lingers on: Hong Kong's Metroplan. *Habitat International*, 41(July 1987), 216–228.

Lai, L.W.C., 1993. Hong Kong's Density Policy Towards Public Housing: A Theoretical and Empirical Review. *Third World Planning Review* 15(1), 63-85.

Lau, E.L, Schooling, C.M, Tin, K.Y & Leung, G.M. 2012. Income Inequality and Cause-Specific Mortality During Economic Development. *Annals of Epidemiology* 22(4), 285-294.

Lawder, R., Walsh, D., Kearns, A. & Livingstone, M., 2014. Healthy Mixing? Investigating the Associations between Neighbourhood Housing Tenure Mix and Health Outcomes for Urban Residents. *Urban Studies*, 51(2), 264–283.

Lee, J. & Yip, N-M., 2006. Public Housing and Family Life in East Asia: Housing History and Social Change in Hong Kong, 1953-1990. *Journal of Family History*, 31(1), 66–82.

Lee, K., Wong, H. & Law, K., 2007. Social Polarisation and Poverty in the Global City: The Case of Hong Kong. *China Report*, 43(1), 1–30.

Leech, T.G.J., 2010. Subsidized Housing, Public Housing, and Adolescent Violence and Substance Use. *Youth & Society*, 44(2), 217–235.

Li, L.H., 2005. The Impact of Social Stigma: An Examination of the Public and Private Housing Markets in Hong Kong. *The Appraisal Journal*, 73(3), 305–317.

Lui, H.K., 2007. The Redistributive Effect of Public Housing in Hong Kong. *Urban Studies*, 44(10), 1937–1952.

Macintyre, S., Ellaway, A., Hiscock, R., Kearns, A., Der, G. & McKay, L., 2003. What features of the home and the area might help to explain observed relationships between housing tenure and health? Evidence from the west of Scotland. *Health & Place*, 9(3), 207–18.

Marmot, M., 2010. *Fair Society, Healthy Lives*. London: The Marmot Review.

Marmot, M., 2005. Social determinants of health inequalities. *The Lancet* 365, 1099-1104.

McLennan, D., Barnes, H., Noble, M., Davies, J., Garratt, E. & Dibben, C., 2011. *The English Indices of Deprivation 2010*, London: Department for Communities and Local Government.

Meijer, M., Röhl, J., Bloomfield, K.. & Grittner, U., 2012. Do neighborhoods affect individual mortality? A systematic review and meta-analysis of multilevel studies. *Social Science & Medicine*, 74(8), 1204–12.

Mueller, E.J. & Tighe, J.R., 2007. Making the Case for Affordable Housing: Connecting Housing with Health and Education Outcomes. *Journal of Planning Literature*, 21(4), 371–385.

ONS, Office for National Statistics, UK, 2012. *Mortality in England and Wales: Average Life Span*. London: The National Archives, available online http://www.ons.gov.uk/ons/dcp171776_292196.pdf.

Peng, R. & Wheaton, W.C., 1993. Effects of restrictive land supply on housing in Hong Kong: an econometric analysis. *Journal of Housing Research* 5: 263-291.

PHE, Public Health England 2014. *Longer Lives*. online, http://longerlives.phe.org.uk/, Jan 2014.

Pollack, C.E., Griffin, B.A. & Lynch, J., 2010. Housing affordability and health among homeowners and renters. *American journal of preventive medicine*, 39(6), 515–21.

R Development Core Team 2011. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna.

Rue, H., Martino, S. & Chopin, N., 2009. Approximate Bayesian inference for latent Gaussian models using integrated nested Laplace approximations. *Journal of the Royal Statistical Society B71(2), 319-392*.

Sassen, S., 2001. The Global City: New York, London, Tokyo. *Heredity*, 93(1), p.447.

Schooling, C.M., Lau, E.W.L., Keith Y.K.T. & Leung, M.G. 2010. Social disparities and cause-specific mortality during economic development. *Social Science & Medicine* 70, 1550-1557.

Spiegelhalter, D.J., Thomas, A. & Best, N.G. 1999. *WinBUGS Version 1.2 User Manual*. MRC Biostatistics Unit.

Stephens, C., 2011. Revisiting urban health and social inequalities: the devil is in the detail and the solution is in all of us. *Environment and Urbanization* 23(1), 29-40.

Subramanian, S.V. & Kawachi, I., 2004. Income inequality and health: what have we learned so far? *Epidemiologic Reviews*, 26(1), 78-91.

Tai, P.-F., 2006. Social polarisation: Comparing Singapore, Hong Kong and Taipei. *Urban Studies*, 43(10), 1737–1756.

Taylor, M., Pevalin, D. & Todd, J., 2006. The Psychological Costs of Unsustainable Housing Commitments. *ISER Working Paper, Insititute for Social & Economic Research*.

WHO World Health Organization 2012. *ICD-10 Version: 2010*. Available online http://apps.who.int/classifications/icd10/browse/2010/en

WHO World Health Organization & UN-HABITAT, 2010. *Unmasking And Overcoming Health Inequities In Urban Settings*, World Health Organization; UN-HABITAT.

WHO World Health Organization 2008. *The global burden of disease. 2004 update*. WHO Library Cataloguing-in-Publication Data, Geneva, CH.

Windle, G.S., Burholt, V. & Edwards, R.T., 2006. Housing related difficulties, housing tenure and variations in health status: evidence from older people in Wales. *Health & Place*, 12(3), 267–78.

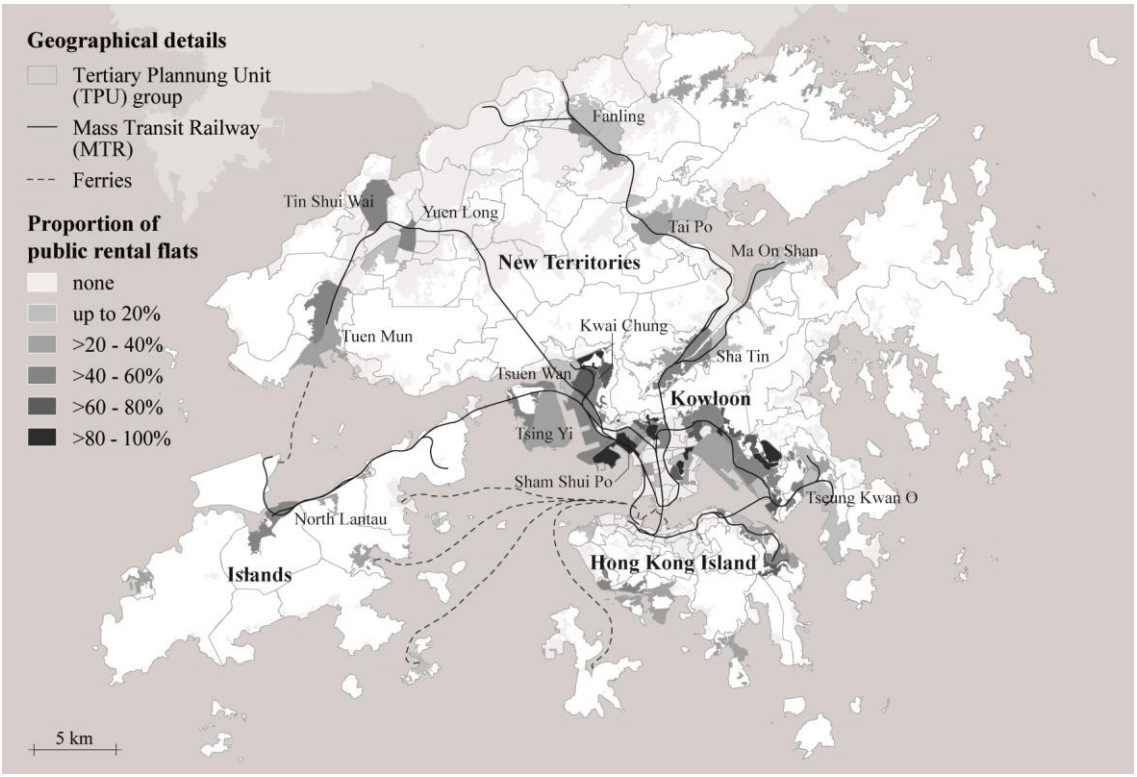
Yip, N.-M., La Grange, A. & Forrest, R., 2009. Making Space: Residential Trajectories in Hong Kong. *Urban Geography*, 30(7), 756–778.

Appendix:

Figures A1-A3. Cause-wise pre-mature mortality in Hong Kong

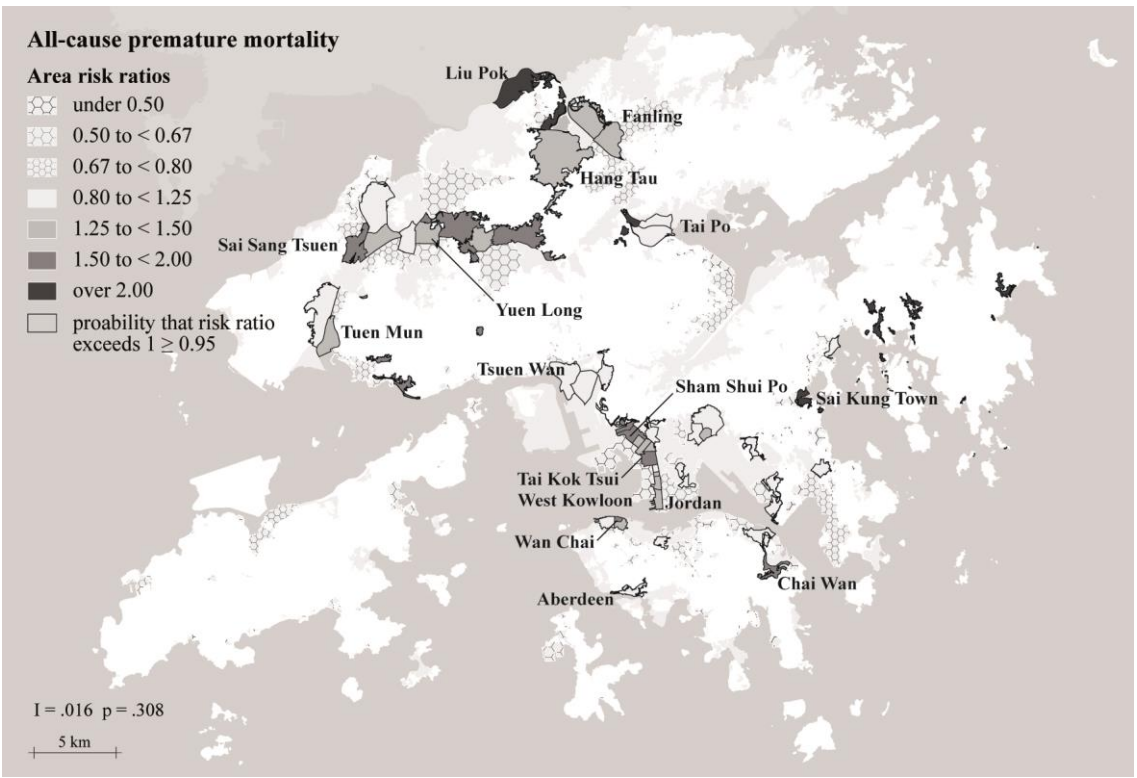
The figures show the spatial pattern of pre-mature mortality due to groups of causes (WHO 2008): communicable, maternal, perinatal and nutritional conditions (type I), non-communicable conditions (type II) and injuries (type III).

Figure 1. Hong Kong: Urban context and public housing



Source: Data from Hong Kong Census and Statistics Department, Hong Kong Lands Department, Hong Kong Planning Department.

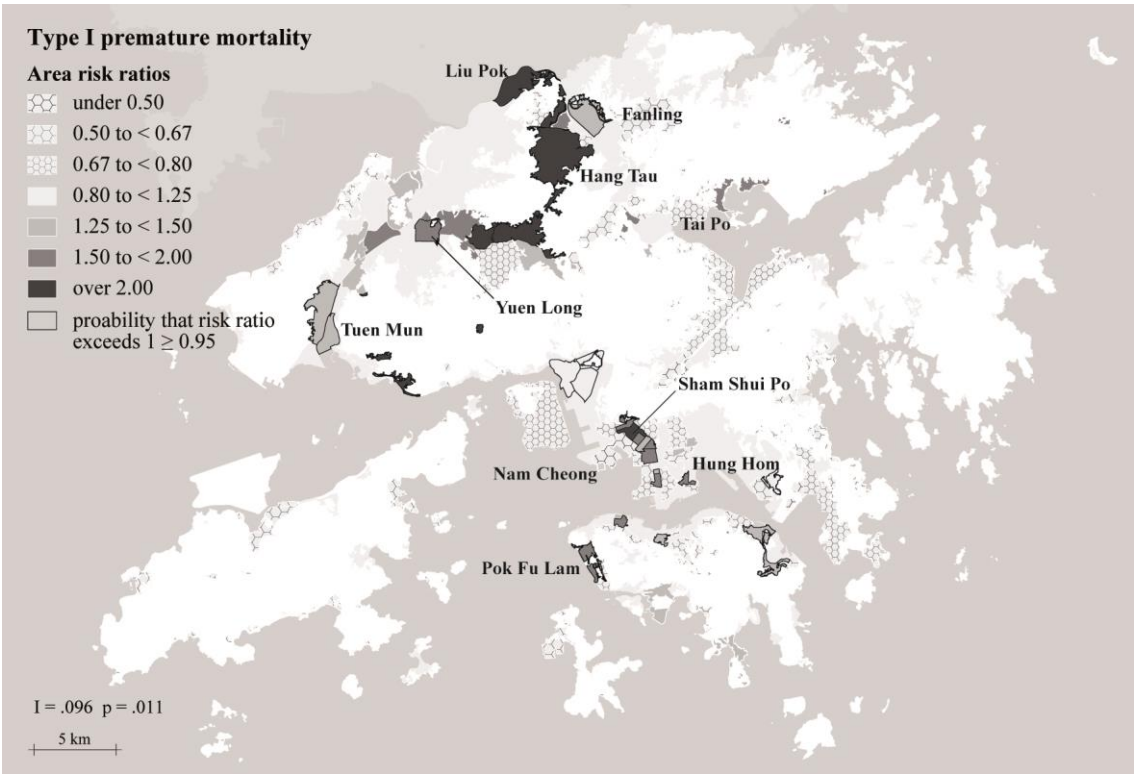
Figure 2. The spatial pattern of all-cause PMR in Hong Kong



Source: Authors' calculations based on data from Hong Kong Census and Statistics Department, Hong Kong Lands Department, Hong Kong Planning Department.

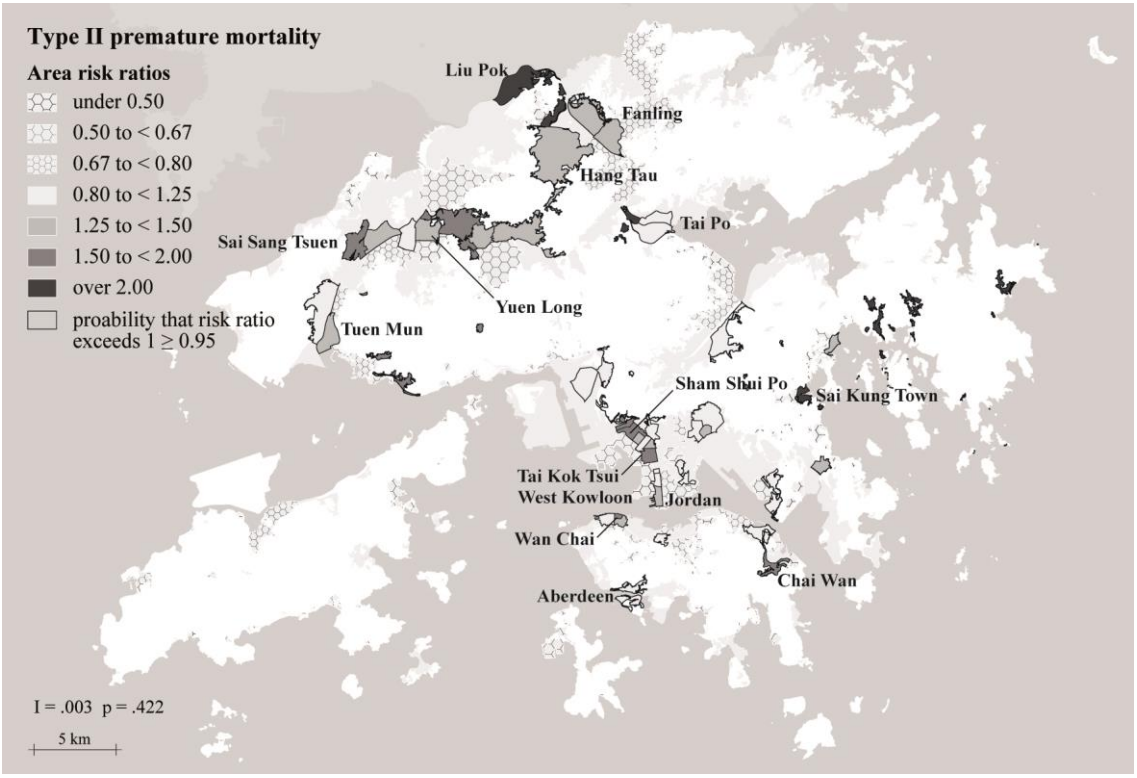
Appendix

Figure A1. The spatial pattern of type I PMR in Hong Kong



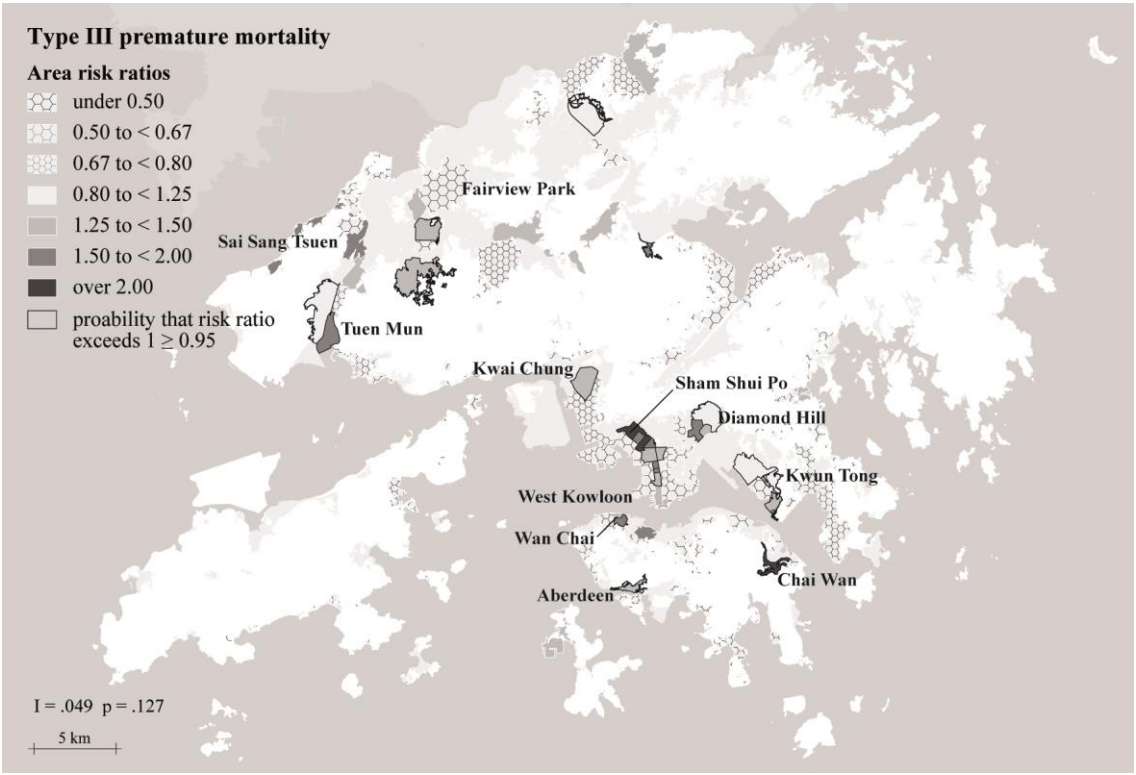
Source: Authors' calculations based on data from Hong Kong Census and Statistics Department, Hong Kong Lands Department, Hong Kong Planning Department.

Figure A2. The spatial pattern of type II PMR in Hong Kong



Source: Authors' calculations based on data from Hong Kong Census and Statistics Department, Hong Kong Lands Department, Hong Kong Planning Department.

Figure A3. The spatial pattern of type III PMR in Hong Kong



Source: Authors' calculations based on data from Hong Kong Census and Statistics Department, Hong Kong Lands Department, Hong Kong Planning Department.

Table 1. Premature deaths in Hong Kong 2005-2009

Premature mortality	**all**	**%**	**male**	**%**	**female**	**%**
Type I (infectious, maternal, perinatal and nutritional conditions)	6,711	8.3	4,838	9.0	1,873	6.9
Type II (non-communicable conditions)	66,844	82.8	44,067	82.0	22,777	84.3
Type III (injuries)	7,215	8.9	4,835	9.0	2,380	8.8
All causes	80,770	100.0	53,740	100.0	27,030	100.0

For classification of mortality into categories of death causes, see WHO 2008. Source: Authors' calculations on data from Hong Kong Census and Statistics Department.

Table 2. Factors describing small area characteristics, used as control variables in models

Variables from HK Census Department[a)]	n'hood affluence	housing instability	elderly residents	social fragmen-tation (reversed)
age < 15	-.055	-.106	-.772	.312
age ≥ 65	-.336	.038	.809	.001
median income [b)]	.756	-.292	-.118	.276
high status occupations	.888	-.164	-.150	-.070
unemployment	-.627	.423	-.097	-.078
high education	.969	-.208	-.073	.064
single household	-.025	-.288	.240	-.570
single elderly household [c)]	-.594	.101	.335	-.233
household size ≥ 5	.219	-.254	-.080	.910
rented accommodation	-.197	.706	.042	-.044
crowding [b)]	-.375	.906	.172	.052
Eigenvalue	3.39	1.82	1.51	1.40
Proportion Variance	.308	.166	.137	.127
Cumulative Variance	.308	.474	.611	.738

HK Lands Department[e)]	centrality (reversed)	HK Lands Department[f)]	land use intensity
d. to clinics	.911	floor area ratio	.998
d. to hospitals	.752	surface coverage ratio	.941
d. to markets	.912	open space ratio	-.999
d. to supermarkets	.934	net population density	.593
d. to recreation centres	.905		
d. to parks	.853		
d. to restgardens	.766		
d. to sports grounds	.840		
Eigenvalue	5.94	Eivenvalue	3.23
Proportion Variance	.742	Proportion Variance	.808

Other variables from HK Census Department	
n'hood daily fluctuation [d)]	control variable (not used in factor analysis)
public housing [c)]	exposure of interest (not used in factor analysis)

a) all variables transformed to z score of location quotient, except where noted • b) z score of absolute values • c) z score of log-transformed location quotient • d) defined as people not working in the same neighbourhood • e) all variables z score of log-transformed distance value • f) z scores of absolute values

Table 3. Contextualisation of premature mortality by type of risk in Hong Kong (2005-2009) [a)]

		FEMALE unadjust.			adjusted			MALE unadjusted			adjusted		
		mean	lower	upper	mean	lower	upper	mean	lower	upper	mean	lower	upper
	TYPE I PMR	(n=1,873)						(n=4,838)					
1	n'hood affluence	-.140	-.241	-.043	-.234	-.359	-.106	-.205	-.315	-.097	-.283	-.423	-.140
2	housing instability	.032	-.045	.110	-.015	-.139	.110	.071	-.016	.160	.054	-.099	.211
3	elderly residents	.115	.018	.211	.099	.008	.189	.046	-.061	.150	-.003	-.107	.098
4	social fragmentation	.100	-.005	.207	.055	-.062	.173	.079	-.026	.184	.002	-.115	.119
5	land use intensity	.127	.007	.249	.054	-.110	.216	.087	-.032	.209	-.062	-.255	.129
6	centrality	.207	.083	.332	.146	-.030	.324	.200	.083	.322	.246	.052	.444
7	n'hood daily fluctuation	-.036	-.117	.044	.064	-.048	.178	-.085	-.174	.003	.059	-.066	.184
8	public housing	.015	-.048	.079	-.026	-.116	.065	.021	-.055	.099	-.107	-.225	.008
9	Intercept				-.100	-.183	-.021				-.152	-.232	-.074
	TYPE II PMR	(n=22,777)						(n=44,067)					
1	n'hood affluence	-.082	-.139	-.026	-.129	-.207	-.051	-.169	-.246	-.095	-.183	-.273	-.092
2	housing instability	.089	.039	.140	.150	.056	.246	.147	.083	.211	.167	.056	.279
3	elderly residents	.018	-.042	.077	.003	-.055	.061	.049	-.027	.125	.018	-.049	.084
4	social fragmentation	.047	-.010	.105	.031	-.031	.093	.031	-.040	.102	-.021	-.089	.046
5	land use intensity	.043	-.020	.109	-.114	-.224	-.004	.053	-.028	.138	-.189	-.316	-.063
6	centrality	.127	.060	.197	.161	.052	.272	.195	.114	.280	.273	.149	.399
7	n'hood daily fluctuation	-.038	-.088	.013	.115	.041	.188	-.118	-.181	-.056	.064	-.020	.148
8	public housing	.043	-.002	.089	-.064	-.133	.005	.088	.028	.149	-.098	-.182	-.014
9	Intercept				-.115	-.161	-.070				-.160	-.214	-.108
	TYPE III PMR	(n=2,380)						(n=4,835)					
1	n'hood affluence	-.188	-.289	-.094	-.328	-.439	-.216	-.311	-.411	-.219	-.404	-.513	-.293
2	housing instability	.101	.026	.178	.123	.006	.242	.129	.049	.211	.100	-.020	.222
3	elderly residents	.133	.043	.223	.078	-.006	.161	.217	.119	.313	.149	.071	.226
4	social fragmentation	.128	.030	.227	.066	-.043	.175	.113	.012	.216	.108	.011	.207
5	land use intensity	.175	.069	.287	.035	-.112	.182	.070	-.042	.190	-.025	-.172	.121
6	centrality	.273	.159	.391	.164	.005	.325	.199	.089	.314	.134	-.012	.281
7	n'hood daily fluctuation	-.098	-.176	-.022	.076	-.026	.178	-.168	-.249	-.088	.071	-.027	.169
8	public housing	.006	-.055	.068	-.140	-.224	-.056	.092	.021	.163	-.067	-.156	.021
9	Intercept				-.145	-.223	-.071				-.180	-.246	-.115
	model fits[b)] TYPE I	ΔDIC=	-1.3	ΔpD=	-18.8	Var=	.685	ΔDIC=	3.1	ΔpD=	-6.27	Var=	.256
	TYPE II	ΔDIC=	-2.8	ΔpD=	-5.41	Var=	.218	ΔDIC=	4.9	ΔpD=	-6.0	Var=	.350
	TYPE III	ΔDIC=	-21.8	ΔpD=	-28.4	Var=	.756	ΔDIC=	-6.5	ΔpD=	-30.6	Var=	.612

a) Authors' calculations based on data from Hong Kong Census & Statistics Department – Vital Events Register • b) Model fits were assessed by comparison to models without covariates (ΔDIC=DIC difference, ΔpD = difference of effective number of parameters) and estimation of variance accounted for (Var).