Is SARS a Poor Man's Disease?

Socioeconomic Status and Risk Factors for SARS Transmission

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Summary/ Abstract

This paper investigates the link between socioeconomic status (SES) and the spread of Severe Acute Respiratory Syndrome (SARS) in Hong Kong in 2003. A comprehensive data set compiled by the author shows a negative and significant correlation between SARS incidence and various measures of income, but not years of education, unlike previous studies on other, mostly non-infectious, health conditions. The income-SARS gradient can be accounted for by controlling for pre-SARS housing values but not an array of measurable living conditions. Areas with more white-collar workers experienced a higher incidence rate, largely driven by the share of service and sales workers, after controlling for SES. These results have implications for the understanding of the SES-health link, the potential causality of the relationship and for future SARS containment strategies.

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Key Words: Socioeconomic Status, Infectious Diseases, Health, SARS, SES

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1. Introduction

The link between socioeconomic status (SES) and health is robust and well-documented in many branches of social science; questions remain on the direction of causation, the relative importance of different SES-health channels in different diseases and subsequent welfare policy implications (Goldman, 2001; Deaton, 2002; Currie and Stabile, 2003). The 2003 outbreak of Severe Acute Respiratory Syndrome (SARS) provides a unique setting to study the direction of causality of the SES-health relationship because it was an unanticipated outbreak of a previously unknown disease, without any evidence linking its prevalence to that of other illnesses in the population. Furthermore, factors affecting individuals' susceptibility are still being debated and related research has focused on genetic, not economic or social, differences (Skowronski et al. 2005). So far there exists no evidence on the size or sign of any SES-SARS gradient.[1] Developing an understanding of the spread of SARS, a disease with epidemic potential and no cure, has important policy implications.

This paper use a compilation of hand-collected datasets to investigate how SES was related to the risk of contracting SARS using data from the most severely hit city in the 2003 epidemic, Hong Kong.[2] Significant variation in the SARS incidence rate across the 18 districts in Hong Kong (Figure 1; Table 1A) and the negative correlation between the incidence of SARS and median income levels suggest a link between SES and the spread of SARS.[3] Firstly, this

[1] According to the WHO, SARS risk factors include close contact to SARS cases, a low baseline health status and environmental contamination. There has been no mention of a direct SES-SARS link. No public health measure was taken with explicit consideration of such a link during or after the 2003 epidemic.
[2] The SARS incidence rate in Hong Kong, at 0.258 per thousand, was the highest among all SARS-affected cities (World Health Organization, 2003). There were 299 SARS deaths in Hong Kong, accounting for more than a third of all SARS deaths.
[3] Regressing the SARS incidence rate on district fixed effects shows that there was no clear dichotomy of geographical areas into high- or low-risk districts. Section 6 provides more details.

paper fills in the gap in data availability by providing an estimate of the SARS incidence rate at a sub-district level for 295 large-scale housing complexes (known as estates) in Hong Kong. It then provides evidence of the SES-SARS link from an intra-city analysis on the estate-level SARS incidence rate and various SES indicators using a Tobit model.[4] The mediating role of living conditions is explored.

The 2003 SARS epidemic illustrates the type of low-probability, high-cost threat of infectious disease that is expected to become increasingly common in a more integrated world economy. During the 2003 epidemic (March-June), 8,096 people were infected, 774 lives were lost and the economic cost in terms of lost GDP for East and Southeast Asian countries is estimated to be US$18 billion (Asian Development Bank, 2003a). Threats of epidemic outbreaks like SARS are contained in an international effort by means of information sharing, public education, surveillance, and intensive tracing and home confinement of disease victims and their close contacts. These actions involve a large government effort and, as with any highly communicable disease, the externalities are high (WHO, 2003). Knowing which population segments are most vulnerable to diseases like SARS should be an important part of the containment strategy. Estimating the SES-SARS gradient can also provide insights into the spread of infectious diseases, and more generally the income-mortality gradient, in a region that is often predicted to be the origin of future epidemics (Loh, 2004). The SES-SARS link, causal or not, has direct implications on the optimal public health strategies on surveillance and disease containment.

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[4] The assumptions behind the Tobit model are discussed in the Appendix.

More generally, this paper sheds light on the complex SES-health association which has fueled debates over health care policy (Deaton, 2002; Meer et al., 2003). In addition to a direct casual impact of SES on health, a SES-health link can be a result of differential access to health care, variation in awareness or health-related behavior, or the impact of health on SES. Each of these channels has varying policy implications (Deaton, 2002). Several characteristics of the SARS epidemic suggest that more can be said about the nature of a SES-SARS link in Hong Kong. Firstly, vigorous epidemic measures and assignment of all SARS patients to specific restricted access wards minimized the difference in quality of epidemic control measures among subpopulations of different SES. Secondly, Lau et al. (2003) find that appropriate precautionary measures were practiced by over 90 percent of the Hong Kong population during the SARS epidemic, implying a low level of variation in preventative health behavior. [5] Thirdly, because SARS was a newly discovered disease, a measure of historical SES status before the epidemic reflects little or no sorting behavior related to SARS. There is no evidence that susceptibility to SARS is related to that of other infectious diseases or to medical history. The SES measures used in this paper are pre-epidemic variables, which avoids a potential problem of reverse causality.[6]

This paper explores the origins of the SES-SARS link in two steps. First, three measures of SES are utilized: income, education and occupation. Income exhibits the most robust relationship with the spread of SARS, which is independent from that between occupation and the spread of SARS. The lack of an education-SARS link contrasts with the education-health gradient identified in the literature for other health status measures (Deaton, 2002; Schnittker,

[5] The measures include mask wearing, frequent hand washing, avoidance of crowded places and the disinfection of living quarters. While the educated or healthcare professionals might be expected to adopt precautionary measures more efficiently, a survey of community doctors (General Practitioners, or GPs) reveals that some clinical practices such as frequent hand washing between patients were not followed. (Lau et al., 2003)

[6] In related work, Wong (2004) explores the impact of SARS on the housing market and finds a significant effect of SARS on housing values.

2004). It resonates with the findings of Tang and Wong (2003) that the adoption of preventive health behaviors during the SARS epidemic increased by perceived susceptibility, self-efficacy and age but not education.

Using data on pre-SARS housing sales, rental prices and living conditions, I find that both permanent income and living conditions explain the income-SARS correlation. When controlling for housing sales or rental prices, the income-SARS link becomes insignificant while the occupation-SARS link remains robust. I further explore the importance of various measurable living conditions. Estates with a higher number of floors per building and facilities such as health clubs or childcare centers experienced a higher incidence rate, possibly through environmental contamination (e.g., elevators) and a meeting-point effect. So did estates with a higher proportion of students and workers using public transportation. On the other hand, household crowding, proximity of health care establishments, building age and public or private ownership display no systematic relationship with the SARS incidence rate. Even when controlling for all relevant measures of housing conditions, the income-SARS correlation remains stable and robust. Comparing this result and the case when both income and housing price are included in the model suggests that factors aside from living conditions that are related to housing prices – such as permanent income and non-housing consumption – contribute to the income-SARS link. Lastly, I find no evidence that income inequality or homeownership explains intra-city variations of the income-SARS link.

This paper is organized as follows: the next two sections provide an epidemiology of SARS and a timeline of the epidemic in Hong Kong; Section 4 reviews related literature; Section 5 describes the data; Section 6 presents empirical findings and Section 7 concludes.

2. SARS Epidemiology

The causative agent of SARS is a newly identified coronavirus (*SARS-CoV*) that is sufficiently infectious to cause a very large epidemic if unchecked, but controllable with public health measures such as early detection, quarantine and treatment of SARS patients. On average 2 to 4 people are infected by each SARS patient in the absence of any control measures.

Transmission mechanism of SARS is through deposit of virus through respiratory exudates and contaminated surfaces on membranes of mouth, nose or eyes. The risk of transmission increases within confined spaces, such as elevators and airplanes. Environmental factors such as sanitation and density are likely to have played a role in some outbreaks (Lipstitch et al., 2003; Riley et al., 2003; Hong Kong Department of Health, 2003; WHO, 2003).

Effective epidemic control measures include reduction of population contact rate, promotion of personal and environmental hygiene (frequent handwashing, mask wearing and disinfecting living quarters and shared facilities such as elevators), and detection and isolation of SARS cases.

It is not yet clear why some virus-carriers demonstrated higher-than-normal infectivity in "super-spreading events" (SSEs), where single individuals infected as many as 300 others. (Dye and Gay, 2003; Lipsitch et al., (2003); Riley et al., 2003) Possible explanations include mutated strains of the virus, differences in modes of transmission and a much skewed population contact rate distribution. For comparability I have excluded the three SSEs from my sample.

3. Timeline of the 2003 SARS Epidemic in Hong Kong

The first SARS cases in Hong Kong are now known to have occurred in February 2003. Figure 2 shows a timeline. At least 125 people were infected around March 3, 2003 in the Prince of Wales Hospital, forming the first SARS cluster (Riley et al., 2003). When seven residents in

Block E of Amoy Gardens, a high-density private housing estate, were diagnosed with SARS on March 26, 2003, the community transmission of the disease – i.e., its spread in the local community outside the group of close medical and family contacts of SARS patients – was confirmed by the government.

After the Amoy outbreak, there was a large-scale shutdown of normal activities. Most people either stayed at home or wore surgical masks, while all schools were suspended on March 29 for more than 3 weeks. Residents were infected across the board, including the educated, the young and the previously healthy. A high level of vigilance was displayed by the government and international organizations. Specific restrict-access SARS wards were set up, isolating all known SARS cases.

The epidemic was declared contained after three months on June 23, 2003, 21 days after the last case in the territory was isolated. 1,755 people in Hong Kong were infected and 300 died from the disease. Less than a quarter of the SARS cases in Hong Kong were health care workers and most of the almost 400 infected residents in Amoy Gardens were strangers to each other.[7]

4. Literature on the SES-Health Gradient

There is a large body of literature demonstrating the positive variation in health status by socioeconomic status (SES). Feinstein (1993) and Goldman (2001) provide a detailed review of the related studies. Below I outline three related main themes.

First, the variation of health status by SES is gradual and it exists at all levels of SES, not just limited to a poverty effect due to deprivation. Therefore there is ample interest in studies of the SES-health link in relatively affluent societies. They include the Whitehall studies (Marmot

[7] Source: The Standard; Oriental Daily; WHO website.

et al., 1984, 1991, 1995) that focus on British civil servants, none of whom is poor. Rogot et al. (1992) find a proportional income-mortality relationship constant at all income levels.

Second, some form of a positive SES-health relationship emerges regardless of the choice of measurement of the SES, including income, education and occupation, or the country studied. However, health measures are shown to have relationships of different strength with different SES indicators (e.g., Hurd et al., 2003). This paper furthers this comparison.

Third, recent studies provide some evidence that the observed SES-health relationship is more than a reverse causal impact of health on SES, i.e., people in poor health drift towards the bottom of the SES distribution, or a third factor effect, where factors such as height affecting both income and health later in life (Goldman, 2001). However, the direction of causality is not well identified in most studies, and this paper aims to help shed light on the subject.

5. Data

A. SARS Incidence Rate

While disaggregate data on the number of SARS cases below the district level are not recorded, the Hong Kong Department of Health provided the total number of cases in the territory and the number of cases in the four SSE sites with the largest clustering of cases. A daily "List of Buildings of Confirmed SARS Cases" (SARS-list henceforth) was published by the Department of Health during the epidemic contained addresses (up to the building level) of all SARS-affected sites on that day. I estimate the number of SARS cases in each housing estate by counting the number of times any building within each housing estate was put on the SARS-list, and then multiplying the number by the average number of SARS cases per listing, excluding the four most severe sites. The estate-level SARS incidence rate is the ratio of the estimated number of SARS cases to the housing estate population.

The reader should be aware that there are several sources of error in my estimate. First, the SARS-list started on April 12, 2003, more than two weeks after the Amoy outbreak when community-level transmission of the disease was confirmed. Second, the variation in the number of cases per listing implies that my estimate is at best a crude measure of the relative severity of the outbreak in the listed buildings. Third, because the SARS-list was published to encourage stringent precautionary measures and self-monitoring of health conditions, especially for residents that might have contact with SARS patients, buildings were only kept on the SARS-list within ten days of hospitalization of the last SARS patient from that building. If there was more than a ten-day lag between the hospitalization of the patient and the diagnosis of SARS, the incubation period was considered to have passed, and the building in which the patient lived would not be put on the list. Therefore some buildings with SARS cases might have never appeared on the SARS-list.

To assess how accurate the estimation method I have adopted for creating the estate-level SARS incidence rate is, I repeat the same estimation process for all 18 districts, using a district instead of a housing estate as the unit of observation. Next I compare the district-level estimates with the actual district-level SARS incidence rates provided by the Department of Health. The two measures have a correlation of 0.96. The two measures are plotted against each other in Figure 3.[8]

B. Measures of Socioeconomic Status and Other Resident Characteristics

Hong Kong is divided into 18 Districts. District-level population density is calculated using population data from the 2001 Hong Kong Census and land area data from the National Bureau of Statistics of China.

[8] Both the estimated and the actual district-level SARS rates are derived using the Census 2001 population.

Demographic and socioeconomic profiles of estate residents are proxied by Census 2001 data at the building-group level. Building groups (a total of 2,817 in Hong Kong, covering all 39,028 residential buildings) are divided according to building characteristics such as location, type, age and height (Fung, 2005). Population-weighted averages are taken for each estate across building groups to which at least one building of the estate belongs. Tables 1A and 1B contain summary statistics.

C. Pre-SARS Housing Sales and Rental Price Data

To measure pre-SARS housing values, I have obtained access to transaction records of all sales and purchases of housing units in Hong Kong during the years 1993-1998 and 2001-2002.[9]

Housing estates are large-scale housing complexes, consisting of many almost-identical blocks of housing units. The substantial similarity of units within each housing estate ensures that the average price level will be a reasonable reflection of housing values within that estate. Only estates with at least 2 transactions per month on average during the period 1993-1996 are included in my sample, for a more accurate measurement of price levels. A site of super-spreading event (Amoy Gardens), suspected to have been struck by a particularly virulent strain, is excluded. Together the 295 housing estates in my sample encompass more than 1.5 million people, about 23 percent of the Hong Kong population. They are situated in 17 of all 18 districts in Hong Kong, except for the *Islands* district that contains the outlying islands with a population of 86,667 (1.3 percent of territory total; Census 2001). There are 58 public housing estates in my sample; excluding the public estates does not change the results quantitatively or qualitatively.

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[9] Data for years 1993-1998 are kindly shared by Tsur Sommerville. Purchase of data for years 2001-2002 was generously supported by a grant from the Andrew M. Mellon Foundation through the Research Program in Development Studies at Princeton University. Both data sets are based on Memorial Day Book of the Hong Kong Land Registry that records all sales and purchase instruments registered with the Registry, subject to the provisions of the Land Registration Ordinance.

Because of potential outliers, I use the median transaction prices as an indicator of housing values.[10] Mean prices have a correlation in excess of 0.99 with the median prices in each year for the 295 estates in my sample. Using mean prices as an indicator of housing values produces very similar results. The housing price data is supplemented with data on monthly mortgage and rental payment from the 2001 Census.

D. Estate Characteristics and Living Conditions

I compiled data on the characteristics of the housing estates that might be related to the spread of SARS including: age, average flat size, availability of estate facilities (such as health clubs, shopping arcades or childcare centers), number of floors, number of flats per floor, and number of blocks.[11] I define the average space per person in each estate as the ratio of the estate-average flat size to the district-average of persons per housing unit derived from Census 2001.[12]

I measure the travel time to city center from a housing estate, defined as the amount of time spent on the most prevalent form of public transport to the closer of the two main commercial/ financial centers in Hong Kong, Tsim Sha Tsui and Central. Information on travel time to city center was collected from real estate agents and transportation companies.

Availability of health care facilities is checked on the website of Centaline Ltd., a leading property agent in Hong Kong. Under the map function, the numbers of three types of health care facilities can be searched within a north-facing 64m X 80m (0.51km^2) rectangle with each housing estate in the center: medical establishments (general hospitals and clinics, dental

[10] For example, it is not uncommon for housing units on the top two floors to be duplex units or penthouses. These units usually cost more than double most other housing units in that housing estate.
[11] These data were compiled by research on the internet, phone calls to real estate agents and property developers, and visits to some of the estates. Age and the number of floors and flats per floor are averages across the housing estate; number of blocks are often counted from site plans of the estates.
[12] There is not a lot of variation across districts. Mean [s.d.] of the number of households per quarter is 1.02 [0.03]; Mean [s.d.] of the number of persons per household is 3.16 [0.19].

hospitals and a variety of health care facilities, both private and public), community doctor/ GP clinics and all other health-related facilities (such as pharmacies, dental clinics and Chinese medicine practitioners). Medical centers apparently unrelated to SARS, such as dental hospitals or optical care centers, are excluded from the *medical establishment* variable and added to the number of *all other health-related facilities*. Information on whether or not the housing estate is public is obtained from the Housing Authority.

6. Empirical Findings

As a first step, I estimate the following Tobit model:

$$SARSP_i = \alpha + \gamma_d + \varepsilon_i \qquad (i = 1, \ldots, 295) \qquad (1)$$

$SARSP_i$ refers to the SARS incidence rate of housing estate *i* bounded between 0 and 1, α is a constant term, γ_d a district fixed effect, and ε_i is a normally distributed error term with density function $N(0, \sigma_i)$. I weight the regression by the total number of flats in each estate to adjust for heteroskedasticity, assuming that σ_i^2 is inversely proportional to the size of the housing estate. If we consider the estate-level SARS incidence rate to be the average of 1-0 outcomes (infected/ not infected) of all estate residents, then the variance of the error term will be of the form σ^2/N_i where N_i is the number of residents. In the Appendix I present evidence that the model specification and the error assumption are appropriate.

District fixed effects are not significant as a group (p-value = 0.25), nor is a district-level population density measure (p-value = 0.35). Because the lack of evidence towards a simple classification of districts into "high-risk type" and "low-risk type", the district-level variables are omitted from results presented.[13] Furthermore, I do not find any strong support for a spatial

[13] For robustness checks, district dummies (or district-level population density) are added to all regressions presented in this paper but neither control ever has statistical significance at 10%.

correlation of the spread of SARS. Regression of the estate-level SARS incidence rate on the self-excluding district-average incidence rate does not suggest a significant link, despite the upward bias due to feedback effects (Case, 1991; Manski, 2000). Therefore in the rest of the paper I focus on the SARS incidence rate of each housing estate as independent.

A. Socioeconomic Status and SARS

As discussed in Section 5, the SES variables are measured at the building-group level in three dimensions: income, education and occupation. Table 2 shows the regression results of the following Tobit model weighted by the total number of units:

$$SARSP_i = \alpha + \beta \; SES_i + \varepsilon_i \qquad (2)$$

Higher household income levels at either the upper quartile, median or lower quartile correlate with a lower SARS incidence rate (columns 1-3). Measures of personal income levels produce similar results. As the rest of the empirical results will show, the SES-SARS link found is the most stable along the dimension of income.

Column 4 shows the link between SARS and the share of working population in different occupations. The SARS incidence increases most significantly with the share of workers employed in service industries/ shops and secondly for professionals, against a baseline category of elementary, agricultural and fishery and other unclassified workers. The share of managers, administrators and craft workers in the workforce does not correlate significantly with the SARS incidence rate. Likely explanations include the workers' high contact rate with the general population (and thus SARS cases) and the proximity of shops and other places where the public convene and the disease spreads. Part of the link between SARS incidence and the share of the workforce who are (associate) professionals can be due to the inclusion of healthcare workers and other client-based professionals (such as consultants) in the category. Similar results are found in column 5 using two broad occupation groups.

Notably, the effect of income on the spread of SARS is independent of occupation. This result is consistent with findings in the literature. As early as 1872, Friedrich Engels (1872) argued that lower income areas where "workers are crowded together are the breeding places of all those epidemics." Income can affect SARS incidence through one of the following channels: consumption, psychobiological impact, and exit. Higher purchasing power or permanent income positively relates to expenditures on goods that might contribute to the functioning of the immune system or general health status (e.g., living conditions, healthcare and nutrition).[14] Further, there is evidence that socioeconomic circumstances have biological effects on immune functions (Brunner, 1997). Higher-income households presumably also found it easier to leave Hong Kong when the epidemic struck.

One hypothesis that supports an SES-SARS link is that the more educated adopt appropriate health habits more efficiently. Columns 6 and 7 show no significant relationship between SARS incidence and the education level, despite the high correlation (0.7-0.8) between the education attainment measures and median household income level. This discounts the differential health behavior story, consistent with findings in Lau et al. (2003). It is also suggestive of a different dynamic for infectious diseases where susceptibility relies on preventive measure adoption (Gregson et al., 2001; Tang and Wong, 2003) and resonates with evidence that more educated groups in sub-Saharan Africa are more vulnerable to HIV (Gregson et al., 2001).

[14] Environmental factors have been proved to be important at least in one super-spreading event. (Hong Kong Department of Health, 2003; WHO, 2003) Household overcrowding and lower population density in less expensive, more remote residential areas both impact the transmission of SARS, but in opposite directions.

Marmot (2002) argues that full participation in society might be as important as the purchasing power derived from income. Columns 8 and 9 in Table 2 do not offer much support that this mechanism was at work in the case of SARS. The last two columns in Table 2 demonstrate the income-SARS link and the occupation-SARS link are more or less independent.

B. Possible Channels of the Income-SARS Link

Housing service consumption is expected to increase with current income level, permanent income and the quality of housing services (which can in turn reflect preferences related or unrelated with SES). To explore the income-SARS correlation identified in the previous section I regress:

$$SARSP_i = \alpha + \mathbf{Income}_i\,\beta + \mathbf{H}_i\,\gamma + \varepsilon_i \qquad (3)$$

where H_i is a measure of value of housing service consumption of the households and other variables defined as before. Four separate indicators are used: building group-level monthly rental price; estate-level average sales price in years 1995-98, 2001-2002; estate-level average sales price in year 2002; and building group-level monthly mortgage payment. While rental price can be expected to best reflect the user cost of housing without influence of price expectations and other macroeconomic factors, it is derived from Census 2001 at the building-group level only. No data closer to the 2003 epidemic or at a more disaggregate level is available. Mortgage payment is likely to have the least accurate indicator out of the four, being both measured by the building group level and affected by factors such as when the mortgage was taken out and structure of the mortgage. Nevertheless, Table 3 demonstrates that different housing service value indicators produce results that point in the same direction. The main conclusion from this analysis is that the income-SARS link is much reduced in both size and statistical significance when housing service value is controlled for, while the occupation-SARS link remains robust.

C. Measurable Living Conditions

One can think of the rental or sales price of a housing unit as the market value of a vector of living amenities and neighborhood qualities, some of them (such as social capital) unobservable. This section explores numerous measurable aspects of living patterns and conditions (***L***) that might have been proxied by housing service value:

$$\text{SARSP}_i = \alpha + \mathbf{Income}_i\, \beta + \mathbf{L}_i\, \tau + \varepsilon_i \,. \qquad (4)$$

Notably, Table 4 shows that while some living condition indicators have a significant correlation with SARS incidence, the income-SARS link remains robust. Also, comparing column 1 with the rest of the table, neither the magnitude of the income-SARS link or that of the occupation-SARS link experiences any noticeable reduction. Results using the other 3 income level indicators are similar and available upon request.

The proportion of students and workers who use public transport relates a higher SARS incidence rate (column 2). This is consistent with WHO (2003) which recommends special consideration to be given to confined spaces including aircrafts and vehicles. A higher incidence rate in estates with facilities such as health clubs and childcare centers (column 3) might either be due to a higher usage rate during the epidemic (as compared to residents in other estates who stopped using similar facilities outside their estates because of the general wariness of transportation) or a lower level of environmental hygiene. The number of floors per building correlates with the sharing of elevators with a sawtooth pattern. As column 4 shows, it is significant at 10%.[15] These are the risk factors that demonstrate a consistent relationship with SARS incidence using different income measures.

On the other hand, the proximity to health-related establishments (public and private hospitals, general practitioner clinics and pharmacies) does not correlate with the spread of SARS. Similarly, three indicators that potentially capture population and living density – travel time to city centers, space per person in the average unit and the average number of units per floor – do not have a strong relationship with SARS incidence (columns 5-8).[16] The average age of buildings within the estate generally relates to more depreciation of less modern facilities, but no significant impact is found (column 9). Column 10 shows that any difference in building management and the level of general building maintenance between private and public estates does not create a gap between the two types of estates in terms of SARS incidence.[17]

D. Testing Other Related Hypotheses

This section examines whether the homeownership rate and income inequality at the building group level affect SARS incidence. There is evidence in the literature that homeowners have more incentives to invest in local amenities and social capital due to low mobility (e.g., DiPasquale and Glaeser, 1999). Because environmental contamination is a risk factor for SARS and there are clear externalities of maintaining a hygienic environment during the epidemic, it is interesting to explore the role of homeownership in this setting. An editorial in the British Medical Journal (1996) proposes an important role of income distribution in determining health

[15] If, say, there is an additional elevator bank for every 15 floors, elevator-sharing increases with the number of floors up to 15 floors, but the amount of elevator-sharing in a 16-story building is only as much as that in an 8-story building, and it keeps increasing until the number of floors reaches 30.
[16] Travel time is significant at 10% but this result is not robust using other income indicators.
[17] One potential bias is that many public housing estates are rental only, and they are excluded from my sample because I do not observe any open market transactions for them. While half of the Hong Kong population live in public housing estates, only about a quarter of my sample are public (Table 1B).

outcomes, while Waldmann (1992) draws a link between income inequality and infant mortality. Because the disease in concern is an acute condition that might affect people with lower baseline health status, an income inequality-SARS link will be of second-order.

I explore the impact of homeownership and income inequality on the SARS incidence rate, controlling for the income level, share of workers in high-contact occupations and living conditions that are significant in the previous section. Columns 2-4 of Table 5 show the results; column 1 is for comparison. Homeownership correlates with SARS incidence only at 15% significance. Experimenting with different functional forms or restricting the sample to private estates leads to similar results. There is no strong evidence for homeownership being an important determinant. Similarly, any effect of income inequality is not apparent in the data.

7. Discussion

This paper investigates the association between socioeconomic status and the spread of a communicable disease, SARS. Understanding SARS incidence is important for devising epidemic control strategies and public health policies. Given that SARS is unlikely to be the last of the emerging diseases posing a global epidemic threat, it is worth considering what lessons we can learn from the 2003 SARS epidemic.[18]

A significant and negative association between SARS incidence and income is identified, after controlling for the share of population in high-contact occupations. The nature of the identified SES-SARS link is likely to be largely causal. Because SARS is a new and unanticipated disease, it cannot have directly led to sorting among the population into housing estates according to their susceptibility to SARS. The prodigious level of public health efforts to combat SARS makes differences in access to suitable health care an unlikely explanation.

[18] SARS: A Pandemic Prevented. Science, Dec 2003.

Moreover, widespread adoption of precautionary practices implies that differential adoption of health habits is likely to be small.

Living conditions potentially form an important channel of the income-SARS link. Estates with higher usage of public transportation, estate facilities and a higher number of floors (perhaps related to elevator-sharing) experienced a higher SARS incidence rate. Proximity to health-related establishments, household crowding, distance from city centers and the average age of the buildings do not show similar correlations, neither do homeownership rate and income inequality. Interestingly, while the income-SARS link is accounted for using housing consumption indicators, it remains robust with an array of living condition measures. This suggests that permanent income plays a role.

Interestingly, education does not seem to have affected susceptibility to SARS; this links to the evidence for the adoption of preventive measures by perceived susceptibility instead of education (Tang and Wong, 2003). It raises questions about the role of education in the control of other infectious diseases where health behavior adoption is important.

While much is still unknown about SARS, this paper contributes to our understanding of the spread of SARS. It also provides new evidence on the SES-health link in the setting of a low-risk but high-cost event. None of the government measures used to combat SARS during and in the aftermath of the 2003 epidemic was devised with a link between SARS and economic conditions in mind.[19] Given the findings in this paper, it is worth taking the SES-SARS gradient into account when formulating the optimal strategy of surveillance and control of related diseases.

[19] "Checklist of Measures to Combat SARS". Hong Kong Government website.

Table 1A: Summary Statistics -- District Characteristics

District No.	District Name	District Population ('000)	SARS Incidence Rate (per 100,000)	Median Monthly Income from Main Occupation (USD)	Median Monthly Household Income (USD)	% of Tertiary Educated, Aged 20+ Non-students	Labor Force Participation Rate (%)	Male Labor Force Participation (%)	Female Labor Force Participation (%)	% of Households Owning Quarters Occupied	Median Monthly Household Mortgage/ Loan Payment (USD)	Median Monthly Household Rent (USD)
1	Central & Western	261.88	4.69	1677	3271	31.0	66.7	75.0	59.6	60.0	1484	800
2	Wan Chai	167.15	9.45	1677	3355	34.1	65.9	74.0	59.5	56.6	1935	968
3	Eastern	616.20	12.25	1548	3059	21.7	62.7	72.4	54.1	61.5	1290	258
4	Southern	290.24	4.84	1355	2994	18.8	62.1	70.1	54.8	41.4	1342	185
5	Yau Tsim Mong	282.02	14.31	1290	1897	16.1	61.2	71.1	51.4	56.3	1187	387
6	Sham Shui Po	353.55	16.88	1290	1806	13.3	56.8	67.1	46.9	38.4	1226	192
7	Kowloon City	381.35	17.49	1355	2555	20.6	60.2	69.4	52.2	55.4	1445	281
8	Wong Tai Sin	444.63	19.74	1290	2077	9.6	57.0	68.3	46.0	36.8	968	194
9	Kwun Tong	562.43	96.11	1290	2032	12.1	58.0	68.4	47.8	38.1	1110	171
10	Kwai Tsing	477.09	20.60	1290	2155	11.3	60.4	70.5	50.3	33.0	1110	183
11	Tsuen Wan	275.53	10.83	1419	2710	17.4	64.2	74.2	54.9	56.2	1419	219
12	Tuen Mun	488.83	10.77	1290	2194	9.9	62.8	75.4	50.4	53.9	839	139
13	Yuen Long	449.07	12.90	1290	2065	11.6	61.6	74.7	49.1	52.1	994	160
14	North	298.66	21.15	1290	2220	10.7	60.2	73.1	47.9	57.5	903	168
15	Tai Po	310.88	64.36	1290	2387	13.6	61.7	73.7	50.5	61.1	895	168
16	Sha Tin	628.63	42.99	1419	2700	16.5	62.5	73.4	52.4	56.3	1092	191
17	Sai Kung	327.69	19.82	1419	2710	16.1	65.2	75.3	55.7	58.5	1123	207
		Total: 6615.827										
Weighted Mean			26.45	1370.04	2441.18	15.74	61.38	71.96	51.41	50.66	1156.20	246.19
Weighted S.d.			26.01	117.93	449.98	5.96	2.68	2.72	3.62	10.00	228.83	177.97
Weighted correlation with SARS Incidence rate			--	**-0.30**	**-0.30**	**-0.29**	**-0.32**	**-0.31**	**-0.38**	**-0.25**	**-0.27**	**-0.27**

Note: No housing estate in the sample is located in Islands District (#18), which is consequently omitted from the table. Mean and standard deviation are weighted by district population. Source: Hong Kong Census 2000, Hong Kong Department of Health. SARS

Table 1B: Summary Statistics -- Housing Estate Characteristics

Weighted Mean [1] (s.d./ s.e.)

	(1) All 295 Estates	(2) 66 SARS-affected[2] Estates	(3) 229 Unaffected Estates	(4) Difference [3] (2)-(3)
SARS Incidence				
Estimated no. of SARS cases per 100,000 residents	17.20	41.38	--	--
	(31.46)	(37.34)		
No. of Times Appearing on SARS-list	0.88	2.12	--	--
	(1.62)	(1.92)		
No. of Days Spent on SARS-list	4.10	9.87	--	--
	(6.60)	(6.95)		
Pre-SARS Sales Price				
Median Sales Price per Sq. Ft., 2002 (USD)	266.10	245.02	283.10	-38.08
	(220.01)	(134.33)	(266.23)	[26.71]
Average Median Sales Price per Sq. Ft., 1995-98, 2001-02	423.26	377.57	460.18	-82.61*
	(327.12)	(173.15)	(404.13)	[42.72]
Estate Characteristics				
Minimum Travel Time to City Centre (Hours)	0.53	0.56	0.51	0.05*
	(0.25)	(0.23)	(0.27)	[0.03]
Average Flat Size (Square Foot)	715.11	728.15	705.84	15.81
	(255.99)	(213.05)	(283.04)	[30.15]
Building Age	16.74	17.41	16.26	1.29*
	(6.57)	(7.73)	(5.61)	[0.77]
No. of Floors per Block	28.53	28.62	28.47	0.33
	(7.94)	(7.62)	(8.19)	[0.93]
No. of Flats per Floor	8.52	8.65	8.42	0.21
	(2.98)	(2.98)	(2.99)	[0.35]
Availability of Estate Facilities (1-0 Dummy)	0.68	0.86	0.55	0.32***
	(0.47)	(0.35)	(0.50)	[0.05]
Public Housing Dummy	0.24	0.18	0.28	-0.11**
	(0.43)	(0.39)	(0.45)	[0.05]
Close-by Healthcare Facilities [4] *(within 0.51 sq km Area)*				
Medical Establishments Dummy	0.63	0.69	0.59	0.10*
	(0.48)	(0.47)	(0.49)	[0.06]
General Practitioners Dummy	0.15	0.18	0.12	0.06
	(0.36)	(0.39)	(0.33)	[0.04]
Other Health-Related Facilities Dummy	0.10	0.08	0.12	-0.05
	(0.31)	(0.27)	(0.33)	[0.04]

[1] All measures are weighted by total no. of flats in each housing estate. Standard deviations reported in parentheses. Standard errors reported in brackets in the 4th column; *** denotes significance at 1%, ** 5% and * 10%.

[2] An Estate was Sars-affected if it ever appeared on the Department of Health "List of Buildings with Confirmed Cases". The housing estates are large-scale housing complexes, located in 17 of all 18 districts of Hong Kong.

[3] Differences in characteristics by whether SARS affected the estate or not amounts to regressing the characteristics on a 1-0 SARS incidence dummy.

[4] *Medical Establishments* include hospitals, clinics and health care centres. *General Practitioners* are the community doctors in Hong Kong. *Other Health-Related Facilities* include pharmacies, dental hospitals or Chinese medicine practitioners.

Table 2: Socioeconomic Status (SES) and SARS Incidence

	Dependent Variable: SARS Incidence Rate per 100,000										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(10)
Monthly domestic household income for the median	-1.012** (0.429)	--	--	--	--	--	--	--	--	-0.912 (1.246)	-1.696*** (0.530)
Monthly domestic household income for the lower quartile	--	-1.540** (0.713)	--	--	--	--	--	--	--	--	--
Monthly domestic household income for the upper quartile	--	--	-0.649** (0.259)	--	--	--	--	--	--	--	--
Log % of working pop who are clerks, service workers and shop sales workers	--	--	--	91.086*** (30.214)	--	--	--	--	--	69.958 (41.023)	--
Log % of working pop who are (associate) professionals	--	--	--	62.074* (32.158)	--	--	--	--	--	60.952 (32.262)	--
Log % of working pop who are managers/ administrators	--	--	--	37.151 (24.868)	--	--	--	--	--	37.658 (24.933)	--
Log % of working pop who are craft workers and machine operators	--	--	--	-1.819 (21.651)	--	--	--	--	--	-6.555 (22.673)	--
Log % of working pop in high-contact† occupations	--	--	--	--	109.546* (59.874)	--	--	--	--	--	206.155*** (68.845)
Log % of pop with primary-school education or less	--	--	--	--	--	10.123 (14.978)	--	--	--	--	--
Log % of pop with high-school education or less	--	--	--	--	--	--	35.751 (35.800)	--	--	--	--
Log % of pop who are employed	--	--	--	--	--	--	--	-50.04 (37.384)	--	--	--
Log % of pop who are not working, retired or in full-time studies	--	--	--	--	--	--	--	--	-3.833 (8.254)	--	--
No. of observations	294	294	294	294	294	294	294	295	291	294	294

1 Standard errors in parentheses

2 * significant at 10%; ** significant at 5%; *** significant at 1%

† High-contact occupations include Service Workers & Shop Sales Workers, Managers & Administrators and (Associate) Professionals. Please see text for more details.

Table 3: Housing Service Consumption and SARS Incidence

	Dependent Variable: SARS Incidence Rate per 100,000			
	(1)	(2)	(3)	(4)
Monthly domestic household income for the median	-0.689	0.410	-0.699	-1.36**
	(0.609)	(1.395)	(1.067)	(0.589)
Log % of working pop in high-contact† occupations	233.916***	244.171***	191.297***	259.425***
	(69.964)	(89.067)	(72.468)	(83.518)
Median monthly household rent for renting domestic households	-5.631***	--	--	--
	(2.063)			
Average median transaction price (per sq. ft.) in 1995-98, 2001-02	--	-1.782	--	--
		(1.124)		
Median transaction price (per sq. ft.) in 2002	--	--	-1.149	--
			(1.084)	
Median monthly mortgage payment for households with mortgage	--	--	--	-2.169
				(1.769)
No. of observations	292	239	279	294

1 Standard errors in parentheses

2 * significant at 10%; ** significant at 5%; *** significant at 1%

† High-contact occupations include Service Workers & Shop Sales Workers, Managers & Administrators and (Associate) Professionals. Please see text for more details.

Table 4: Income, Living Conditions and SARS Incidence

	Dependent Variable: SARS Incidence Rate per 100,000									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Monthly domestic household income for the median	-1.696***	-1.432***	-1.750***	-1.633***	-1.682***	-2.309***	-1.461***	-1.514***	-1.701***	-1.705***
	(0.530)	(0.543)	(0.550)	(0.522)	(0.539)	(0.761)	(0.527)	(0.550)	(0.534)	(0.541)
Log % of working pop in high-contact† occupations	206.155***	166.033**	113.049*	211.326***	209.611***	224.065***	215.961***	222.270***	206.526***	202.792**
	(68.845)	(70.985)	(68.248)	(68.203)	(70.644)	(71.352)	(68.346)	(71.185)	(68.985)	(78.221)
Log % of students & workers who take public transportation	--	71.771*	--	--	--	--	--	--	--	--
		(39.740)								
=1 if estate facilities (e.g., health club) are available	--	--	87.191***	--	--	--	--	--	--	--
			(18.093)							
Average no. of floors per building	--	--	--	1.536*	--	--	--	--	--	--
				(0.814)						
=1 if medical establishments are closebyΦ	--	--	--	--	17.767	--	--	--	--	--
					(13.724)					
=1 if community doctors are closebyΦ	--	--	--	--	12.019	--	--	--	--	--
					(20.298)					
=1 if other health-related facilities are closebyΦ	--	--	--	--	-15.76	--	--	--	--	--
					(25.862)					
Average space per household member, sq. ft.	--	--	--	--	--	0.148	--	--	--	--
						(0.125)				
Minimum travel time to city centers, hours	--	--	--	--	--	--	45.788	--	--	--
							(26.516)			
Average no. of units per floor	--	--	--	--	--	--	--	2.904	--	--
								(2.391)		
Average age of buildings	--	--	--	--	--	--	--	--	-0.079	--
									(0.915)	
=1 if estate is public	--	--	--	--	--	--	--	--	--	-1.717
										(19.089)
No. of observations	294	294	294	294	294	294	294	294	294	294

1 Standard errors in parentheses
2 * significant at 10%; ** significant at 5%; *** significant at 1%
† High-contact occupations include Service Workers & Shop Sales Workers, Managers & Administrators and (Associate) Professionals. Please see text for more details.
Φ "Closeby" establishments refer to those within approximately 0.5 sq. km. Please see text for more details.

Table 5: Homeownership, Income Inequality and SARS Incidence

	Dependent Variable: SARS Incidence Rate per 100,000			
	(1)	(2)	(3)	(4)
Monthly domestic household income for the median	-1.473**	-1.186**	-1.156	-1.878*
	(0.554)	(0.584)	(1.317)	(1.118)
Log % of working pop in high-contact[†] occupations	84.583	121.207	84.475	82.151
	(70.656)	(75.908)	(70.604)	(71.123)
Log % of students and workers who take public transportation	62.964	43.756	61.582	66.620
	(40.171)	(41.970)	(40.483)	(41.307)
=1 if estate facilities (e.g., health club) are available	86.640***	89.733***	86.354***	86.778***
	(17.970)	(18.271)	(17.968)	(18.032)
Average no. of floors per block	1.317	1.380*	1.287	1.336
	(0.828)	(0.828)	(0.835)	(0.833)
Log % of household with owner-occupiers, with or without a mortgag	--	88.937	--	--
		(60.663)		
Household income interquartile range	--	--	-0.306	--
			(1.162)	
Personal income interquartile range	--	--	--	0.528
				(1.248)
No. of observations	293	294	294	294

1 Standard errors in parentheses

2 * significant at 10%; ** significant at 5%; *** significant at 1%

† High-contact occupations include Service Workers & Shop Sales Workers, Managers & Administrators and (Associate) Professionals. Please see text for more details.

Table 6: Heteroskedasticity

	Dependent Variable: No. of SARS cases per 100,000					
	Maximum Likelihood Regrssions with Restrictions on the Error Term Variance					
Restriction on the Error Term Variance σ_i^2	$\sigma_i = \sigma * T_i^{-0.5}$		$\sigma_i = \sigma * T_i^{\delta}$		$\sigma_i = \sigma + \omega T_i$	
(T_i = total number of flats in estate *i*)	(1)	(2)	(3)	(4)	(5)	(6)
Median monthly household rent for renting domestic households	-6.981***	-5.473***	-7.842***	-6.161***	-7.581***	-5.660***
	(1.747)	(1.765)	(2.220)	(2.104)	(2.205)	(2.120)
Log % of working pop in high-contact† occupations	215.263***	76.535	116.543	31.537	114.047	20.565
	(66.951)	(66.770)	(87.879)	(83.771)	(89.581)	(88.691)
% of students and workers who take public transportation	--	1.514**	--	1.716*	--	1.903*
		(0.768)		(0.959)		(1.005)
Average no. of floors per building	--	0.844	--	1.954	--	1.679
		(0.835)		(1.072)*		(1.135)
=1 if estate facilities (e.g., health club) are available	--	79.697***	--	71.019***	--	72.364***
		(17.799)		(19.197)		(20.492)
δ	--	--	-0.087	-0.199**	--	--
			(0.082)	(0.082)		
ω	--	--	--	--	-0.003	-0.004***
					(0.002)	(0.001)
No. of observations	292	292	292	292	292	292

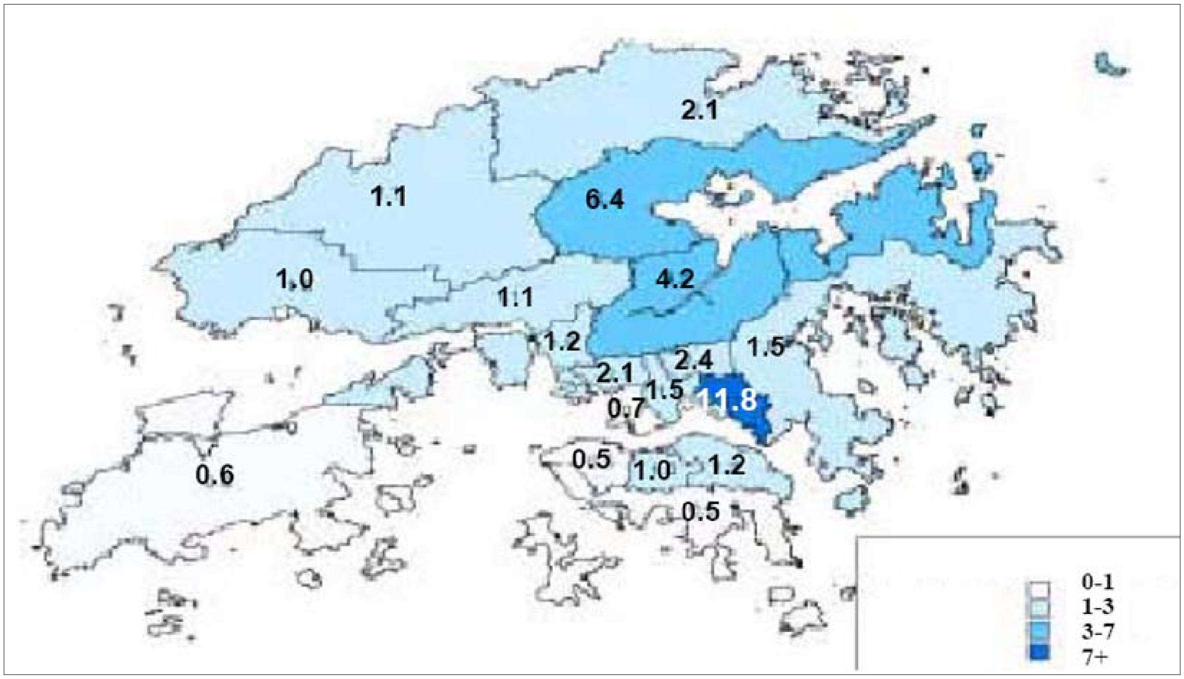
1 Standard errors in parentheses

2 * significant at 10%; ** significant at 5%; *** significant at 1%

† High-contact occupations include Service Workers & Shop Sales Workers, Managers & Administrators and (Associate) Professionals. Please see text for more details

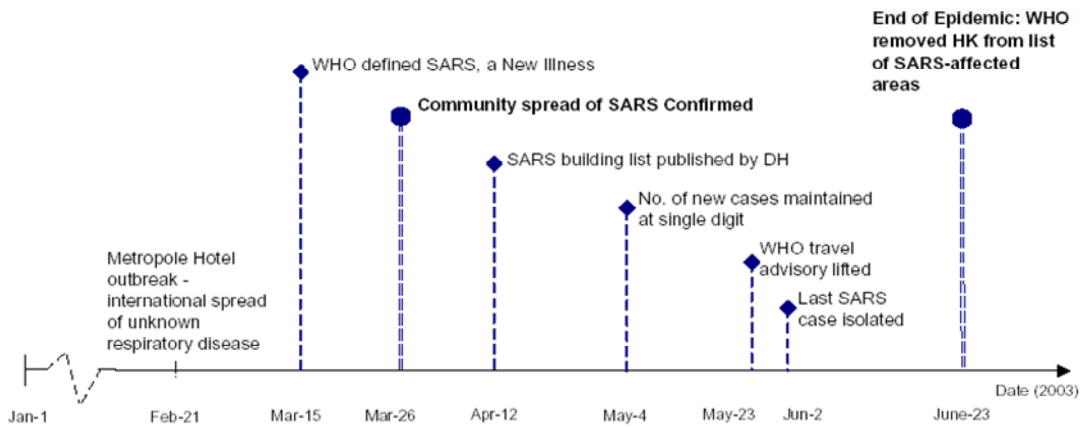
Figure 1: Incidence of SARS Cases by District

(per 10,000 residents)



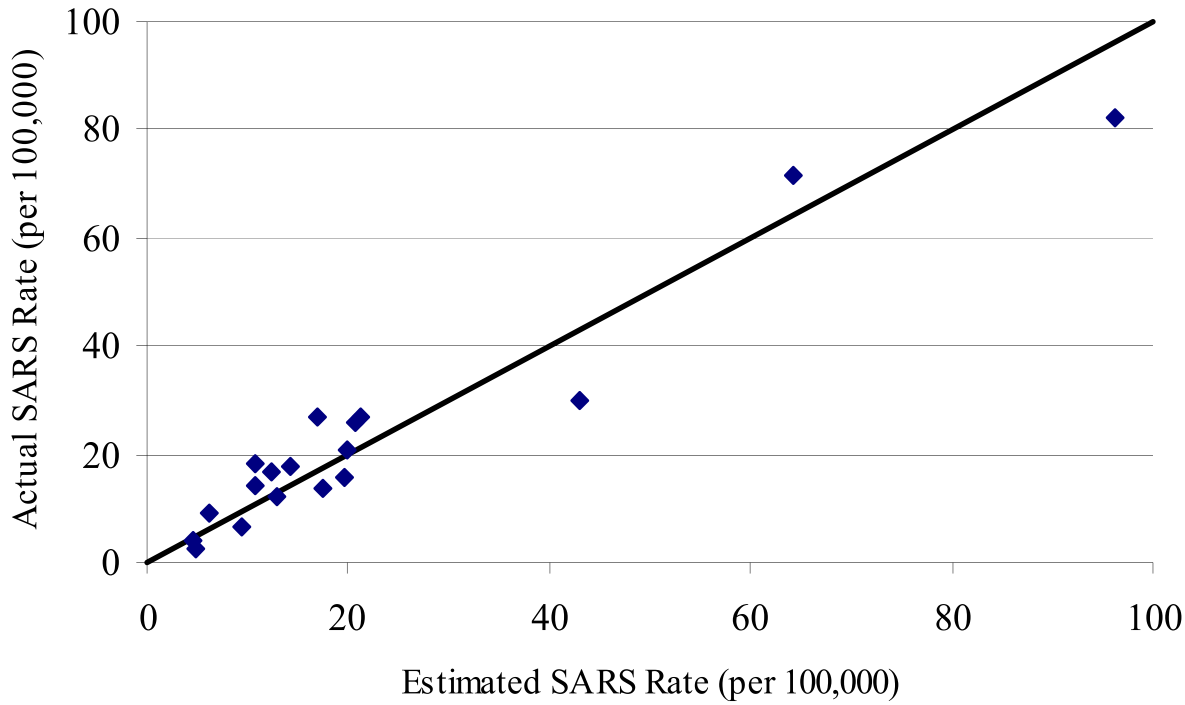
Source: HK Department of Health. SARS Bulletin, 13 June, 2003.

Figure 2: Timeline of the 2003 SARS Epidemic in Hong Kong



Source: Wong (2004).

Figure 3: Estimated vs. Actual District-level SARS Incidence Rates (per 100,000)



**straight line indicates the 45 degree line*

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<u>Appendix</u>: Model Specification and Heteroskedasticity

A. Restrictions of the Tobit Model

A more general approach to study the impact of various factors on the spread of SARS is to distinguish between the impact of those factors on whether a housing estate is affected by SARS at all, and on how severely it is affected, conditional on it being affected. Following Cragg (1971) and Lin and Schmidt (1984), these two relationships can be expressed as follows:

$$Pr(SARSP_i \leq 0) = 1-\mathbf{\Phi}(X_i\beta_1) \quad (5)$$

$$Pr(SARSP_i > 0) = \mathbf{\Phi}(X_i\beta_1)$$

$$Pr(SARSP_i = y_i \mid SARSP_i > 0) \sim N(X_i\beta_2, \sigma^2)\ , \quad (6)$$

where $SARSP_i$ is the SARS incidence rate. $\mathbf{\Phi}$ refers to the standard normal cumulative density function, and $N(\cdot)$ the normal distribution. X_i are the explanatory variables. (5) can be estimated by the Probit model, and (6) by the truncated regression model. The Tobit model imposes the condition that $\beta_1 = \beta_2/\sigma$ and maximizes the following likelihood function:

$$Pr(SARSP_i=0) = 1-\mathbf{\Phi}(X_i\beta/\sigma_i) \quad (7)$$

$$Pr(SARSP_i = y_i \mid SARS_i=1) = 1/\ \sigma_i * \phi(y_i-X_i\beta/\sigma_i) / \mathbf{\Phi}(y_i\beta/\sigma_i)\ ,$$

where ϕ the standard normal probability density function. If this condition is not satisfied, the Tobit model is misspecified. In results not shown here, the truncated regression and the Probit models are estimated separately and a log-likelihood test is performed following Greene (2000). For all regressions presented in this paper the null hypothesis that the Tobit restriction is valid is not rejected at 1% level. Results are available upon request.

B. Heteroskedasticity

One way to correct for heteroskedasticity is to estimate and test some assumption on the error term variance, σ_i^2. Note that the estate-level SARS incidence rate is an average of 1-0 values, defined by whether a resident is infected by SARS or not. This gives rise to an inverse relationship between σ_i^2 and the number of flats (T_i):

$$\sigma_i = \sigma * T_i^{\delta} \quad (8)$$

The weighted Tobit regressions presented in this paper restricts δ to be -0.5 (Table 6, columns 1 and 2). In columns 3 and 4 I relax this assumption.

Lastly, one can model a linear relationship between σ_i and all or some of the explanatory variables (Maddala, 1983; Rutemiller and Bowers, 1968). I experiment with various specifications and the total number of flats seems to have the most robust relationship with σ_i:

$$\sigma_i = \sigma + \omega T_i , \quad (9)$$

A test of heteroskedasticity amounts to a test of $\omega = 0$. Note that columns 3 and 5 suggest the absence of heteroskedasticity because neither δ nor ω is significant. However, columns 4 and 6 indicate the opposite. δ is estimated at -0.20 in column 4, giving support to the specification of column 2, which is equivalent to the weighted Tobit model. All regressions discussed in this paper are replicated without restricting the value of δ in (8) and similar results are obtained.