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# Has SARS infected the property market? Evidence from Hong Kong <sup>☆</sup>

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## Abstract

This paper uses the 2003 Hong Kong Severe Acute Respiratory Syndrome (SARS) epidemic as a natural experiment to investigate how housing markets react to extreme events. A panel data set of large-scale housing complexes (estates) is used to exploit the cross-sectional variation in the spread of SARS to estimate the effect of the disease on real estate prices and sales. SARS risk is measured by: (1) the estate-level SARS infection rate, (2) news reports, and (3) government announcements of infections. The average price declines by 1–3 percent if an estate is directly affected by SARS, and by 1.6 percent for all estates as a result of the outbreak of the disease. A back-of-the-envelope calculation of the expected price fall under the rational asset-pricing model implies that the economic value of life consistent with the SARS-related price movement was less than \$1 million. This low figure contrasts with the predictions of overreaction from psychological and behavioral economics theories. An analysis of transaction volume suggests that the absence of price overreaction is likely to be related to housing market characteristics, including transaction costs, credit constraints and loss aversion.

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## 1. Introduction

Severe Acute Respiratory Syndrome (SARS) is the first new, serious and contagious illness of the 21st century. Three hundred Hong Kong residents died during the 2003 SARS epidemic (March–June), accounting for a third of all SARS deaths worldwide. The risk of contracting SARS in Hong Kong during the epidemic was 0.026 percent. This apparent vulnerability raises the possibility that Hong Kong has since been perceived as a less desirable place in which to work and live.<sup>1</sup> Coincident with the unanticipated epidemic, housing prices in Hong Kong fell by 8 percent. Is this dramatic price decline—representing a total value of \$28 billion, equal to about \$16 million per SARS case—a continuation of the pre-SARS downward trend, or a response to the epidemic?<sup>2,3</sup>

This paper attempts to answer this question. Firstly, the extent to which the drop in housing prices can be attributed to the SARS epidemic is estimated. A unique panel data set of weekly transaction prices of 44 housing complexes (estates) is used to estimate the effect of SARS on the housing market, exploiting the cross-sectional variation in the timing and spread of SARS within Hong Kong. The perceived location-specific risk is measured by analyzing all major sources of public information related to the 44 estates. A best estimate of the estate-level SARS infection rates is also created.<sup>4</sup> Next, we investigate whether the drop in prices can be characterized as an overreaction, as compared with the predictions of the standard asset pricing model [12]. To better understand the price movements, a similar analysis is performed for turnover rates in the housing market.

While the epidemic is unlikely to have any significant impact on the supply of the housing stock, it is likely to reduce demand for housing in Hong Kong. If only a small part of the population believes that Hong Kong is more susceptible to another outbreak and subsequently moves away, it can translate to lower agglomeration benefits for all residents, translating to territory-wide price declines. Cross-sectional differences in price changes come from variations in the spread of SARS, but this misses the Hong Kong-wide effect. To estimate the Hong Kong-wide effect of SARS on the housing market, I use a territory-wide onset-of-epidemic indicator controlling for historical time trends at both the territory and estate levels.

Because of its exogenous nature and severe health consequences, the SARS epidemic provides a unique setting to measure market reactions to extreme events. Unlike other exogenous extreme events that have previously been studied (e.g., flooding), the 2003 epidemic involves a clear change in risk level. A growing body of research points to social amplification of risks when they

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<sup>1</sup> Hong Kong was the most severely hit city in the world in the 2003 SARS epidemic, accounting for 21 percent of all SARS cases and 33 percent of SARS deaths.

<sup>2</sup> The value of private housing stock is evaluated using year-end 2002 prices. Source: Hong Kong Housing Authority <http://www.housingauthority.gov.hk/hdw/ihc/pdf/bhfs.pdf>.

<sup>3</sup> Many related the housing price decline in the second quarter of 2003 to the SARS epidemic. David Carse, the Deputy Chief Executive of the Hong Kong Monetary Authority, attributed the sharp increase in negative equity loans (by HKD 30 billion, or 22 percent) to the acceleration of the housing price decline due to SARS (<http://www.info.gov.hk/hkma/eng/press/2003/20030814e4.htm>). DTZ Debenham Tie Leung, a prominent property consultancy, claimed that SARS had a “devastating impact” on the Hong Kong housing market shortly after the outbreak started.

<sup>4</sup> The main information sources include the daily Department of Health SARS-building list (the only form of government announcement related to SARS cases in specific buildings), and local newspaper reports. There is no record of the SARS infection rate in different parts of Hong Kong below the district level. (Hong Kong consists of 18 districts. See Section 4 for details.)

involve unknown and dreaded events beyond the control of the individual, causing rippling effects much greater than the direct impacts, and reaching far beyond the direct victims.<sup>5</sup> Economists have also long observed that societal responses to health risks tend to be extreme and inconsistent, suggesting an overestimation of the frequency of rare risks [17,18]. This tendency to overreact to new risk may be offset in this case, however, because there is reason to believe that cognitive errors in judgment are less likely when the costs to the decision maker are high [5]. Housing sale prices are likely to have a significant impact on household wealth positions, especially for leveraged households. Thus, the SARS epidemic provides an interesting example to evaluate the significance of information in markets.

This paper provides an indirect measurement of the marginal household's evaluation of the SARS risk, by estimating the compensating differential for greater SARS risk in the housing market [13].<sup>6</sup> Given the low turnover rate in housing markets as compared to other asset markets, measurement errors make it difficult to test precisely when new information has an impact. Consequently, the focus is on the "medium-run" impact of the various indicators over a period of 38 weeks, 13 during the epidemic and 25 after, which is relevant to most households given the long holding period of housing units.<sup>7</sup> It is worth pointing out that the measured compensating differentials reflect not only the economic value of life and the SARS risk, but also the perceived permanence of the risk and the disutility related to non-fatal SARS cases. Because we have no direct measurement of the perceived persistence of the epidemic or the disutility of non-fatal incidents of the disease, instead of a point estimate, a range of estimates of the marginal willingness-to-pay to avoid the risk of the epidemic is presented.

Several noteworthy results emerge from this analysis. A Hong Kong-wide price decrease of 1.6 percent above the preceding trend is identified after the start of the epidemic for all housing estates, as well as an additional decrease of less than 3 percent for the average SARS-affected estate, i.e., those that were publicly known to have had SARS cases or were mentioned in the newspapers in relation to SARS. The implied economic value of life, from \$121,000 to just over \$1 million, falls towards the lower end of the range based on studies of less extreme risks. Although the nature of the SARS risk limits the extent to which this value of life estimate can be generalized, it helps put the SARS-related price decline in perspective. Given the low implied values of life, I conclude there is no evidence for price overreaction.

These results also yield some insight concerning the dissemination of public health information during the SARS epidemic. A significant negative price reaction in response to the estimated infection rate is identified, although no direct measure of the estate-level SARS risk was publicly available. Independently, the per capita number of SARS-related mentions of specific estates in the English-language (but not Chinese-language) newspapers was associated with significant price decreases. However, public exposure through the government SARS-list did not have sim-

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<sup>5</sup> For example, see [1,15].

<sup>6</sup> Because the SARS epidemic was unexpected, pre-sorting of households into different housing locations according to their valuation of the risk is less likely.

<sup>7</sup> Another difficulty arises because asset prices react to the difference between the prior expectation and the realization of announcements, and we have no information for the former. The "news" component in an announcement can be denoted as  $n = (V - E)/\sigma$ , where  $V$  stands for the realized value of an economic variable,  $E$  a surveyed expectation prior to the announcement, and  $\sigma$  the sample standard deviation of  $(V - E)$ . An overly pessimistic view of the future on a previous day will make today's market response to unfavorable announcements seem tame. This paper abstracts from short-run price movements.

ilar effects.<sup>8</sup> Price reactions towards all SARS indicators are small, however, providing little evidence for a magnification of noises in public information [11].

Several explanations for the lack of observed price overreactions are examined through a similar analysis of transaction volumes. Measurement errors in the SARS risk indicators attenuate coefficient estimates in the price regressions, but the significant decreases in turnover rates identified suggest that this does not drive the price results.<sup>9</sup> A “wait-and-see” attitude, driven by either liquidity constraints [16] or loss aversion [4], implies a decline in volume and an attenuation of negative price reactions. Evidence for this phenomenon is found in the significant turnover rate declines associated with appearance on the SARS-list and the Chinese news indicators, to which there is a lack of related price responses.<sup>10</sup>

The following section provides a chronology of the 2003 epidemic. Section 3 then discusses the related literature, Section 4 describes the data, Section 5 reports the empirical findings, and Section 6 offers conclusions.

## 2. The 2003 SARS epidemic in Hong Kong

Figure 1 shows a timeline of the 2003 epidemic. Several events are particularly relevant for this study. The time lag between the occurrence of the first case in February and the government confirmation of the community spread of SARS on March 26 highlights the difficulty in pinning down the start date of the epidemic.<sup>11</sup> March 26, 2003 is adopted as the start date, as this marks the point at which Hong Kong’s residents were left with no doubt that SARS was to affect the general population, not merely the small circle of close medical and family contacts of existing SARS cases.<sup>12</sup> Using alternative dates adjusts estimates slightly upwards.

As residents became infected across the board, including the educated, the young and the previously healthy, unanswered questions about diagnosis, treatment and transmission mechanism added to feelings of uncertainty and trepidation. There was anecdotal evidence for people taking refuge in friends’ or relatives’ homes in areas with fewer known SARS cases. The World Health Organization (WHO) issued a travel advisory to suspend all but essential travels to Hong Kong on April 2.

More than two weeks after the start of the epidemic, the Hong Kong Department of Health began publishing a daily “List of Buildings of Confirmed SARS Cases” (SARS-list) on April 12, making it available to the general public, to the media, and on the Internet. It was relied upon as the main source of statistics. A building appeared on the list only within 10 days (the incubation period) of the onset date of any known SARS case; if the case was diagnosed after 10 days of the onset date, the building would not be listed. No information on the SARS case demographics, number of cases related to each listing, or connection among the cases was made available. As

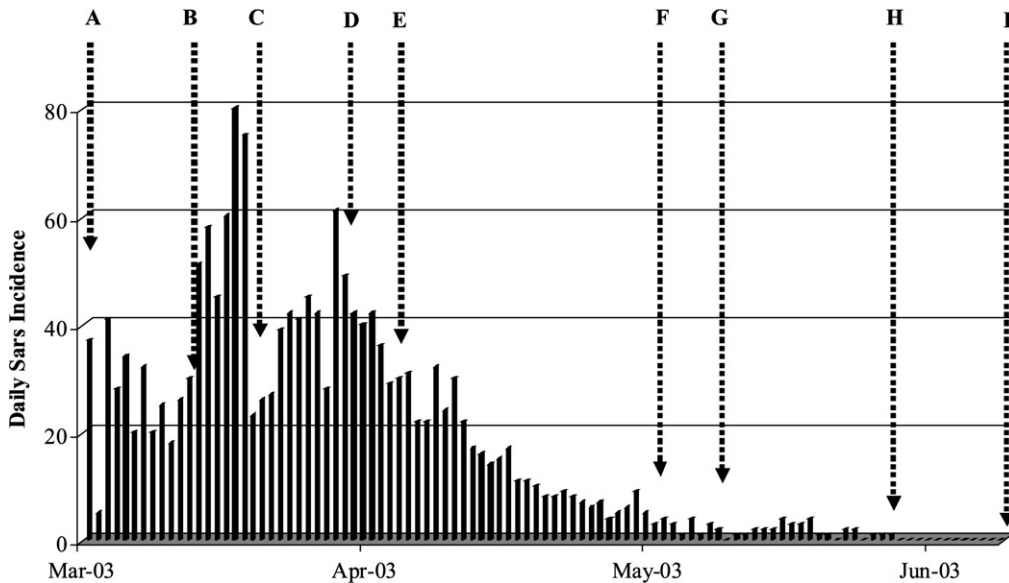
<sup>8</sup> I also calculated a predicted SARS risk indicator related to living conditions, based on scientific links cited in government and WHO reports. It does not have a significant impact.

<sup>9</sup> The average decline in turnover rate is between one to five basis points. The pre-SARS average turnover rate is 6.8 basis points.

<sup>10</sup> A search model predicts a dry up in transaction volume when search costs are high. While this might be part of the story, persistent drops in turnover rates imply this is not a complete explanation.

<sup>11</sup> Adding to the complication, there was high-profile denial by the government about community spread of SARS on March 17, 2003.

<sup>12</sup> As it turned out, less than a quarter of all SARS cases in Hong Kong affected health care workers, and most of the 329 infected residents in the first SARS cluster, Amoy Gardens, were strangers to each other. Source: *The Standard*; *Oriental Daily*; WHO website.



**Main Events:**

- A: WHO defined SARS as a new disease (Mar. 15, 2003).
- B: Community spread of SARS confirmed by Hong Kong Government (Mar. 26, 2003).
- C: WHO travel advisory against all non-essential travels to Hong Kong (Apr. 2, 2003).
- D: Start of the daily Government List of Buildings with Confirmed SARS Cases (Apr. 12, 2003).
- E: Publication of the Amoy report, identifying links between living conditions and the spread of SARS (Apr. 17, 2003).
- F: WHO report on Amoy published (May 16, 2003).
- G: WHO travel advisory lifted (May 23, 2003).
- H: Last SARS patient diagnosed (Jun. 12, 2003).
- I: Hong Kong removed from the WHO list of SARS-affected areas (Jun. 23, 2003).

Fig. 1. Daily incidence and main events in the 2003 SARS epidemic in Hong Kong.

such, the SARS-list contained only coarse information about the relative severity of the outbreak by location.

The mass media filled part of the information gap. After March 26, SARS-related reports dominated newspaper headlines. Suspected SARS cases mentioned in the newspapers might or might not appear on the government SARS list, and there was often information on specific cases in other dimensions, such as demographics. I conducted a detailed study on newspaper reports that related specific housing estates to the epidemic.

The first official scientific SARS analysis was published on April 17, 2003, in a Hong Kong Department of Health report on the outbreak at Amoy Gardens. It ruled out the theory that SARS was airborne, but concluded that sewage flaws, sharing of communal facilities, environmental contamination, and pests played parts in spreading the virus. An independent WHO investigation (May 16) resulted in similar findings. A predicted SARS risk measure is generated based on these findings.

After a large-scale shutdown of normal activities, including a suspension of all school classes for more than three weeks, the last SARS case was isolated on June 2. Hong Kong was removed from the WHO List of Areas Affected by SARS on June 23, 2003, but many medical experts believe that SARS will return.

Table 1  
Summary statistics, mean (s.d.)

	All 44 estates	20 listed estates	24 unlisted estates
Sales price in Jan.–July 2003 (per sq. ft.; \$)	370.08 (176.81)	281.78 (93.42)	391.84 (185.57)
Sales price in 2002 (per sq. ft.; \$)	417.17 (195.41)	329.47 (96.93)	490.26 (226.64)
Weekly turnover rate in Jan.–June 2003 (%)	0.07 (0.08)	0.06 (0.05)	0.07 (0.10)
Weekly turnover rate in 2001–2002 (%)	0.09 (0.09)	0.09 (0.06)	0.09 (0.11)
Number of blocks	23.07 (21.84)	30.60 (23.07)	16.80 (19.01)
Number of floors per block	31.66 (10.20)	29.10 (5.99)	33.79 (12.43)
Number of flats per floor	6.67 (5.52)	7.02 (1.71)	6.38 (3.05)
Estate resident population ('000)	13.74 (12.97)	19.53 (14.09)	8.92 (9.86)
Building age	14.27 (5.37)	16.13 (5.52)	12.72 (4.82)
Number of times listed <sup>a</sup>	1.24 (2.17)	2.70 (2.58)	0.00 (0.00)
Number of times listed <sup>a</sup> excluding Amoy Gardens	1.03 (1.72)	2.32 (1.97)	–
Number of days listed <sup>a</sup>	5.12 (7.66)	11.20 (7.97)	0.00 (0.00)
Number of days listed <sup>a</sup> excluding Amoy Gardens	4.91 (7.63)	11.05 (8.16)	–
Number of SARS cases	10.37 (49.46)	22.35 (72.35)	0.00 (0.00)
Number of SARS cases excluding Amoy Gardens	2.76 (4.52)	6.21 (5.09)	–
SARS infection rate (%)	0.07 (0.31)	0.15 (0.46)	0.00 (0.00)
SARS infection rate (%) excluding Amoy Gardens	0.02 (0.03)	0.04 (0.04)	–
Total number of news mentions in connection to SARS up to 6/24	5.84 (46.46)	27.67 (101.38)	0.46 (4.55)
Total number of news mentions excluding Amoy Gardens	1.36 (2.96)	3.61 (4.68)	–
Predicted SARS risk (%)	0.02 (0.03)	0.05 (0.03)	0.01 (0.01)

<sup>a</sup> Listed refers to housing estates that were ever listed on the Department of Health “List of Buildings with Confirmed Cases.” Amoy Gardens was the first and most serious cluster site.

Amoy Gardens deserves special attention, because it was the site of the first and most severe cluster of SARS in Hong Kong, with a total of 329 cases—a large number of which occurred before the government confirmed the community spread of SARS or precautionary measures were taken. Not only was Amoy Gardens much more severely affected by SARS, the number of news reports on Amoy Gardens with a direct relation to the epidemic is 10 times that of the average estate in the sample appearing on the government list (Table 1). Amoy is an outlier by any measure. To ensure that the estimation results are not driven by Amoy Gardens, it is excluded

from the sample for all regressions. As a robustness check, results both with and without Amoy Gardens are discussed.

### 3. Theoretical background

#### 3.1. Rationality and forward-looking behavior

Considering the expected magnitude of housing price changes due to SARS under the standard asset-pricing model [12] helps put the realized price movements in context. Any expected change in the net present value of future housing services, either due to health risk or to reduction in agglomeration benefits, causes an immediate change in prices.<sup>13</sup>

For a “back-of-the-envelope” calculation, assume that the service value of the housing unit, tax rate, interest rate, and inflation rate are all time-invariant. The real value of housing services  $Q$  can be approximated as a function of  $S$ , the real value of annual housing services net of depreciation, taxes, and maintenance costs, and the effective real interest rate  $r$

$$Q(t) \sim S/r. \quad (1)$$

To consider an extreme but transitory shock, suppose that six months of housing services ( $0.5S$ ) are destroyed completely by the epidemic. The percentage decrease in  $Q$  will be

$$\Delta Q/Q = 0.5S/(S/r) = 0.5r. \quad (2)$$

During the fiscal year 2003–2004, the after-tax real interest rate in Hong Kong was between 2.41 and 2.58 percent, which implies a decline of 1.21–1.29 percent under the standard asset pricing framework if six months of housing services were destroyed by the epidemic.<sup>14</sup> This is a relatively small price movement compared to the observed nominal decrease of 8 percent. Any permanent decrease in annual housing service flows  $S$ , by contrast, causes a decrease one-for-one in  $Q$ . Clearly, the SARS threat must be perceived as permanent or long lasting to explain such a large decrease in prices under the standard rational asset-pricing model.

The calculation above implicitly assumes a uniform impact of SARS on the value of housing services for all housing units in Hong Kong. In reality, besides decreasing the general quality of life in Hong Kong, thus creating a territory-wide impact, SARS also created a new health risk specific to each building. To consider relative price movements, one can think of higher-quality housing units as those that produce a larger quantity of housing services during any given time period. Health risk is substitutable for other building characteristics, such as number of rooms. Denoting the housing services provided by housing structure at time  $t$  by  $S(t)$ , a positive SARS risk in year  $t$  reduces  $S$  so  $S(t) < S(t-1)$ . The newly recognized health risk decreases the total expected units of housing services available in the market, reducing the supply of housing services and leading to a higher unit price for housing services. However, it is unambiguous that

<sup>13</sup> The size of the decrease can be derived from the formula  $Q(t) = \int_t^\infty S(z)e^{-r(z-t)} dz$ , where  $Q(t)$  is the real value of a housing unit at time  $t$ , and  $S(z)$  denotes the real value of housing services provided in period  $z$  minus depreciation, taxes, and maintenance costs. The housing services are discounted by the effective real interest rate  $r = (1-\theta)(L * i_b) + (1-L)i_l - \pi$ , where  $\theta$  is the salary tax rate,  $L$  the mortgage-to-value ratio,  $i_b$  the nominal borrowing rate,  $i_l$  the nominal lending rate, and  $\pi$  the inflation rate. Mortgage interest payments are deductible from salary (personal income) taxes in Hong Kong.

<sup>14</sup> The average 1-month HIBOR (Hong Kong Interbank Offered Rate) during the first quarter of 2003 was 1.38 percent. The deflation rate was approximately 1.20 percent. The present calculations are based on a mortgage ratio ranging from 0 to 80 percent.



post-epidemic prices of housing structures with higher SARS risks would be lower than their pre-epidemic prices, relative to the difference between the pre- and post-epidemic prices of housing structures with lower or no SARS risk, other things being constant. The estate-specific SARS indicators attempt to capture this.

### 3.2. *Overreaction*

Although appealing, the assumption of rationality upon which the asset-pricing model is based is probably not appropriate, since strong emotions and uncertainty associated with the SARS epidemic might cause decisions to deviate from rationality.<sup>15</sup> The SARS risk was likely perceived at a higher level than the actual infection and fatality risks.

Research in psychology highlights three factors that increase the level of perceived risk: how dreaded, uncontrollable and fatal the risk is; how unobservable, unfamiliar and unknown it is; and the level of personal and social exposure to the risk [15]. Prospect theory [7] predicts that rare events tend to be overweighed, in the absence of the risk-learning process through repeated experience. “High-signal” events—relatively small incidents in poorly understood systems—are also likely to cause a social amplification of risks [1,8,14,15].

There is a vast economic literature documenting risk perception biases, where rare risks tend to be overestimated. Viscusi [18] provides a survey and illustrates that upwards-biased risk perception causes a steeper increase in compensation, as long as the marginal utility of income in the healthy state is at least as high as that in the unhealthy state. Moreover, this difference in market responses tends to be the most significant when a risk is discovered, and the probability jumps from zero to positive.

### 3.3. *Related theories on transaction volume*

The standard asset-pricing model has no clear implication for the effect of an exogenous shock on trading volume. The market-clearing condition abstracts from the existence of frictions, a likely phenomenon in real estate markets where both buyers and sellers invest substantial resources in the search process [9].

During the epidemic, search costs were likely to have increased significantly due to the risk of contracting SARS. Because this risk was expected to decrease after the epidemic ended, it would be rational to delay house searching activities. A standard search model, e.g. [20], predicts that transaction volume decreases with an increase in search costs, and returns to normal when search costs do so.

Two alternative theories predict more persistent movements in transaction volume. Stein [16] shows that the down payment requirement leads to a dependence of housing demand on buyers’ liquidity. In imperfect capital markets, homeowners who would have been able to trade down are constrained to stay when prices fall, if repayment of the mortgage prevents them from making a down payment for a new home. They either postpone sale, or to set a higher asking price and wait to “fish” for a higher-than-average price offer. This implies an attenuated price decline

<sup>15</sup> For example, when a hoax message posted by a 14-year-old on the Internet resulted in a wave of panic-buying of food stock, the government quieted fears by sending SMS messages to 6 million mobile phones. The modern psychology literature illustrates the importance of affective reactions in decision-making, especially under uncertainty. Holtgrave and Weber [6], for example, argue that affective reactions are crucial even in more “objective” contexts such as financial investment decisions.

in the event of an adverse shock, and a decrease in turnover rate, because “fishing” does not always pay off. The impact on volume will increase with the severity of shock and the share of liquidity-constrained homeowners. This theory explains decreases in volume in the presence of an exogenous negative shock to housing prices under the assumption of rational behavior.

Alternatively, Genesove and Mayer [4] turn to prospect theory for an explanation. Loss aversion implies that reactions to current housing prices might differ depending on the level of prospective losses, i.e., the difference between the current price and the reference price, such as the initial purchase price, or the highest price their homes have ever attained [7,8]. A loss-averse seller will try to attenuate the prospective loss by setting a higher asking price, thus taking a longer time to sell. Similar to the down payment requirement, loss aversion will therefore lead to an attenuated price reaction to an adverse shock, compared with the prediction of the standard asset-pricing model, and a decrease in observed trading volume.

## 4. Data

### 4.1. Measuring housing prices in Hong Kong

The current panel data set represents hedonic-adjusted prices for 44 housing estates that form a widely-used residential housing market index, the Centa-City Leading Index (CCL). The 44 estates are located in 14 of Hong Kong’s 18 districts. Housing an average population of 13,000, each estate forms a mini-city by itself; there exists little variability within estates and wide variability in age, layout and other characteristics across estates. Collectively, these estates house 18 percent of the Hong Kong private housing population (or about half of the total population). Twenty of the 44 estates were listed on the Department of Health SARS-list at some point during the epidemic.<sup>16</sup> As discussed in Section 2, one of the 44 estates, Amoy Gardens, is excluded from my analysis because most of its cases occurred before the community spread of SARS was known.

The prices are weekly averages after hedonic adjustments of quality variations across housing units within each estate, such as floor level and view. They are based on preliminary contract prices of secondary residential property transactions handled by a leading estate agent with a 20 percent market share (Centaline Property Agency Ltd.).<sup>17</sup> The data span 64 weeks, including 25 before the start of the epidemic and 25 after its end.

The structure of the data offers an analytical advantage. The size of the estates and the similarity of housing units within an estate allow reasonably accurate measurements of estate-level weekly price movements, with an average of three transactions in an estate per week. The panel structure of the data allows the circumvention of two problems often encountered in housing studies. Heterogeneity in housing units in cross-sectional samples gives rise to comparability problems, since structural and location characteristics are often difficult to measure. Repeat sales samples are generated from units that are sold multiple times and might not be representative.<sup>18</sup>

<sup>16</sup> The Appendix Section, available on my website <http://real.wharton.upenn.edu/~wongg/>, shows more details.

<sup>17</sup> The hedonic-adjusted price data series has a high correlation (0.96) with the unadjusted data. I repeat all estimations with the unadjusted transaction price data, obtaining qualitatively identical results. Provisional agreements include the payment of an initial deposit, forfeitable in case of default (3–5 percent of the price).

<sup>18</sup> For example, Viscusi [2] shows that repeat sales data give rise to spurious serial correlation. For a survey of empirical issues in house price estimations, see [3].



Fig. 2. The Centa-City leading index vs. the Centa-City index.

The substantial similarity of units within each housing estate makes this sample an attractive alternative.

To investigate the potential bias of the CCL, based on contracts handled by Centaline only, compare it with the Centa-City Index (CCI).<sup>19</sup> While both indices are derived from hedonic-adjusted price data for the same 44 constituent estates, the CCI is computed using prices from all transactions registered with the Land Registry. In addition, the CCI is based on final transaction prices instead of preliminary contract prices. However, the estate-level prices which form the CCI are not available. Figure 2 shows the movements of the two indices over the past nine years. Obviously, there has been a close correspondence between the two. The correlation coefficient between the monthly average of the weekly CCL and the monthly CCI is 0.998, using data from 1994 to the first quarter of 2004.

#### 4.2. Transaction volume data

The Memorial Day Book of the Hong Kong Land Registry, from January 2001 to June 2003,<sup>20</sup> contains the registration date, property address, consideration (price) and date of execution for all property transactions. A total of 245,240 sales and purchase instruments were registered over this period.

The weekly transaction volume of a housing estate is defined as the number of sales and purchase contracts executed during each particular week. To eliminate contracts involving non-residential properties, data are assembled on a weekly basis for the 44 estates covered by the Centa-City price series. To avoid a potential downward bias of volume caused by the time lag

<sup>19</sup> CCI is another widely-used residential housing market index. Both indices are part of a joint project between Centaline and the City University of Hong Kong (the Centa-City team) to monitor the Hong Kong secondary residential housing market.

<sup>20</sup> This data purchase was generously supported by a grant from the Andrew M. Mellon Foundation through the Research Program in Development Studies, Princeton University.

between execution and registration of a contract, the last two weeks of observations in June 2003 are removed from the sample, so that the first 24 weeks of 2003 are in focus.<sup>21</sup>

#### 4.3. Housing estates characteristics

Hand-collected data considers characteristics of the 44 housing estates that might be related to the spread of SARS, including: age, number of floors, number of flats per floor, and number of blocks.<sup>22</sup> To generate an estimate of each estate's population, the total number of flats (blocks times floors times flats per floor) is multiplied by the number of households in each housing unit, and the number of persons in each household. The last two measures are district-level averages from the Hong Kong Census 2000 (Table 1).<sup>23</sup>

The travel time to city center from an estate is measured by 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 the transportation companies and real estate agents.<sup>24</sup>

#### 4.4. SARS indicators

Five indicators of the risk associated with SARS are used. Each is described below.

##### 4.4.1. Territory-wide onset of SARS epidemic indicator

The onset of the SARS epidemic indicator is defined as March 26, 2003, when the Chief Executive of Hong Kong declared that the outbreak had reached epidemic levels. Experimenting with alternative definitions does not materially change the results. This variable is simply a dummy that equals 1 for weeks after March 26, 2003, and 0 before.

##### 4.4.2. SARS infection rate

Were there a perfect measure of perceived health risk, no other measures of SARS should have any additional impact on prices. In reality, perceived risks are unobserved. There is also no publicly known, scientific estimate of estate-specific health risk from SARS. In fact, the number of cases in each building or estate was not recorded by the Department of Health, outside of the four sites with the largest clustering of cases.

An estimate of the estate-level SARS infection rate is calculated as follows. For the 24 housing estates with no SARS-listing, the infection rate is assumed to be 0. For the 19 remaining estates, the number of cases is estimated by multiplying the number of times each appeared on the SARS-list by the average number of cases per listing outside the four largest clusters.<sup>25</sup> Be-

<sup>21</sup> The mean lag between execution dates and registration dates is 20 days.

<sup>22</sup> These data were compiled by Internet research, telephone communications with real estate agents and property developers, and visits to some estates. Age, the number of floors, and flats per floor are averages across the housing estate; number of blocks is often counted from site plans of the estates.

<sup>23</sup> There is little variation across districts: mean [s.d.] of household per quarter = 1.02 [0.03]; mean [s.d.] of persons per household = 3.16 [0.19].

<sup>24</sup> Twenty-two of the 44 housing estates are situated near an MTR (underground) station, and seven others are close to a KCR (train) station. The rest of the estates are served by bus, minibus or ferry, and for those in the Mid-levels, by taxi.

<sup>25</sup> The average number of cases per listing outside the four largest clusters = (total number of cases in Hong Kong – Total number of cases in the four largest clusters) / (Total number of listed addresses – Total number of times the four largest clusters were listed).

cause scientists suspect that the transmission mechanism in some large clusters (super-spreading events) might be caused by certain persons who were extraordinarily efficient at transmitting the SARS virus, the average listing in those sites are expected to represent a higher number of SARS cases.<sup>26</sup> By excluding the outliers in the number of SARS cases, which turn out to be the four largest clusters in Hong Kong, I hope to minimize the upward bias and estimation error due to potential super-spreading events. The ratio of the estimated number of cases to the estate population gives the SARS infection rate in these 19 estates. Analogous estimation at the district level creates SARS infection rate estimates highly correlated ( $\rho = 0.96$ ) with the actual district-level rates provided by the Department of Health. The information used in estimating the SARS infection rate became available only after the epidemic had ended. Therefore, SARS risk variable is defined as 0 before the end of the epidemic, and as equal to the estate-specific infection rate afterwards.

#### 4.4.3. SARS-list indicators

Because the SARS infection rate is not directly or accurately observed, it is interesting to contrast its price impact with that of SARS-related public information. The primary official source of information on SARS during the epidemic was the Hong Kong Department of Health List of Buildings with Confirmed SARS Cases, published daily. SARS-related public exposure of each estate is measured by the cumulative number of days an estate appeared on the SARS-list. This captures how frequently government announcements related each estate to the epidemic, experimenting with both the raw count and the per capita measure.

#### 4.4.4. SARS-related news count

The media was an alternative source of information about SARS during the epidemic. To create a news count, newspaper articles mentioning each of the 44 estates in connection to SARS are tabulated from four prominent newspapers, two in English and two in Chinese (the two official languages in Hong Kong), with a total daily circulation of approximately 320,000 copies.<sup>27</sup> The news count is then created by dividing the number of articles by estate population. The information content of the news articles does not perfectly correspond to that of the SARS-list statistics.<sup>28</sup> The period in focus spans March 26–June 24, 2003, outside of which individual housing estates were rarely mentioned in connection with SARS.

#### 4.4.5. Predicted SARS infection risk

While the four SARS indicators above are based on information that was available to the public on the actual occurrence of SARS cases, it is also useful to predict the SARS infection rate (SARSP) for each building based on building characteristics. This variable is of interest primarily because if an epidemic were to strike again, SARSP reflects the systematic component of the SARS risk and thus a reasonable indicator of the likelihood that residents of a building would be at risk of contracting SARS. Building conditions are particularly relevant because starting with the Amoy report, scientific reports available to the public drew links between living conditions and the spread of SARS during the 2003 outbreak. This might have caused the housing market to

<sup>26</sup> The WHO <http://www.who.int/csr/sars/archive/research/en/>.

<sup>27</sup> According to the United Nations, the per capita circulation of daily newspapers in Hong Kong in 1996 was 786 per thousand people, compared to 324 in Singapore, 329 in the United Kingdom and 212 in the United States.

<sup>28</sup> Rumours or unconfirmed suspicion of SARS cases in specific estates were often reported in the papers. Some of them proved to be false, others to be local knowledge slightly ahead of the Health Department.

Table 2  
Pre-SARS estate characteristics and SARS infection rate

	(1)	(2)	(3)	(4)	(5)
Pre-SARS median sales price 2002 in \$/10,000	−1.36*** (0.49)	−1.17** (0.51)	−1.54*** (0.54)	−1.72*** (0.61)	−1.20** (0.61)
Travel time to city center (hours)	–	26.18 (27.67)	–	–	67.59** (30.74)
Availability of estate facilities (1 = Yes)	–	–	89.99*** (18.24)	–	43.91** (19.00)
Estate population ('000)	–	–	–	10.30*** (2.18)	8.91*** (2.26)
Estate population squared	–	–	–	−0.15*** (0.04)	−0.13*** (0.04)
<i>P-value of F-tests</i>					
Population quadratic	–	–	–	0.00	0.00
Model log likelihood	−481.3	−480.9	−463.2	−454.2	−448.29
No. of observations	280	280	280	280	280

Notes. Dependent Variable: No. of Cases/100,000 Estate Residents Tobit Regressions [weighted by no. of flats in each housing estate].

All regressions include a constant term. Standard errors reported in parentheses. Weighted mean [standard deviation] of the dependent variable is 17.20 [31.46].

Using Log housing prices as the housing value indicator produces very similar results. Source: Wong [21].

\*\* Statistical significance at 5% and 10%.

\*\*\* Idem, 1%.

respond to SARS-related housing characteristics instead of actual SARS occurrences, which may have had a large random component. If a correlation between, say, building age and the SARS infection rate during the outbreak was perceived, there might be a negative reaction towards all old buildings indiscriminately. Given that housing markets should be forward looking, the way in which a building's characteristics related to the future risk of SARS should potentially affect housing values. To predict the SARS risk associated with various building characteristics, I estimate the following Tobit model for the SARS infection rate

$$\text{SARSP}_i = \alpha + X_i\beta + \gamma_d + \varepsilon_i, \quad (3)$$

where  $\text{SARSP}_i$  refers to the actual SARS infection rate of housing estate  $i$ ,  $\alpha$  is a constant term,  $X_i$  a vector of time-invariant pre-SARS housing estate characteristics,  $\gamma_d$  a district fixed effect, and  $\varepsilon_i$  is a normally distributed error term. The explanatory variable  $X_i$  includes the baseline price level in 2002, travel time to the center of the city, and building attributes, including the availability of communal facilities and a population quadratic. Wong [21] offers a more detailed discussion of how the spread of SARS relates to living conditions and socioeconomic status.<sup>29</sup> The model is estimated for 280 housing estates for which data are available and Table 2 contains the regression results. The predicted SARS risk is generated from column 5 for all estates as an index of empirically important observables in determining the spread of SARS. The predicted SARS risk indicator is defined as zero before the publication of the Amoy report.

<sup>29</sup> Amoy Gardens is excluded. Similar conclusions were drawn from analogous regressions on the total number of days each housing estate appeared on the SARS-list. The age of building, proximity to healthcare facilities, formation of a residents' association, style of building management, and whether the housing estate is public or private do not have a significant correlation with the spread of SARS.

## 5. Estimation results

### 5.1. Impact of SARS epidemic on housing prices

Focusing on the 64-week period beginning 25 weeks before the epidemic and extending to 25 weeks after its end, and using weekly prices of 44 housing estates, feasible general least squares (FGLS) is used to estimate regressions of the form

$$\ln(P_{it}) = \alpha + \beta \text{SARS}_t + \theta_i + \gamma_d t + t + t^2 + t^3 + \varepsilon_{it}, \quad (4a)$$

$$\ln(P_{it}) = \alpha + \beta \text{SARS}_{it} + \theta_i + \gamma_d t + \Phi_t + \varepsilon_{it}. \quad (4b)$$

Equations (4a) and (4b) are identical except for the SARS indicator and the time trend variables.  $P_{it}$  is the weekly average of transaction prices in estate  $i$  (after within-estate quality adjustment) during week  $t$ ,  $\alpha$  is a constant term,  $\theta_i$  is an estate-fixed effect,  $\gamma_d t$  is a set of district-specific linear time trends (which is accomplished by interacting each estate dummy  $\gamma_d$  with the linear time trend  $t$ ), and  $\varepsilon_{it}$  is an error term assumed to follow an estate-specific AR(1) process to allow for serial correlation in the price series.

Equation (4a) estimates the market-wide price impact of the onset of the epidemic, using  $\text{SARS}_t$ , the Hong Kong-wide time-varying Onset of Epidemic Indicator, which is common to all estates (see Section 4.4.1).  $\text{SARS}_t$  is equal to one for all estates after the community spread of SARS was known. This model estimates a break in the Hong Kong-wide price trend after the start of the SARS epidemic, so it cannot be distinguished from a weekly time fixed effect. Instead, I control for a cubic time effect ( $t + t^2 + t^3$ ) in addition to the district-specific linear time trends ( $\gamma_d t$ ). In Eq. (4b),  $\text{SARS}_{it}$  refers to one of the time- and estate-varying SARS indicators outlined in Section 4.4.2 to 4.4.5. They reflect SARS-related information on specific estates based on the government SARS list and newspapers reports.  $\Phi_t$  is a weekly fixed effect.

In both equations,  $\beta$  measures the extent to which housing prices responded to SARS-related information, after controlling for time trends and estate-fixed effects. Because price observations are weekly averages for estates that vary in size and transaction frequency, all regressions are weighed by the total number of flats in each estate to adjust for heteroskedasticity.<sup>30</sup>

Panel A of Table 3 shows the primary results. Column (1) demonstrates that, on average, housing prices fell by 1.6 percent after the community spread of SARS was known, after controlling for estate-fixed effects and a cubic time trend. This estimate is insensitive to alternative definitions of the start of the epidemic, such as when the WHO defined SARS as a new disease on March 15, 2003. Column (1) was repeated using data from 12 months before the epidemic, resulting in no similar decline in prices. This suggests that the frequently cited 8 percent drop in the housing price index from March to June 2003 was largely due to historical trends. Adding Amoy to the sample produces almost identical estimates.

Estate-specific SARS indicators measure the price movements directly attributable to the epidemic. Firstly, the impact of the best estimate of the estate-specific SARS infection rate (per 1000) is investigated. Column (2) reports a significant and negative impact of every SARS case per 1000 people at 7 percent, implying that conditional on a non-zero infection rate, an aver-

<sup>30</sup> In all regressions presented in this section, omitting the district-specific linear time trends produces qualitatively and quantitatively similar results. The three groups of control variables—estate fixed effects, the time effect (weekly or polynomial), and the district-specific linear time trends—are all significant at the 1 percent level in all specifications presented in this paper.

Table 3  
Price impact of various SARS information channels

SARS Indicator	Onset-of-epidemic dummy	SARS infection rate (per 1000)	Per capita, cumulative no. of weeks listed	Per capita, cumulative no. of all news articles	Per capita, cumulative no. of English news articles	Per capita, cumulative no. of Chinese news articles	Predicted SARS risk
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<i>A. Main effect</i>	−0.016*** (0.004)	−0.071*** (0.014)	−0.273 (0.490)	−0.052*** (0.020)	−0.054** (0.024)	−0.061 (0.041)	−0.016 (0.026)
Impact on median affected estate (%)	1.60	2.78	–	1.30	1.11	–	–
Impact on the 25th percentile (%)	1.60	0.00	–	0.00	0.00	–	–
Impact on the 75th percentile (%)	1.60	1.78	–	1.15	0.63	–	–
<i>B. Main effect</i>	−0.014*** (0.004)	−0.080*** (0.014)	−0.135* (0.078)	−0.050** (0.020)	−0.053** (0.024)	−0.070* (0.041)	−0.022 (0.027)
Log 2001 price interaction term	0.007 (0.005)	−0.088*** (0.021)	−1.066*** (0.316)	0.013 (0.061)	0.010 (0.077)	0.109 (0.113)	−0.010 (0.008)
No. of estates	43	43	43	43	43	43	43
No. of observations	2752	2752	2752	2752	2752	2752	2752

Notes. Dependent variable: Log(Hedonic-adjusted Weekly Prices per sq. ft.) GLS regressions with Estate-specific AR(1) Error

Standard errors reported in parentheses. All regressions include a constant term, estate fixed effects and district-specific linear time trends. They also include weekly fixed effects, except for column (1) where I control for a cubic time effect. All controls are significant at 1%.

Mean [standard deviation] of the dependent variable is 5.80 [0.43].

Mean [standard deviation] of the log pre-SARS baseline price is 0.00 [0.43] for the 43 estates included in column (2).

An estate was listed on any given day if it appeared on the Department of Health “List of Buildings with Confirmed Cases.”

\* Statistical significance at 10%.

\*\* Idem, 5%.

\*\*\* Idem, 1%.



Table 4  
Risk valuation and the implied economic values of life

Sample	SARS risk (per 100K)	Mean housing value in 2002 (‘000 \$)	Median housing value in 2002 (‘000 \$)	Implied economic value of life			
				Mean housing value		Median housing value	
				Lower bound	Upper bound	Lower bound	Upper bound
43 estates in the sample	17.55	273.07	212.83	110.27	735.14	85.94	572.95
Territory-wide	25.80	448.93	207.74	123.32	822.11	57.06	380.43
Territory-wide, excl Amoy Gardens	21.02	450.04	208.65	151.74	1011.59	70.35	468.99

*Notes.* All calculations make use of my estimate of a 7.08 percent housing price decline for each SARS case in 1000 people. The upper bound is derived under the assumption that the SARS-related price fall is solely due to the fatality risk of 15%, but not the morbidity risk. The lower bound is derived assuming that a SARS death caused as large a price decline as a non-fatal SARS case.

Median value of owner-occupied housing units in the US in year 2000 is \$119,600. The 1999 median household income in the US is \$42,000, compared to around \$30,000 in Hong Kong in 2001.

age estate suffers a price decline of 2.78 percent.<sup>31,32</sup> A significant price decrease of smaller magnitude is identified when Amoy is included.

Interestingly, there is no significant price decline for public exposure as measured by the per capita number of days an estate remained on the SARS-list (column (3)). Results (not presented) are similar using a measure unadjusted for estate population. The housing market seems to have correctly taken into account the fact that a longer stay on the list meant less than a higher number of separate listings, which is proportional to the infection rate estimate.

To put this estimate in context, the implied economic value of life is calculated and compared with findings in the literature on non-extreme events.<sup>33</sup> Without knowledge of how much of the price decrease is attributable to the non-fatal SARS risk, a range for the implied value of life is calculated in Table 4. This is derived by dividing the mean price decline by the unconditional mortality risk (SARS infection rate times case mortality risk). Assuming that the price decline is solely due to the fatal risks involved with SARS, at the WHO world average of 15 percent, an upper bound of the value of life is obtained. The lower bound is derived under the assumption that SARS deaths led to as much price decrease as a non-fatal SARS case. For good measure this calculation is repeated for three different groups of the population using the group-specific SARS infection rates:

- (1) the 43 estates in the sample,
- (2) the Hong Kong population excluding the Amoy Gardens, and
- (3) the entire Hong Kong population.

<sup>31</sup> I have also experimented with a SARS risk indicator that is zero before the start of the epidemic and constant thereafter, which can be viewed as a rescaled version of the start of epidemic indicator. In results not shown, this alternative indicator is not statistically significant.

<sup>32</sup> Conditional on having at least one case, the infection rate in the sample is 39.67 per 100,000. The territory-wide infection rate in the 2003 SARS epidemic is 1755/6.8 million = 25.81 per 100,000.

<sup>33</sup> Please note that the value of life calculation is more for comparison purposes than for understanding how much markets value human lives.

Using average housing prices for these three different samples, the implied economic value of life falls within the range of \$121,000 to just over \$1 million. Compared with labor market study estimates of economic value of life from \$600,000 to over \$10 million (see [19, Table 2], for a summary of the literature), our estimate suggests that the housing prices did not overreact to the SARS risk. While this is a rough calculation based on an average concept, it provides useful insights into the question of overreaction.<sup>34</sup>

These estimates are also much smaller than what [10] finds in two surveys conducted during the epidemic in Taiwan (\$3 million–\$12 million) via contingent valuation methods. The authors note that the time of data collection might have led to large estimates. Our results suggest that the analytical approach might also play a role, because similar evidence in the Hong Kong housing market is not found around the same period.

Besides the government SARS list, the mass media was another important information source during the epidemic. Returning to Table 3, column (4) shows a 5 percent decrease per news mention per 1000 estate residents. Since the estates had 0.25 news mentions (per 1000 residents) on average, conditional on being ever mentioned, the estimated 5 percent decrease implies an average impact of 1.25 percent for estates ever mentioned.<sup>35</sup> Further separating the news mentions by the language of the papers, we find that the news mention impact in column (4) is mainly driven by the English-language newspaper reports (columns (5) and (6)).

It is worth pointing out that the SARS infection rate indicator in column (2) and the English news mention indicator in column (5) represent very different information, in terms of source, content and timing. The infection rate could only be known after the end of the epidemic, while estates ceased to be mentioned in direct relation to SARS in the newspapers slightly before that time. Newspaper reports making references to specific estates often referred to unofficial sources, such as neighborhood interviews or volunteered information from local residents. The correlation of these two indicators for the 43 estates (excluding Amoy) is  $-0.01$ . Interestingly, the Chinese news mentions indicator, which does not have a significant impact, shares a much higher correlation with the infection rate indicator (0.63). A regression with both the SARS infection rate indicator and the English news mention indicator provides individually significant estimates almost identical to those reported in columns (2) and (5). This implies that the two indicators are essentially orthogonal to each other. The combined average impact, conditional on being non-zero, is 2.61 percent.

The predicted SARS risk measure serves as an index of observable housing characteristics that are empirically correlated to the SARS infection rate; the correlation between living conditions and SARS risks was well publicized. Buildings that share common features with those that had a high number of SARS cases have a high predicted SARS risk; this is independent of their actual infection rates during the 2003 outbreak. The predicted SARS risk measure is a reasonable but not the only way to measure the perceived future SARS risk. Column (7) shows that the predicted SARS risk does not have a significant price impact.<sup>36</sup> The lack of price reaction towards the predicted risk measure can either be because the housing market participants used a different

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<sup>34</sup> Calculation is based on 2002 housing prices. Using 1997–1998 prices inflates estimates by 100 percent, but they are still low compared to estimates in the literature. Thanks to Joe Gyourko for pointing this out.

<sup>35</sup> Using the number of news articles unadjusted for population yields a negative but insignificant point estimate.

<sup>36</sup> For consistency I have excluded Amoy Gardens from the sample. In this case, however, the predicted SARS risk for Amoy Gardens is within two standard deviations from the mean—which is expected because this measure is intended to capture future risk. The estimates with Amoy Gardens included are very similar both qualitatively and quantitatively to those presented.

method to calculate the future SARS risk or it lacked information available for this study. In results not shown, allowing for a rebound in prices points to a temporary price decline (lasting for 25–75 days) of 1.6 percent. This is sensitive to the rebound cut-off point, and should be taken as suggestive only, as other SARS indicators do not show similar rebound patterns.

To put the magnitude of the coefficient estimates in perspective, three predicted impacts are reported for all statistically significant SARS indicators at the bottom of panel A (Table 3). First I compute the impact for the median affected estate by multiplying the coefficient estimate and the median value of the SARS indicator for affected estates. In addition I report the predicted impacts for the 25th and 75th percentiles of all estates (affected and unaffected by SARS) by multiplying the coefficient estimate with the unconditional 25th and 75th percentiles of the SARS indicator for all 43 estates in the sample.

Panel B of Table 3 presents results allowing for baseline price interaction terms with the SARS indicators. Demeaned average prices in 2001 are used. The SARS infection rate indicator shows a significant differential impact by pre-SARS average sales price. Housing estates with baseline average prices one standard deviation (0.43) below the mean suffer roughly half the price decline of those at the mean. This is consistent with the view that households with a higher level of income or wealth have higher values of life. However, given that the baseline price might either be directly related to the spread of SARS in each estate or correlated with other factors affecting it (Table 2), this differential might be due to non-linearities. There is some evidence that a long stay on the SARS-list affected expensive estates more significantly. Given that the standard deviation of housing prices in Hong Kong is more than seven times the standard deviation in the current sample, caution should be exercised in extrapolating these results to draw conclusions about the territory as a whole.

### 5.2. Why was there no price overreaction? Impact of SARS on turnover

Under the same framework as above, we can estimate Tobit regressions of the form

$$T_{it} = \alpha + \beta \text{SARS}_t + \theta_i + \gamma_d t + t + t^2 + t^3 + \varepsilon_{it}, \quad (5a)$$

$$T_{it} = \alpha + \beta \text{SARS}_{it} + \theta_i + \gamma_d t + \Phi_t + \varepsilon_{it}, \quad (5b)$$

where  $T_{it}$  is the turnover rate in housing estate  $i$  during week  $t$  (i.e., 100 times the number of units sold divided by the total number of flats), and the other variables are as before. This is the exact same framework used in the previous section; the dependent variable only is different.  $T_{it}$  can be conceived as the probability of any unit in estate  $i$  being sold in week  $t$ . The three control groups included as before—the estate-fixed effects, district-specific linear time trends and time effect—are significant at the 1 percent level in all regressions presented.  $\beta$  represents the average change (in percentage points) in turnover rates due to SARS.

Table 5, panel A presents the results.<sup>37</sup> Column (1) shows a significant territory-wide drop in turnover rate of 0.05 percentage points. Compared to the average pre-SARS turnover rate of 0.068 percent, this is a 72 percent decrease. We also see a significant fall in turnover for estates with a higher infection rate, representing a 30 percent decrease from the pre-SARS turnover (column (2)). The per capita SARS-list indicator has a significant impact on turnover, contrary

<sup>37</sup> In all regressions presented in Table 5, Amoy Gardens was excluded. Results including it are available on request, showing similar results with smaller point estimates.

Table 5  
Volume impact of various SARS information channels

	Onset-of-epidemic dummy	SARS infection rate (per 10,000)	Per capita, cumulative no. of weeks listed	Per capita, cumulative no. of all news articles	Per capita, cumulative no. of English news articles	Per capita, cumulative no. of Chinese news articles	Predicted SARS risk
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<i>A. Main effect</i>	−0.050*** (0.018)	−0.006*** (0.002)	−1.723* (1.032)	−0.535* (0.292)	−0.237 (0.367)	−1.285** (0.541)	0.042 (0.044)
Impact on median affected estate (%)	−0.05	−0.02	−0.02	−0.01	−	−0.01	−
Impact on the 25th percentile (%)	−0.05	0	−0.004	0	−	0	−
Impact on the 75th percentile (%)	−0.05	−0.02	−0.02	−0.003	−	0	−
<i>B. Main effect</i>	−0.051*** (0.018)	−0.004 (0.002)	−1.535 (1.089)	−0.491 (0.313)	−0.262 (0.388)	−1.146 (0.827)	−0.020 (0.058)
Log 2001 price interaction term	−0.048* (0.026)	−0.012* (0.007)	2.695 (5.036)	−0.247 (0.639)	0.145 (0.72)	−0.398 (1.793)	−0.107* (0.064)
No. of estates	43	43	43	43	43	43	43
No. of observations	1032	1032	1032	1032	1032	1032	1032

Notes. Dependent variable: weekly turnover rate (%) Tobit regressions.

Standard errors reported in parentheses. All regressions include a constant term, estate fixed effects and district-specific linear time trends. They also include weekly fixed effects, except for column (1) where I control for a cubic time effect. All controls are significant at 1%.

Mean [standard deviation] of the dependent variable is 0.060 [0.080]. Mean [standard deviation] of the dependent variable for the pre-SARS period is 0.068 [0.078].

Mean [standard deviation] of the log pre-SARS baseline price is 0.00 [0.43] for the 43 estates included in column (2).

\* Statistical significance at 10%.

\*\* Idem, 5%.

\*\*\* Idem, 1%.

to what is found in prices (column (3)). The average impact on the typical SARS-affected estate is 0.02 percentage points. The magnitude of the turnover responses to the SARS indicators alleviates concerns about significant attenuation bias in the price impacts due to measurement errors.

There is a way to find out if the decrease of transaction volume connected to the per-capita SARS-list indicator is mainly due to an increase in search costs. I explore the impact of the On-list indicator, which is defined as the number of days an estate appeared on the SARS-list during a given week. The SARS-list indicator, on the other hand, represents the cumulative number of days an estate had spent on the SARS-list. Despite potential spillovers of search cost increases across time, the increase in search costs are expected to be the most significant when the estates were still on the list and less so afterwards. Therefore the On-list indicator should have a larger turnover impact if search costs are the most important driver behind the turnover decrease in column (3). In results not shown, the On-list indicator is not statistically significant, lending support to the more complex stories of transaction volume that relate credit constraints and loss aversion in a down market to the observed price and volume changes.

SARS-related news mentions reduce the turnover rate by 0.01 percentage points on average (column (4)), which is mainly driven by the Chinese-language newspapers (columns (5) and (6)). Compared to the predicted SARS risk measure which has no price or volume effect (column (7); Table 3 column (7)), the per capita SARS-list and the Chinese news indicators reduce turnover volume but have no significant price impact. The lack of impact by the predicted SARS risk measure is consistent with my conjecture earlier that the housing market calculated the future SARS risk differently or lacked information available to me. On the other hand, results do not suggest that the SARS-list or Chinese-language newspapers were ineffective in disseminating SARS-related information but that the information led to decreased turnover frequency and an attenuated price response. Two explanations can rationalize this result: either loss-averse sellers tried to attenuate the prospective loss by setting a higher asking price and waiting for a longer time to sell (the loss aversion model), or liquidity-constrained homeowners postponed sales or set a higher selling price (the downpayment model).

There is only weak evidence for any differential in turnover rate reactions according to pre-SARS prices (Table 5, panel B). My estimates of the primary effects remain stable in magnitude, but are measured with less precision. The territory-wide impact seems to have a greater impact on the more expensive estates, but the interaction term is significant at the 10 percent level only. Because of the lack of volume data after the end of the epidemic, the impact of the SARS infection rate on turnover rates is not examined.

## 6. Conclusions

SARS first struck human populations in 2003, infecting 8422 people worldwide and killing 916. The virus bears a particular relevance to the housing market because it is believed that building characteristics and environmental conditions made some housing estates more susceptible to the spread of the disease than others. During the epidemic, many Hong Kong residents took refuge in relatives' and friends' homes located in areas with fewer cases of SARS, and it was unclear whether the 8 percent housing price decline that coincided with the epidemic was a market reaction to expectations of a significant decrease in demand or a continuation of past trends. Exogenous and unanticipated, the 2003 SARS epidemic provides a unique setting to study whether emotions associated with extreme events have strong market implications as predicted by psychological and behavioral economics theories, or whether standard economic models built

upon the assumption of rationality serve as reasonable benchmarks in predicting housing market reactions to extreme shocks.

Despite the widely held belief that SARS devastated the already frail Hong Kong housing market, this study finds little evidence of overreaction. The territory-wide indicator points to an average price decline of less than 2 percent after the start of the outbreak, controlling for estate-fixed effects and a historical time trend. Using weekly fixed effects to absorb any territory-wide SARS impact or trend shifts, the various estate-specific SARS indicators capture price declines directly attributable to public information related to the SARS epidemic. This specification points to an average price decline of 2.61 percent.

My own estimation of the SARS infection rate at the estate level compensates for the lack of public record. The price changes related to the estimated infection rate suggest that the marginal buyer in the housing market was aware of the SARS infection risk at the estate level, without any direct information on the magnitude of the risk. Price responses are also associated with per capita measures of newspaper mentions. No reaction is identified in relation to the more visible but cruder measures, such as the number of days listed on the government list or number of news mentions. This paints a different picture than some models of financial markets where agents with private information outweigh noises in public information (e.g. [11]). To put the SARS-related price decline in perspective, the implied economic value of life ranges from \$110,000 to approximately \$1 million. This estimate is toward the bottom end of the range in the existing literature, consistent with my conclusion that the housing market did not overreact to the epidemic [19].

The small magnitude of the price responses is unlikely to be caused by measurement errors, because substantial turnover declines are identified using the same indicators. Further findings indicate a turnover dry up that is more persistent than the increase in search costs brought about by the epidemic. Moreover, marked decreases in turnover are found in response to SARS indicators that do not have significant price impacts. This pattern points to a mechanism where expected downward pressure on prices leads to non-participation of sellers in the market and therefore a muted price response [4,16]. Glaeser [5] argues that under situations when the costs of errors to the decision makers are high, mistaken beliefs such as overweighing of short-term well-being and overreaction should be less common. Given the importance of housing in the average Hong Kong household's wealth portfolio, it is perhaps unsurprising that the market adopted a cautious, wait-and-see attitude in response to the SARS epidemic and did not show significant signs of overreaction.

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