The Impact of the Coronavirus Pandemic on New York City Real Estate: First Evidence

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Abstract

Concerns about the lingering novel Coronavirus could have led to long-term structural change in desired dwelling locations in large U.S. cities. Densely concentrated neighborhoods may be at higher risk of contagion, encouraging more individuals to move out. We investigate whether this potential pandemic-induced reduction in demand has adversely affected real estate prices of one- or two-family properties across New York City. First, OLS hedonic results indicate that greater case numbers are concentrated among neighborhoods with lower-valued properties. Second, as an identification strategy we use a repeat-sales approach for the period 2018-2020, and find that sale prices fall by nearly $100,000 or around 10% for every 1,000 additional infections per 100,000 residents in a given MODZCTA. Based on cumulative MODZCTA infection rates through mid-2020, the estimated COVID-19 price discount ranges from approximately 7% to nearly 50% in the most affected neighborhoods. Finally, we consider the relationship between the number of cases and the number of sales in a neighborhood. Our Poisson process shows a negative relationship between case numbers and sales volumes as well as a notable compositional shift. The highest value properties experience an increase in sales as case numbers rise, while properties priced below the pre-COVID median report relatively fewer sales with more cases. This is indirect evidence on how COVID impacted the distribution of homeowner wealth across differently priced houses, as those with greater housing wealth before COVID were able to enhance wealth during the pandemic, while the opposite occurred for the owners of the lowest priced homes.

Keywords: COVID-19, Hedonic, Repeat Sales, Price Discount, Composition
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1 Introduction

The novel Coronavirus has completely transformed life as previously known throughout the world. The U.S. has seen one of the highest per-capita death rates among virtually any other country. In the early months of 2020 during the pandemic, New York City experienced a disproportionate intensity of cases and deaths, relative to the rest of the United States, partly due to the relatively high density in many parts of the City. As the pandemic worsened throughout the first two quarters of 2020, vast numbers of New York City residents chose to flee the city for the suburbs, where more spacious residences and automobile-dependent towns were appealing due to their relatively insulated way of life. Although this major shift is still unfolding to some degree, it leads one to wonder how the novel Coronavirus is impacting residential real estate prices in New York City. An abundance of detailed New York City COVID-19 case data, with relatively precise locations of these cases within the City, lends to the ability to examine how strong the relationships are between the novel Coronavirus and residential real estate prices in the 5 boroughs. It also raises the question of whether homes in the City that are already located on larger lots of land (i.e., much higher priced) may not be impacted in the same ways as homes that are much closer together in some of the lower-priced neighborhoods of the City. These are the issues that we study in this paper.

As the world is still reeling from subsequent waves of the virus, the impacts on real estate markets are an ongoing issue and the nascent literature in this area is still developing. The limited existing research on residential real estate includes analyses of U.S. house price responses to shutdowns and re-openings related to COVID-19, along with aggregate U.S. market impacts from COVID-19. One micro-analysis for the U.S. finds that there are substantial distributional differences in the COVID-19 effects across different income groups. A small number of other studies focus on housing markets in other parts of the world.

One of the few known existing U.S. studies is D'Lima et al. (2020), who consider the effect of closures and re-openings. Employing a difference-in-differences identification strategy, the authors assess the impacts of COVID-19 on residential real estate prices throughout the United States. Their approach follows the commonly used hedonic house price methods, which assume that the demand for housing can be broken out into an array of property characteristics (Rosen, 1974), such as numbers of bedrooms, bathrooms, square footage, acreage, etc., and amenities and/or disamenities (Banzhaf and McCormick, 2012). Then linear regression estimation of this hedonic price equation, where the natural logarithm of house price is the dependent variable, can yield elasticities of house prices with respect to the amenities/disamenities.

D'Lima et al. (2020) include an indicator in their hedonic model for whether or not each property sale at time t was in a state that had shut down at time t, and a separate indicator for whether said property that sold at time t was in a state that had reopened at time t. These authors control for zip-code fixed-effects and cluster at the zip code level. Their findings include that the shutdowns had a statistically insignificant negative effect on prices, while reopening had a statistically significant negative effect (with elasticity of approximately 0.9). They argue that not all restrictions were immediately lifted upon reopening, which led to the negative effect of reopening.

Zhao (2020) studies aggregate and micro (zip code level) effects of COVID-19 on U.S. housing markets. Aggregate level findings include that prices have risen much faster than they did in the months prior to the Global Financial Crisis; and there has been a structural break in housing demand after mortgage rates have fallen post-March 2020. Zhao (2020) also notes on the micro-level that individuals on the lowest and highest levels of the income distribution have demonstrated the greatest increases in housing demand. Finally, demand in cities has not changed differentially compared with demand in suburbs and rural areas.

Studies of the real estate market impacts of COVID-19 outside the U.S. are sparse. While Francke and Korevaar (2020), for example, examine how historical pandemics impact house prices in Amsterdam, they do not specifically consider COVID-19. Rather, they focus on other past pandemics. They find that there is a significantly negative effect within 6 months after a pandemic, but this discount is only temporary. This transitory finding potentially bodes well for the impacts of COVID-19 in many cities throughout the world. In another recent study beyond the U.S. context, the impact of deaths from COVID-19 on Chinese housing markets is the focus of Chong and Liu (2020). Their finding is that months with the fewest numbers of deaths experienced the lowest house price changes in response to more deaths. This relationship is reversed in months with larger numbers of deaths. The authors refer to this phenomenon as a "U-shaped" effect.

This review of the brief literature on residential real estate and COVID-19 indicates gaps that deserve further examination. For instance, a micro analysis of one particular city, and how local rates of COVID-19 cases impact house prices in the very short term, could yield some poignant evidence of any potential relationships. New York City is an excellent laboratory for this type of analysis, given the heterogeneity across its 5 boroughs and many hospitals in the city. Another desirable feature of our New York City focus is the recent exodus of residents to the suburbs, in order to evade potential future waves of the pandemic. By focusing on a specific 'big-city' real estate market and estimating the response to the intensity of the outbreak (i.e. cumulative case numbers) rather than shut downs, we are able to assess a tremendous degree of heterogeneity. That is, all of New York is shut down, and still there are differences in how the market reacts across boroughs and/or modified zip codes (MODZCTAs) due to variation in actual COVID-19 intensities.

We have three separate prongs to our approach. The first is a classic hedonic housing price model for New York City (NYC) one- or two-family house sales, where the dependent variable is house price at time t; we include a variable for the cumulative number of novel Coronavirus infections per 100,000 residents within the local MODZCTA, at time t (CC_t). Across neighborhoods, we find a negative relationship between CC_t and house prices suggesting that NYC neighborhoods with lower home values experience more intense COVID-19 outbreaks. Within NYC neighborhoods (i.e. within a lower- or higher-valued neighborhood), however, we find a statistically insignificant coefficient estimate for CC_t. That is, either COVID-19 has no causal impact on NYC property prices, or COVID-19 does adversely affect prices of all properties, but also changes the neighborhood-specific composition of sold properties along some unobservable home attribute, such that the estimated price effect becomes insignificant. One possible scenario supported by some anecdotal evidence (Goodman and Rashbaum, 2020; Haynes, 2020) is exodus of the more affluent residents, such that COVID-19 triggers the sale of more valuable properties within NYC neighborhoods. As a result of this compositional shift, the observed average sale price in a given neighborhood rises and offsets the otherwise adverse impact of the pandemic on the value all properties - sold and unsold.

In the second approach, we attempt to reconcile these initial findings and explore the causality of the underlying relationship by restricting ourselves to transactions of repeatedly-sold properties between 2018 and 2020. We estimate a differenced model, where the difference in prices (between repeat sales) is regressed against the difference in cumulative case rates, as well as fixed effects. This approach identifies the COVID-19 price effect by estimating the average change in sale prices at the property level and is therefore immune to the potential pandemic-induced compositional changes of real estate markets at the neighborhood level. Differencing out observable and unobservable home and neighborhood characteristics, such as whether a home is a high- or low-valued property in a low- or high-valued neighborhood, we find that the coefficient on the change in cumulative infection rates is negative and statistically significant in the repeat-sales models. In other words, as there are more cases per resident over time, this adversely affects house prices. For every 1,000 additional COVID-19 infections per 100,000 residents in a given MODZCTA, the value of a one- or two-family NYC home declines by $100,000 between two sales of the same property, on average. Based on the cumulative MODZCTA-specific infection rates in NYC through July, 2020, our estimates point to economically (and statistically) significant price reductions ranging from $65,000 (or 7%) in the least ’infected’ neighborhoods to over $450,000 (or 50%) in the most severely affected MODZCTAs. These findings are robust to a host of sensitivity analyses that scrutinize our identification strategy.

Finally, we consider a Poisson process in modelling the impact of the number of cases per resident on the number of sales in a given neighborhood, which we find to have a negative relationship. Interestingly, homes that sold below the neighborhood-specific pre-Covid median price experienced a significantly lower number of sales in response to higher cumulative cases, while properties priced in the top 10 percent of recorded pre-COVID sales prices experienced a positive but statistically insignificant response to higher cumulative cases. But the top one percent of property sales prices saw a statistically significant higher number of sales. This may be due to the fact that some of these higher priced properties were more spread apart from their neighbors and residents may have perceived them as relatively “safe” compared with lower priced homes that are clustered closer together. An alternative explanation may be low interest rates that stimulate speculative purchases of highly desirable properties that rarely become available in the NYC real estate market. Regardless of the underlying mechanisms, the implication that housing wealth accrued disproportionately to owners of higher valued houses during the pandemic is startling. Those homeowners who already started with a high degree of housing wealth saw this wealth move in the opposite direction from those homeowners with relatively little housing wealth.

All-in-all, our findings highlight the powerful adverse effect COVID-19 has had on the NYC real estate market through July, 2020. Over the span of just five months since the first reported cases, COVID-19 infections have shrunk the volume of the NYC real estate market by nearly 35% and reduced average house sale prices by around 27%. In comparison to the expected pre-COVID home value appreciation, the pandemic has eroded a value equivalent to a seven-year expected return on residential property investment in just five months. Moreover, these average effects are not equally distributed across the NYC universe of one- or two-family homes, but concentrated among lower-valued neighborhoods that experience greater rates of infections and lower-valued properties that experience a greater reduction in the number of sales.

The remainder of this paper proceeds as follows. In the next section, we provide some background on NYC residential real estate and COVID-19. In section 3, we describe the empirical models that we implement, followed by a detailed description of our data in section 4. We present the results of our estimations in section 5, after which we provide some discussion and conclusions along with suggestions for future work.

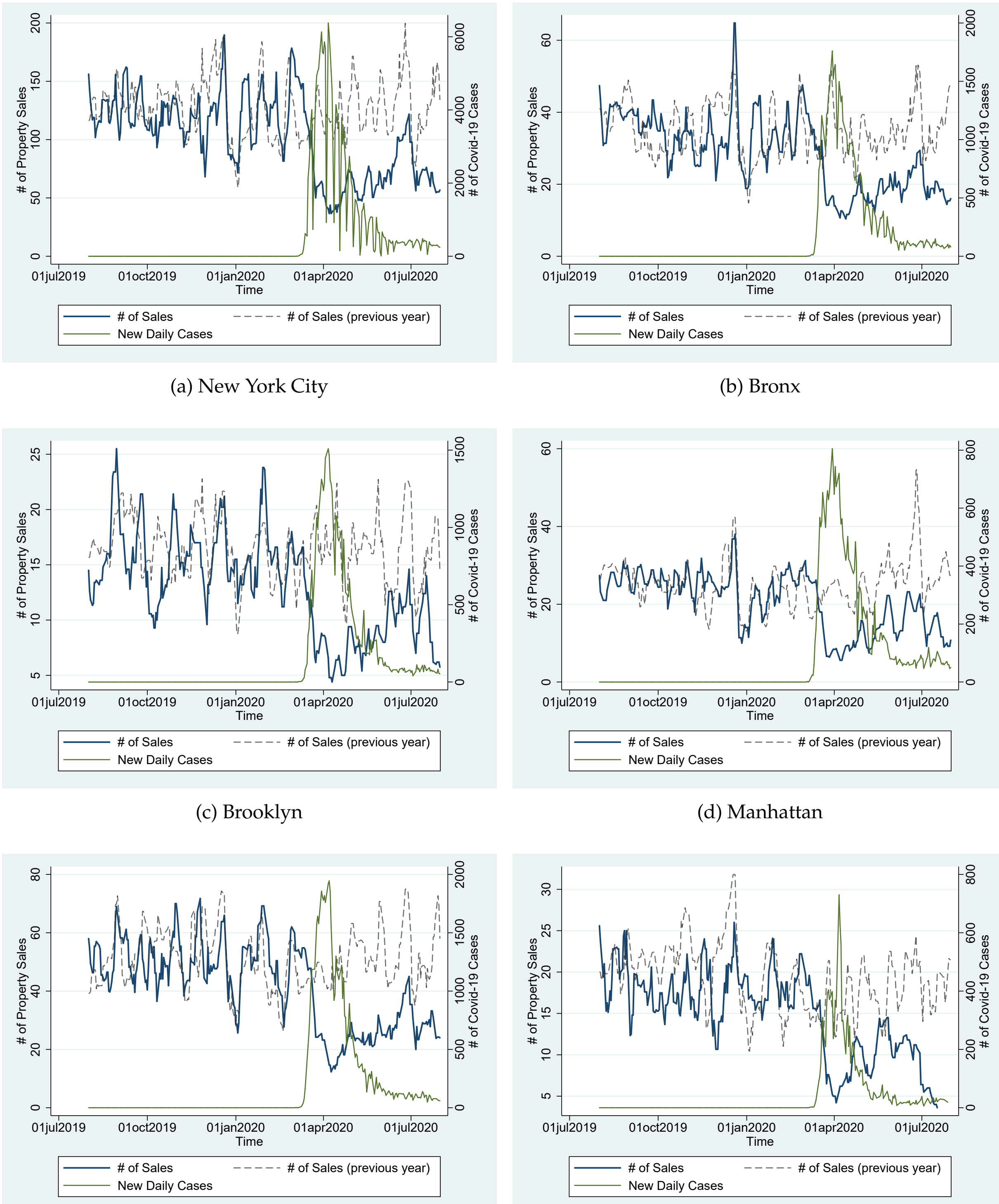
2 Background

It is a rare occurrence to see an Op-Ed in the *New York Times* by a certain famous New York-based stand-up comedian and sitcom star defending the future of New York City (Seinfeld, 2020) against hyperbolic claims that NYC is "dead forever" (Altucher, 2020). Then again, these are exceptional times. Major news outlets have told a story of large-scale outbound migration from New York City due to Coronavirus restrictions. Manhattan vacancy rates are climbing to 14-year high levels (Haag, 2020b). Conversely, surrounding suburbs are struggling to absorb the demand of "fleeing" New Yorkers. A home in East Orange, N.J., for example, was listed at $285,000, hosted 97 showings, received 21 offers, and went under contract 21% over asking – all over a three-day period in July of 2020 (Haag, 2020a).

Figures 1a through 1f provide a first look at the NYC housing market before and after the outbreak of the novel Coronavirus and corroborate the anecdotal evidence reported in these recent news articles. In each figure, we plot the number of daily new COVID-19 cases and 7-day moving average of the number of daily property sales from August 1, 2019 to July 31, 2020 (solid blue and green lines) and contrast the latter against the moving average number of daily real estate transactions in the previous year (i.e. August 1, 2018 through July 31, 2019) (dashed grey line). Figure 1a presents these data for all of NYC, whereas Figures 1b through 1f illustrate the real estate and pandemic dynamics for each of the five NYC boroughs.

Each of the six graphs clearly show that the outbreak of the novel Coronavirus in NYC coincides with notable disruption of the city's real estate market. While daily sales across all property types in the second half of 2019 and early 2020 tend to track the volume of transactions in the previous year, the two series diverge starting in March 2020 as the first cases are reported in NYC. With the number of property transactions falling by as many as 20 sales per day by April 1, 2020, the Bronx, Brooklyn and Queens, for example, show an immediate 50% to 70% decline in the volume of the real estate market one month after the outbreak relative to pre-pandemic data (see Figures 1b, 1c, and 1e). While the markets seem to temporarily recover towards the end of June, 2020, our data show that the number of property sales in these boroughs experience another sharp decline in July and tend to stay depressed until the end of the sample period, even after the first wave of infections had passed and new Coronavirus infections fell to less than 150 cases per borough.

The real estate markets in Manhattan and Staten Island, depicted in Figures 1d and 1f, show slightly different patterns in response to the outbreak. Similar to the Bronx, Brooklyn, and Queens, both boroughs



(a) New York City

(b) Bronx

(c) Brooklyn

(d) Manhattan

(e) Queens

(f) Staten Island

Figure 1: New York City Daily Case Counts and Avg. House Sale Prices by Borough

experience a significant reduction in the number of property transactions as the daily case numbers rise in March and April, but give the impression of recovery by late May, 2020. By July 2020, however, the volume of real estate transactions collapses in Staten Island relative to the previous year and is notably lower for Manhattan as well towards the end of our sample. In aggregate, Figure 1a shows that the number of daily sales falls by around 50 transactions (≈-50%) per day during the first few month of the COVID-19 outbreak in NYC and that this response not only persists, but actually worsens to around 80 lost sales per day through July 31, 2020.

3 Model

To evaluate the impact of the COVID-19 pandemic on the NYC real estate market more formally, we take two complementary methodological approaches. In the first, we estimate the impact of novel Coronavirus infections on NYC property sale prices using the typical hedonic model popularized by Rosen (1974)[1] and used in many economic studies on real estate markets.[2] In the second, we employ a Poisson model to quantify the pandemic-induced changes in the frequency of property sales. Across both of these methodologies, we are able to estimate the pandemic effects on the full sample of one- and two-family property transactions as well as the more restrictive repeat-sales sample. The latter offers a sound identification strategy to quantify the causal COVID-19 price and volume effects.

To begin, we derive the traditional hedonic model to evaluate the price effect of the COVID-19 pandemic on NYC homes. Typically, the purpose of the hedonic model is to determine how various characteristics of the property and neighborhood demographics as well as a particular feature of interest (i.e. the rise in novel Coronavirus cases) affect property sale prices. By controlling for the demographics and characteristics with regression analysis, it is possible to estimate how additional infections influence property sale prices. Therefore, the hedonic model may take the following form:

$$P_{it} = \beta_0 + \beta_1 CC_{bt} + \gamma H_i + \alpha_b + \alpha_t + \epsilon_{it}, \tag{1}$$

where P_{it} represents the vector of sale prices of properties $i = 1, 2, .., N$ at time t, β_0 is an intercept term

[1] Rosen (1974) popularized the study by Kain and Quigley (1970).

[2] For a review of this literature see, for example, Chau and Chin (2003), while an example of a specific application to another dis-amenity - aircraft noise pollution - is given by Cohen and Coughlin (2008).

and H_i represents a matrix of time-invariant property characteristics, such as the age of a home, its square footage, and number of floors, among others.[3]

The variable of interest is given by CC_{bt} and represents the cumulative local Coronavirus infections per resident measuring the severity of a property's exposure to local cases in neighborhood b at the time of sale. Socioeconomic neighborhood characteristics that are relatively constant over a short-sample period (2018-2020), such as demographics or median income, are captured by a neighborhood fixed effects α_b. Finally, α_t represents a matrix of time-of-sale fixed effects to capture citywide differences over time, such a general appreciation in property values, and ϵ_{it} is an error term that is i.i.d. with mean zero and constant variance, along with zero co-variance across observations i, where $i = 1, 2, .., N$ and N is the number of houses in the sample. The coefficient of interest is given by β_1 and measures the average change in house sale prices in response to a rise in cumulative local Coronavirus infections conditional on the other control variables.

The primary issue with this specification is that unobservable home and/or neighborhood characteristics of sold properties may correlate with the intensity of the local COVID-19 outbreak and bias our coefficient estimate of interest. If, for example, more affluent homeowners in any given neighborhood flee the City to avoid the pandemic, the neighborhood-specific composition of sold homes changes with the pandemic and potentially undermines our COVID-19 price effect estimate. Taking advantage of the repeat-sales sample, we can control for time-invariant observable and unobservable home and neighborhood characteristics by taking the first difference of Equation (1) between the initial and repeat sales. Since not all home and neighborhood characteristics are observable, this reduces the risk of omitted variable bias and inconsistent estimates (Chau and Chin, 2003) and identifies the COVID-19 price effect at the property rather than neighborhood level. As a result, the repeat-sales sample estimate is no longer sensitive to the composition of homes sold within a given neighborhood and much less prone to be biased.[4] Taking the first difference (Δ) of Equation (1) for two separate sale dates for property i, which is sold at both time $t + \tau$ and time t (where t represents the initial sale and $t + \tau$ represents the subsequent sale), yields:

$$\Delta P_{it+\tau} = \beta_1 \Delta CC_{bt+\tau} + \alpha_{t+\tau} - \alpha_t + \epsilon_{it+\tau} - \epsilon_{it}. \tag{2}$$

[3]While the PLUTO^{TM} dataset contains a number property characteristics, it does not report all of the desirable home attributes, such the number of bedrooms and number of bathrooms.

[4]Of course, even the repeat-sales estimator is subject to a few concerns, such as changes in property attributes over time. We conduct a host of robustness analysis to scrutinize our repeat-sales identification strategy. The results of these sensitivity tests are presented and discussed in the Appendix (see Table A1) and produce consistent estimates that lend support to our identification strategy.

Since the characteristics of house i, H_i, and neighborhood b, α_b, are assumed to be time-invariant, they drop out when taking the first difference of Equation (1). Furthermore, time-of-home-sale and repeat-sale fixed effects (α_t and $\alpha_{t+\tau}$) control not only for the specific timing of each sale of a given house, but also the difference in the time elapsed between the two sales. That is, we would expect there to be a pandemic-unrelated difference in home value appreciation between a house sold 10 years ago and one sold 1 year ago. Similarly, we expect there to be a difference in the change in property prices for a home that was sold in 2010 and 2018 versus a home that was sold in 2012 and 2020. Our fixed effects capture the timing of both sales as well as the duration of time that has passed between repeat sales and therefore control for both of these potentially confounding factors.

The coefficient of interest is still given by β_1, but the interpretation changes slightly. Given the specification in first differences, β_1 quantifies the average discount or premium on the change in sale prices of repeatedly-sold homes correlated with a rise in novel Coronavirus infection rates near a given property. A priori, we expect the severity of the pandemic to be a significant dis-amenity to home buyers that leads to a decline in average sale prices (or smaller home value appreciation between sales) in neighborhoods with rising Coronavirus infections ($\beta_1 < 0$).

In addition to the price analyses, we also investigate the impact of cumulative local Coronavirus infections on the number of observed arms-length transactions of one- and two-family homes. To this end, we determine the frequency of sales (Y_{bt}) in a particular neighborhood b in a given month t. In line with the price analyses, this transaction count may include all sales of one- and two-family homes or restrict the sample to transactions of repeatedly-sold properties. We model this random count variable as Poisson distributed with the probability density:

$$Pr(Y_{bt} = y_{bt}) = \frac{exp^{-\lambda_{bt}} \lambda_{bt}^{y_{bt}}}{y_{bt}!}, \qquad y_{bt} = 0, 1, 2, ..., \quad b = 1, 2, ..., B, \quad t = 1, 2, ..., T \tag{3}$$

where y_{bt} is the realized number of sales across a set of neighborhoods B and time periods T and the mean and variance of the distribution are given by λ_{bt}. We specify this parameter as a stochastic function:

$$\lambda_{bt} = exp(\beta_0 + \beta_1 CC_{bt} + \gamma H_{bt} + \alpha_b + \alpha_t + \epsilon_{it}), \tag{4}$$

where β_0 is an intercept term and H_{bt} represents a matrix of the average property characteristics for the homes sold in neighborhood b at time t. As before, we continue to control for unobservable neighborhood characteristics and common time trends, such as the seasonality of the real estate market, via neighborhood and time fixed effects α_b and α_t and ϵ_{bt} represents the i.i.d. random error component.

The key variable is given by CC_{bt} and represents the neighborhood-specific cumulative count of novel Coronavirus infections per 100,000 residents at time t. In this model, the coefficient of interest, β_1, captures the expected change in the log of the mean of the number of property sales for the average neighborhood in response to a one unit increase in the local rate of infections. A priori, we expect that, conditional on the observable home and neighborhood characteristics, the pandemic has a negative impact on the volume of the NYC real estate market on average ($\beta_1 < 0$). Nonetheless, we acknowledge the potential market segmentation across unobservable determinants (Adair et al., 1996; Fletcher et al., 2000) and expand our empirical analysis by investigating whether the COVID-19 outbreak has heterogeneous effects on the number of sales across the distribution of potential home values. That is, we test whether the pandemic-induced response in the ultra-luxury market (i.e. sale price $> 99^{th}$ percentile), for example, deviates from those in market segments of lower-valued properties.

4 Data

To estimate the COVID-19 impact on NYC property sale prices and the number of transactions, we construct a novel dataset that combines the relevant information from multiple sources. The housing data, for example, was created through two publicly available resources from NYC government agencies. The first is the PLUTO™ database maintained by the NYC's Department of City Planning.[5] The PLUTO file contains detailed information on property characteristics by individualized tax lot. The second dataset entails information on the timing and price of every NYC property sale and is publicly available through the NYC's Department of Finance.[6] The two files share a unique identifier field in borough-block-lot (BBL) and may be merged easily once compiled.[7] Notably, the housing data includes both residential and commercial properties, the majority of which are reported sales of one- or two-family homes, which are the focus of our analyses. The combined housing records span from January, 2003 through July, 2020.

In an attempt to isolate market arms-length transactions and minimize potential data errors, we employ

[5] https://www1.nyc.gov/site/planning/data-maps/open-data/dwn-pluto-mappluto.page
[6] https://www1.nyc.gov/site/finance/taxes/property-rolling-sales-data.page
[7] Variations of these data have been used in the past (see, for example, Barr and Cohen (2014)).

Table 1: NYC Borough One- and Two-Family Housing Market and Pandemic Summary Statistics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Before Outbreak (03/01-07/31/2019)		After Pandemic Outbreak (03/01-07/31/2020)							
Borough	Total # of Sales	Avg. Sale Price ($ '000)	Total # of Sales	Avg. Sale Price ($ '000)	Total # of Cases	Total # of Hosp.	Total # of Deaths	Max. Case Rate	Max. Hosp. Rate	Max. Death Rate
Brooklyn	1,909	1,060.1	1,116	1,033.3	62,136	15,411	5,614	2,405.7	596.7	217.4
Bronx	943	543.4	572	585.9	50,156	12,273	3,923	3,495.9	855.4	273.4
Manhattan	75	7,445.4	40	6,889.2	46,209	11,622	3,689	3,220.8	810.1	257.1
Queens	3,475	969.6	1,940	745.5	67,802	16,975	5,944	2,962.5	741.7	259.7
Staten Island	1,678	580.5	870	611.4	14,649	2,335	895	3,076.4	490.4	188.0
NYC Average	1616	920.5	907.6	748.4	44,738	10,990	3,776	2,747	636	219
NYC Total	8,080	-	4,538	-	223,692	54,948	18,879	13,736.4	3,177.6	1,093.7

Notes: Data on the number of one- and two-family property transactions and average sale prices are published by the NYC Department of Finance. Statistics on COVID-19 cases, hospitalizations, and deaths are publicly available from NYC Department of Health and reported on a daily frequency starting February 29, 2020. Based on our sample, we define the post outbreak period from March 1, 2020 until the end of our sample July 31, 2020. For the purposes of comparison, we calculate pre-outbreak statistics on the number of sales and average property prices based on limited sample restricted to March 1 to July 31, 2019.

a number of standard adjustments to these housing data. First, we remove all transactions with a sale price below $10,000. Next, we exclude all records with zero buildings, zero floors, zero total units, zero lot depth or zero square footage. In the event a property's designated land use changed during our sample or a sale was classified as a residential transaction, but the property has no residential units, it was removed. All records with a year built or year altered before 1800 were removed. Finally, we exclude all observations pertaining to multiple sales of the same property on the same day.[8] In aggregate, this leaves 478,900 total NYC property transactions, of which 337,438 are sales of one- or two-family homes, between January, 2003 and July, 2020. During the relevant sample period (January, 2018 through July, 2020), we observe 47,883 transactions of 43,341 unique one- or two-family properties. 4,538 of these sales are reported during the COVID-19 period from March to July, 2020 (see Table 1). In terms of repeatedly-sold homes, the data show a total of 170,143 transactions for 70,762 unique one- or two-family NYC properties since January, 2003. Of these, we observe 20,300 from January, 2018 to July, 2020 and 999 from March to July, 2020.

To provide initial evidence of the likely pandemic impact on the NYC real estate market, we compare year-over-year changes in average sale prices and the number of transactions before and after the initial

[8]For some transactions these duplicate records may be plausible, perhaps indicating the simultaneous sale of multiple apartments or condominiums. For our sample of one- or two-family homes, however, these duplicate records cannot be easily reconciled. We error on the side of caution and exclude these observations, but note that our results are not sensitive to this (or any of the other) sample restrictions.

COVID-19 outbreak between March 1 and July 31, 2019 relative to 2020 (see columns (1) through (4) of Table 1). Taking the difference between columns (1) and (3) of Table 1, for example, shows that the total number of transactions of NYC one- and two-family homes decreases by 3,542 year-over-year and that this 43.8% reduction in the frequency of sales after the outbreak is not driven by a single borough, but the combined result of a notable housing market collapse in each of the five districts. Across NYC boroughs, the number of sales declined anywhere from 35 (Manhattan) to 1,535 (Queens) or 39.3% (Bronx) to 48.2% (Staten Island) in relative terms.

Interestingly, the change in average sale prices for these transactions appears more moderate. In aggregate, the average property sale price from March 1 to July 31 fell by 18.7% from $920,500 in 2019 to $748,400 in 2020 and masks significant heterogeneity across each of the five boroughs. While Manhattan and Queens, for example, experienced declines of roughly 8% to 23% in the average sale price, property values of sold one- and two-family homes located in the Bronx and Staten Island, for example, rose by around 5% to 8% over the same time period. In contrast, sale prices of homes sold in Brooklyn remained relatively stable slightly declining by about 3% year-over-year.

To investigate whether these adjustments in the number of real estate transactions and sale prices correlate with the local rise of the COVID-19 pandemic, we combine these housing data with spatially disaggregated information on the NYC outbreak of the novel Coronavirus. Data published by the NYC Department of Health documents the number of positively tested COVID-19 cases, the number hospitalized COVID-19 patients, and the number of COVID-19 related deaths as well as their respective rates per 100,000 residents on a daily basis. The earliest reporting dates back to February 29, 2020 and provides these statistics at the NYC borough level differentiating, for example, between Brooklyn and Manhattan case counts and rates. Starting on April 3, 2020, the NYC Department of Health began to publish pandemic statistics on the total number of tests and positive test results at the more disaggregated modified zip code (MODZCTA) level. By May 18, 2020, the agency augmented these data with information on death counts and death rates per 100,000 MODZCTA residents. We use the overlap in MODZCTA- and borough-level data from April 3 through July 31, 2020 to backcast case counts at the MODZCTA level through March 1, 2020 based on the available borough counts.[9] Our results are robust to this extrapolation.

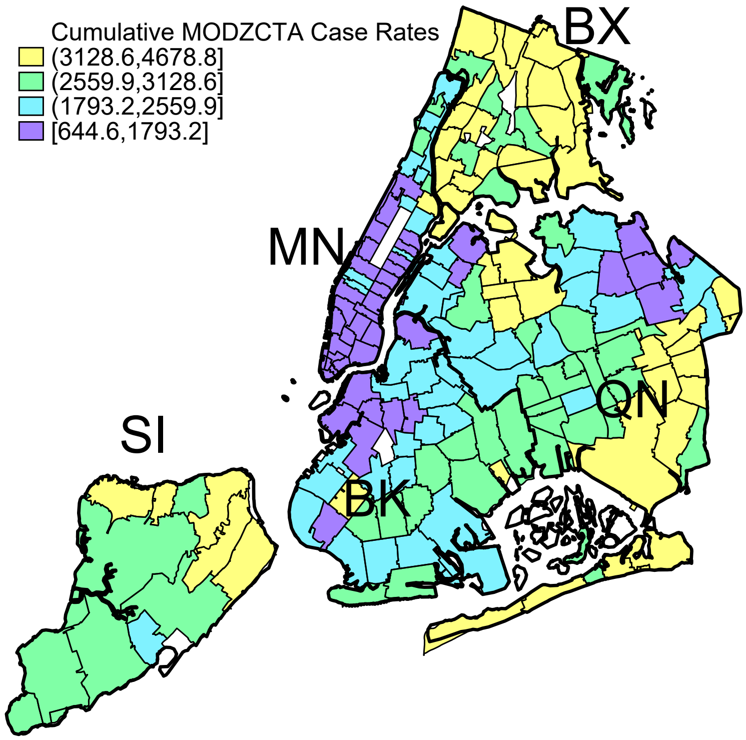
In total, there are 176 MODZCTA's located in one of five NYC boroughs including the Bronx, Brook-

[9]Specifically, we calculate the MODZCTA share in total borough cases when both case counts are available and use these shares to predict MODZCTA case counts from March 1 through April 3, 2020, when only borough-level data are available.

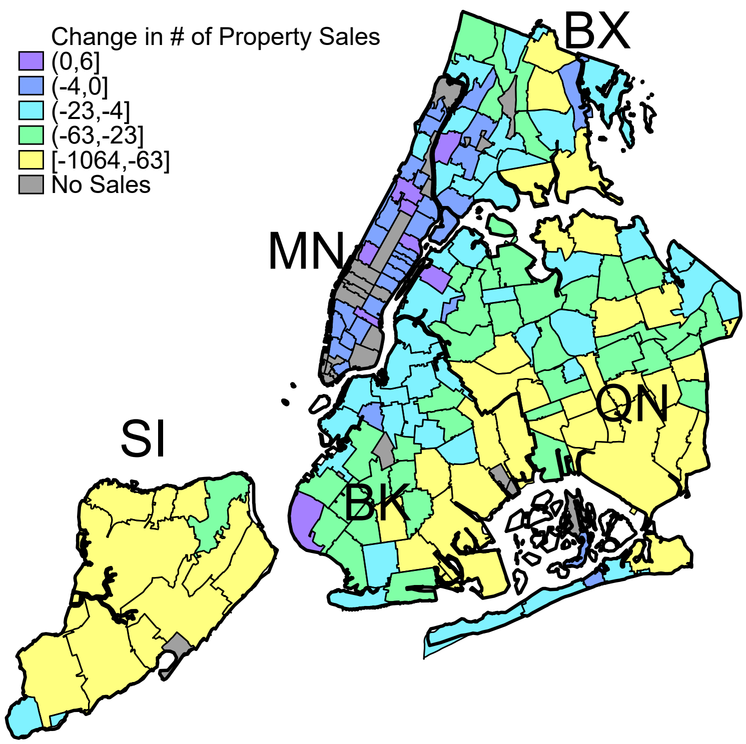
lyn, Manhattan, Queens, and Staten Island. We build a MODZCTA-to-BBL concordance and match each of the sold properties to its corresponding MODZCTA and borough. In addition to the aforementioned real estate statistics, Table 1 also summarizes pandemic information at the borough level (see columns (5) through (10)). Column (5) indicates that nearly 224,000 people residing in NYC contracted the Coronavirus by July 31, 2020, most of whom live in the Bronx, Brooklyn, Manhattan, and Queens. Of these individuals who tested positive, nearly 55,000 were hospitalized and 18,879 died in NYC. Brooklyn and Queens lead these statistics ranging from 15,000 to 17,000 hospitalized patients and 5,500 to 6,000 infected individuals who passed away (see columns (6) and (7)). The pandemic statistics for the Bronx and Manhattan are just slightly lower than those observed in Brooklyn and Queens. In contrast, the outbreak in Staten Island appears much less severe, often reporting case, hospitalizations, and death counts four to five times lower than those observed in the other boroughs. This distinction, however, becomes less obvious when taking borough-level population into account. Considering case, hospitalization, and death rates per 100,000 borough residents, all boroughs experience the COVID-19 outbreak with similar severity by July 31, 2020.

Combining the information on real estate and pandemic statistics, we note that, while all borough real estate markets experienced a significant degree of local exposure to novel Coronavirus infections and saw a notable reduction in the number of transactions after the outbreak, only Brooklyn, Manhattan, and Queens experienced a reduction in average property sale prices. Moreover, Table 1 shows that these three boroughs do not experience the highest case, hospitalization, or death rates per 100,000 residents. To take a closer look at the spatial pattern, we map COVID-19 cumulative case rates as of July 31, 2020 and the change in the number of transactions and average house sale prices at the MODZCTA level. Figures 2a through 2c reiterate our initial observations. First, the severity of the outbreak is greater in the Bronx, Queens, and Staten Island where the majority of MODZCTAs report cumulative case rates above the 50^{th} percentile of the NYC COVID-19 case rate distribution. In contrast, many of Manhattan's MODZCTAs experience cumulative cases rates below the 25^{th} percentile by July 31, 2020 (see Figure 2a). Moreover, we note that by this date the virus had spread far throughout NYC with a mimimum MODZCTA case rate of 645.

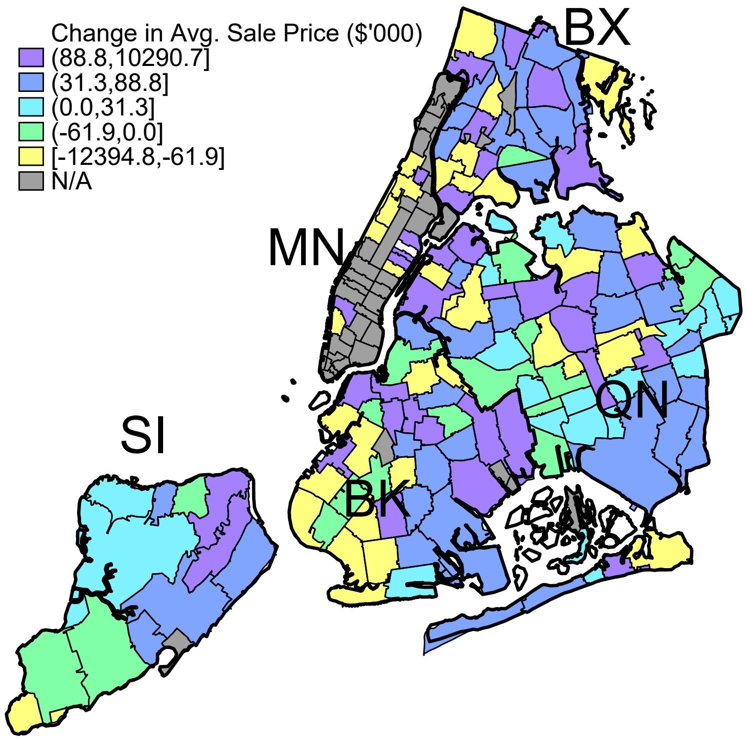
Second, Figure 2b shows that the spatial distribution of the year-over-year change in the number one- or two-family home sales tends to negatively correlate with the number of COVID-19 cases mapped in Figure 2a. The simple correlation coefficient equates to -0.30. MODZCTAs in Staten Island, Brooklyn, and Queens experience some of the largest reductions in the number of transactions. MODZCTAs in Manhattan report the smallest year-over-year changes in the number of property sales, but also have the smallest number



(a) Cumulative MODZCTA Case Rates as of July 31, 2020



(b) Yr.-over-Yr. Change in # of Sales (Mar. 1 - Jul. 31, 2019 to 2020)



(c) Yr.-over-Yr. Change in Avg. Prices (Mar. 1 - Jul. 31, 2019 to 2020)

Figure 2: Cumulative Case Rates and Changes in the # of Property Sales and Avg. Sale Prices by MODZCTA

of one or two-family homes to begin with. Lastly, we note that a handful of MODZCTAs experience a year-over-year increase in the number of sales and that these tend to be located in or near Manhattan.

Third, year-over-year changes in the average MODZCTA sale prices are much more volatile and more dispersed across NYC MODZCTA's than Coronavirus case rates and are therefore only mildly and negatively correlated. Most MODZCTAs in Manhattan report zero sales during the COVID-19 period in 2020 and therefore we cannot determine the change in average sale prices. For those Manhattan MODZCTAs that report sales during the relevant periods in 2019 and 2020, the average sale price of one- or two-family homes either falls drastically by as much as $12.4 million or increases dramatically by up to $10.3 million. Across the remaining boroughs, around two-thirds of MODZCTAs experience a modest increase in average sale prices.

5 Results

Our empirical analysis has three components. In the first two, we estimate the COVID-19 case effect on the sale price of NYC one- and two-family homes using the full sample of one- and two-family homes as well as the restricted repeat-sales sample. In the third, we quantify the pandemic's impact on the volume of these transactions. While the first two price analyses are grounded in the hedonic framework, the latter employs a Poisson model to capture the adjustments in sales counts. Given the large volume of the NYC real estate market, we not only employ the full sample of one- and two-family home sales, but are able to take advantage of a more restrictive sample of repeatedly-sold properties improving our identification of the COVID-19 impacts across the hedonic and Poisson methodologies. For all specifications, we cluster the coefficient standard errors at the MODZCTA level adjusting for correlations within these neighborhoods. Depending on the sample restriction, this implies adjustments across 155 to 173 clusters for our primary analyses.

Regarding our price analyses, the traditional measures of goodness of fit lend support to our modeling choices. For our full model specification applied to the full sample of one- and two-family homes the regression produces a F-statistic of 13.2 statistically significant at the 1% level. With respect to the repeat-sales sample, our preferred estimation delivers a F-statistic of 28.5 that is also statistically significant at the 1% level. Regarding the volume (i.e. number of sales) analysis, our preferred models yield the lowest log-likelihood values across any of our specifications and the traditional tests of the goodness of fit deliver insignificant deviance and Pearson statistics that suggest the appropriate use of the Poisson distribution to model the frequency of sales. This is true for the full sample of one- and two-family property transactions as well as the preferred repeat-sales sample analysis.

5.1 Price Analysis

We begin our price analysis with the full sample of one- and two-family home sales between January 1, 2018 and July 31, 2020 and an estimation of the parsimonious model that solely includes a constant and the rate of cumulative MODZCTA Coronavirus infections per 100,000 residents. Column (1) of Table 2 shows that the naíve, unconditional coefficient estimate suggests a negative, yet statistically insignificant, correlation between the rate of infections and average NYC one- and two-family home sale prices. This estimate remains negative and statistically insignificant when we include home characteristics, such as the age of home, its building and lot square footage, number of floors, and whether the property has a basement and has been altered since 2000 (see column (2)).[10] The inclusion of borough and time fixed effects notably increases the size of our coefficient of interest and renders the estimate statistically significant at the 1% level. That is, controlling for the listed property attributes, common trends and/or seasonality of the NYC real estate market, and time-invariant differences across NYC boroughs, an additional 1,000 novel Coronavirus infections per 100,000 MODZCTA residents are associated with a $138,000 reduction in the average property sale price (see column (3) of Table 2).

Following Equation (1), the results for the complete model specification are given in column (4) of Table 2 and based on an expanded set of spatial fixed effects. Controlling for these local time-invariant differences across NYC neighborhoods, along with home characteristics and common time trends, renders the coefficient estimate of interest statistically insignificant and overturns its sign. Combined, the estimates reported in columns (1) through (4) suggest that while larger COVID-19 case numbers occur in neighborhoods of lower-valued properties (see columns (1) through (3)), a worsening of the COVID-19 outbreak within any given neighborhood does not cause a reduction in the average value of concurrently sold properties within that MODZCTA (column (4)).[11] This finding echoes some of the recent reports on COVID-19, which have shown that the outbreak is more concentrated among poorer individuals (Goldstein, 2020), who are more likely to own or occupy lower-valued homes. But when we control for these differences across neighborhoods, an increase in the rate of infections within a high- or low-valued neighborhood does not seem to cause a change in the average price of properties sold within that given locale. This remains true even when we differentiate the average COVID-19 price effect by borough. None of the interaction terms shown in column (5) of Table 2 are statistically significant at the conventional levels.

In terms of our control variables, most of the included home characteristics carry the expected sign (Chau and Chin, 2003) and three are statistically significant at the 1% or 10% levels (see columns (4) and (5) of Table 2). Across the statistically significant estimates, we find that a newer home commands a relatively small price premium of around $1,700 per year, whereas an alteration to a given property, that changes the assessed value for the purposes of taxation, has a large positive impact on the average sale price within a

[10] According to the meta data of the $PLUTO^{TM}$ dataset, the NYC Department of Finance defines alterations as modifications to the structure that, according to the assessor, change the value of the real property. The year of alteration is based on the associated building permits.

[11] One possible explanation may be that the contemporaneous level of infections is less important than the past severity of the outbreak when a property was showing on the market. Accordingly, we test whether lagged MODZCTA Coronavirus case rates exert more influence on home sale prices than the contemporaneous COVID-19 measure. In short, we do find any statistical evidence of these potential dynamics.

Table 2: COVID-19 Case Effect on NYC One & Two Family Home Prices

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	All Sales Sale Price (in $100,000)					Repeat Sales Δ Sale Price (in $100,000)	
	Parsi-monious	incl. Home Charact.	incl. Boro Fixed Effects	incl. MZCTA Fixed Effects	by Boro	Avg. Effect	by Boro
Cum. Case Rate ('000)	-0.153	-0.109	-1.387***	0.140		-0.996***	
	(0.096)	(0.097)	(0.426)	(0.399)		(0.254)	
Cum. Case Rate ('000) x BK					0.297		-0.266
					(0.370)		(0.339)
Cum. Case Rate ('000) x BX					0.199		-0.580***
					(0.253)		(0.205)
Cum. Case Rate ('000) x MN					-2.666		6.266
					(10.006)		(4.472)
Cum. Case Rate ('000) x QN					0.049		-0.562**
					(0.400)		(0.230)
Cum. Case Rate ('000) x SI					0.149		-0.949***
					(0.308)		(0.264)
Year built		-0.011	0.006	0.017*	0.017*		
		(0.019)	(0.012)	(0.010)	(0.010)		
Altered		2.758***	1.729***	1.345***	1.342***	5.452***	5.444***
		(0.803)	(0.392)	(0.309)	(0.310)	(0.777)	(0.778)
Home Sqft. ('000)		6.018***	4.718***	3.685***	3.686***		
		(1.032)	(0.669)	(0.577)	(0.577)		
Lot Sqft. ('000)		-0.075	0.023	0.043	0.043		
		(0.073)	(0.022)	(0.035)	(0.035)		
of Floors		2.443***	1.129**	0.580	0.580		
		(0.852)	(0.443)	(0.420)	(0.422)		
Basement		-2.400	-4.314	-3.083	-3.088		
		(3.777)	(4.013)	(2.914)	(2.915)		
Constant	7.950***	16.433	-10.171	-30.326	-30.349	2.600***	2.527***
	(0.372)	(39.973)	(24.018)	(21.396)	(21.385)	(0.125)	(0.118)
N	47,883	44,266	44,179	44,176	44,176	20,300	20,300
adj. R^2	0.000	0.173	0.393	0.510	0.510	0.119	0.121
F	2.5	7.5***	22.4***	13.2***	10.7***	28.5***	11.6***
Time-of-sale FE	N	N	Y	Y	Y	Y	Y
Borough FE	N	N	Y	N	N	N	N
MODZCTA FE	N	N	N	Y	Y	N	N
Time-of-previous-sale FE	N	N	N	N	N	Y	Y

Notes: Standard errors are reported in parenthesis. Across all specifications, we cluster standard errors at the MODZCTA level. The estimation sample underlying the results presented in columns (1) through (5) include all one or two-family homes sold in NYC between January, 2018 and July, 2020, whereas the estimation sample underlying the results shown in columns (6) and (7) is restricted to repeatedly-sold one- or two-family homes for which we observe a repeat sale between January, 2018 and July, 2020. Depending on the sample restriction and selection of control variables, these estimation samples include 155 to 161 MODZCTAs. The dependent variable in columns (1) through (5) is given by the recorded sale price in $100,000, whereas the dependent variable in columns (6) and (7) is given by the change in sale prices between sales in $100,000. The cumulative case rate is defined per 100,000 MODZCTA residents. Column (1) shows the COVID-19 cumulative rate effect per 100,000 local MODZCTA residents (measured in units of 1,000 cases per 100,000 residents) for the parsimonious model specification, while columns (2), (3), and (4) present this effect when we control for home characteristics, time and borough as well as time and MODZCTA fixed effects, respectively. In column (6), we present the COVID-19 case effect on the change in sale prices implicitly controlling for home, neighborhood, and borough fixed effects and explicitly including time-of-sale and time-of-previous-sale fixed effects. In columns (5) and (7), we differentiate the respective COVID-19 case effects by NYC borough. Statistical significance at the conventional 10%, 5%, and 1% thresholds is given by *, **, ***, respectively.

given neighborhood. For every alteration since the year 2000, the average sale price of one- and two-family homes rises by $135,000. Similarly, the a building's square footage carries a sizeable price premium adding over $360,000 in value per 1,000 additional square feet. Controlling for these characteristics, the coefficients on a property's lot square footage and number of floors carry the expected positive sign but are statistically insignificant at the conventional levels.[12]

When we turn to the repeat-sales sample and estimate our preferred specification (see Equation (2)), we find that the negligible local pandemic effect on the average value of sold homes is overturned. Among recent transactions (since January, 2018) of repeatedly-sold NYC one- or two-family properties, a worsening of the local COVID-19 outbreak has a statistically significant negative impact on sale prices. That is, for every 1,000 additional cumulative cases of the novel Coronavirus per 100,000 residents within a given MODZCTA, the change in prices between sales of a given property drops by nearly $100,000 on average (see column (6) of Table 2). This negative impact on sale prices appears to be primarily driven by repeatedly-sold properties in the Bronx, Queens, and Staten Island (see column (7)).

How can we reconcile these differences in coefficient estimates regarding the pandemic's impact across the full and restricted repeat-sales samples? One plausible explanation is that COVID-19 has changed the distribution of homes that are on the market with respect to unobservable property-specific characteristics. If, for example, a rise in local cases causes the more affluent home owners within a given neighborhood to sell their relatively higher-valued properties, perhaps in response to the early soar in NYC COVID-related deaths, fear of infection through children in overcrowded public schools (Goodman and Rashbaum, 2020; Haynes, 2020) or improved access to remote work, the distributional shift in the types of sold homes will raise the average price within a given MODZCTA, even though the pandemic has lowered the value of all local properties (sold and unsold). The repeat-sales sample overcomes this issue by differencing out unobservable property-specific characteristics, such as whether a home is a relatively high-valued property within a given neighborhood, which may be uncorrelated with the observable characteristics we previously included. The repeat-sales estimate of the COVID-19 effect is therefore identified through the variation in price and COVID-19 exposure at the property level, rather than changes in the average price across a given neighborhood, where the sample of sold homes may have been altered by the pandemic itself. Accordingly,

[12] The PLUTO^{TM} dataset includes a number of potential control variables that describe the characteristics of a sold property. Among the possibilities, we integrate structural home attributes that are consistently available for our sample of sold homes and have been shown to be relevant determinants of house sale prices in the previous literature (see, for example, Chau and Chin (2003)). Our results are quantitatively and qualitatively robust to the inclusion of alternative characteristics, such as indicator variables for NYC neighborhood or health area, among others, and are available upon request.

we interpret the repeat-sales estimate as the causal effect on COVID-19 on NYC property prices.

Since our identification strategy rests on the repeat-sales sample to make this argument, we conduct a host of robustness checks to test the sensitivity of these repeat-sales sample findings. A detailed description of these tests, along with the relevant coefficient estimates, is provided in the Appendix (see, for example, Table A1). Briefly, we note that our estimate holds up to a variety of sample restrictions (i.e. exclusion of outliers or inclusion of past repeat sales since 2003, among others) and alternative measures of COVID-19 intensities (i.e. the rate of new infections or borough-level case rates). All of these robustness checks produce quantitatively and qualitatively consistent results. Moreover, by strategically restricting the sample of repeat sales we are able to test a number of the assumption underlying our identification strategy and implement a quasi-difference-in-differences approach. Each of these tests yields an estimate consistent with our primary price effect shown in column (6) of Table 2 and provides further evidence in support of our argument that COVID-19 causes an economically and statistically significant reduction in NYC property sale prices.

5.2 Volume Analysis

We now turn towards the aforementioned volume analysis to gain a fuller understanding of the overall impact of the pandemic on the NYC real estate market and shed more light on these potential distributional shifts that can offer an explanation for the insignificant neighborhood-level price estimate. Similar to the price analyses, we begin with an investigation of the full sample COVID-19 effects on the number of sales of one- and two-family homes between January, 2018 and July, 2020. To this end, we aggregate property-specific daily transactions and MODZCTA-specific cumulative case rates up to monthly MODZCTA transaction counts and infection rates. This aggregation yields up to 5,363 observations of the monthly number of sales and infection rates reported for up to 173 MODZCTAs observed over 31 months. We scale the cumulative monthly infection rates dividing by 1,000. The parsimonious model results are given in column (1) of Table 3 and show that the number of monthly real estate transactions are negatively and statistically significantly correlated with the rate of local Coronavirus infections. Column (2) of Table 3 demonstrates that this naíve estimate is robust to the inclusion of the aforementioned home characteristics, which now represent the average property attributes for all homes sold during a particular month in a given MODZCTA. The inclusion of borough and time fixed effects, however, overturns our key coefficient estimate rendering it statistically insignificant (see column (3)). Across these three sets of estimates, the statistically significant goodness-of-fit test statistics, however, indicate that these Poisson models may not be the most appropriate specifications.

Our preferred specification, given by Equations (3) and (4), uses more disaggregated MODZCTA fixed effects instead of Borough-specific indicators and renders these goodness-of-fit measures insignificant lending support for this modeling choice. The coefficient estimate of interest once again caries the expected negative sign, but is statistically indistinguishable from zero (see column (4) of Table 3). That is, controlling for the listed property attributes, common trends and/or seasonality of the NYC real estate market, and time-invariant differences across NYC MODZCTAs, an additional 1,000 novel Coronavirus infections per 100,000 local residents per month are associated with a moderate 4.9%$(= exp(-0.05) - 1)$ reduction in the average number of monthly MODZCTA sales of one- and two-family homes, albeit this estimate is statistically insignificant at the conventional levels.[13]

Differentiating our estimate of the COVID-19 volume effect across boroughs offers an explanation for this somewhat surprising result. The point estimates reported in column (5) of Table 3 show that three of the five boroughs, including Manhattan, Queens, and Staten Island, indeed experience statistically significant adjustments in the volume of sales in response to COVID-19. Furthermore, the negligible average estimate reported in column (4) appears to be the result of a sizeable and uniquely positive pandemic response of real estate markets in Manhattan neighborhoods offsetting the evidenced downturn in other boroughs. While the average MODZCTA in Staten Island, for example, experiences a 11.7%$(= exp(-0.124) - 1)$ decline in the number of transactions for every 1,000 additional monthly local infections per 100,000 residents, the number of monthly transactions of one- and two-family properties in the average MODZCTA in Manhattan responds positively to the worsening of the outbreak. For every 1,000 additional monthly infections per 100,000 residents in a Manhattan MODZCTA, this neighborhood is expected to experience a 37.0%$(= exp(0.315) - 1)$ increase in the volume of monthly sales, on average.

Similar to the price analysis, we also consider the volume effects of the pandemic on the number of repeatedly-sold properties in NYC. Columns (6) and (7) of Table 3 show that this estimation sample yields the expected and statistically significant results. Controlling for differences across MODZCTAs, average

[13] The traditional interpretation of a Poisson model coefficient estimate (β) is that a one unit change in x causes a β-sized expected change in the log of the mean of the outcome variable. By exponentiation β_1 and subtracting one, we can interpret our transformed Poisson model coefficient estimate as the expected percentage change in the mean of the number of monthly sales in the average MODZCTA.

Table 3: COVID-19 Case Effect on the # of Sales of NYC One & Two Family Homes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
			All Sales			Repeat Sales	
	Parsi-monious	incl. Home Charact.	incl. Boro Fixed Effects	incl. MZCTA Fixed Effects	by Boro	Avg. Effect	by Boro
Cum. Case Rate ('000)	-0.222***	-0.250***	0.087	-0.050		-0.152**	
	(0.016)	(0.014)	(0.082)	(0.047)		(0.062)	
Cum. Case Rate ('000)					-0.071		-0.197**
x BK					(0.052)		(0.087)
Cum. Case Rate ('000)					-0.008		-0.119**
x BX					(0.036)		(0.057)
Cum. Case Rate ('000)					0.315***		0.119
x MN					(0.111)		(0.134)
Cum. Case Rate ('000)					-0.085**		-0.203***
x QN					(0.042)		(0.057)
Cum. Case Rate ('000)					-0.124***		-0.227***
x SI					(0.041)		(0.059)
Year built		0.015***	0.010***	0.003***	0.003***	0.002***	0.002***
		(0.003)	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)
Altered		-0.281*	-0.165	0.050	0.046	-0.068	-0.071
		(0.156)	(0.153)	(0.071)	(0.071)	(0.071)	(0.071)
Home Sqft. ('000)		-0.562***	-0.541***	-0.047**	-0.045**	-0.041**	-0.038*
		(0.095)	(0.107)	(0.020)	(0.019)	(0.021)	(0.021)
Lot Sqft. ('000)		0.040***	0.049***	0.001	0.002	-0.004	-0.005
		(0.008)	(0.011)	(0.003)	(0.003)	(0.003)	(0.003)
of Floors		-0.077	-0.115	0.068*	0.076*	0.102***	0.109***
		(0.143)	(0.144)	(0.039)	(0.039)	(0.039)	(0.039)
Basement		-1.294	0.927	1.089*	1.186**	2.725***	2.764***
		(1.351)	(0.963)	(0.590)	(0.599)	(0.886)	(0.890)
Constant	2.244***	-24.377***	-16.432***	-6.488***	-6.507***	-7.136***	-7.166***
	(0.087)	(5.506)	(4.956)	(0.314)	(0.308)	(0.315)	(0.311)
N	5,363	5,299	5,237	5,299	5,237	5,308	5,215
Pseudo R^2	0.015	0.494	0.527	0.748	0.745	0.693	0.688
Log-likelihood	-38,658	-19,710	-18,150	-9,796	-9,779	-7,424	-7,417
Deviance Statistic	61,439***	27,724***	20,604***	3,896	3,862	2,886	2,872
Pearson Statistic	69,830***	24,697***	22,004***	3,869	3,837	2,908	2,896
Time FE	N	N	Y	Y	Y	Y	Y
Borough FE	N	N	Y	N	N	N	N
MODZCTA FE	N	N	N	Y	Y	Y	Y

Notes: Standard errors are reported in parenthesis. Across all specifications, we cluster standard errors across MODZCTAs. The underlying estimation samples include the number of sales for 170 to 173 MODZCTAs over 31 months. The dependent variable in columns (1) through (5) represents the monthly number of sales of all one- or two-family homes sold in NYC between January, 2018 and July, 2020, whereas coefficients reported in columns (6) and (7) capture the effects on the number of sales of repeatedly-sold one- or two-family homes between January, 2018 and July, 2020. The explanatory variable of interest is given by the cumulative MODZCTA Coronavirus case rate per 100,000 local residents. Column (1) shows the COVID-19 cumulative rate effect (measured in units of 1,000 cases per 100,000 residents) for the parsimonious model specification, while columns (2), (3), and (4) present this effect when we control for home characteristics, time and borough as well as time and MODZCTA fixed effects, respectively. In column (6), we present the COVID-19 cumulative rate effect on the number of monthly sales of repeatedly-sold properties. In columns (5) and (7), we differentiate the respective COVID-19 case effects by NYC borough. Statistical significance at the conventional 10%, 5%, and 1% thresholds is given by *, **, ***, respectively.

home characteristics and common trends, the average MODZCTA experiences a 14.2%($= exp(-0.152) - 1$) reduction in the number of property sales (among repeatedly-sold homes) in response to 1,000 additional novel Coronavirus infections per 100,000 residents (see column (6)). Across boroughs, this average pandemic impact on the volume of monthly one- and two-family home sales (of repeatedly-sold properties) ranges from -11.2% in the Bronx to -17.9% in Brooklyn, to -18.4% in Queens, to -20.3% in Staten Island; estimates that are statistically significant at the 5% or 1% levels. Only MODZCTAs in Manhattan exhibit a positive, yet statistically insignificant, coefficient estimate.

Lastly, we test whether this COVID-19 volume effect is homogeneous across the distribution of sale prices observed prior to the initial outbreak. To this end, we calculate the distribution of prices for each MODZCTA between January and July 2018 and 2019 and categorize each sale based on the observed sale price against the relevant neighborhood-specific pre-COVID price distribution. We create seven distinct bins including the number of sales reporting sale prices in: 1) the bottom 10%; 2) the 10^{th} percentile to the 25^{th} percentile; 3) the 25^{th} percentile to the 50^{th} percentile; 4) the 50^{th} percentile to the 75^{th} percentile; 5) the 75^{th} percentile to the 90^{th} percentile; 6) the top 10%; and 7) the top 1% of the local MODZCTA where the property is located. This categorization against the neighborhood-specific price distributions allows us to evaluate whether COVID-19 creates a neighborhood-specific change in the composition of the local real estate market and therefore influences the average COVID-19 price effect in a given neighborhood.

Panel A of Table 4 shows our findings on the number of all NYC transactions of one- and two-family homes, whereas Panel B reports the results we obtain when we restrict the sample to repeat sales only. A clear pattern emerges across both panels. As the COVID-19 outbreak worsens in a given neighborhood, we observe significantly fewer transactions of homes priced below the 2019 median and a sharp increase in the number of sales of properties at the very top of the local pre-COVID-19 pricing distributions. Sales of all homes priced in the 10^{th} to the 25^{th} percentile, for example, decrease by nearly 25%, while the number of transactions of properties priced in top 1% of the distribution increase more than 120%(≈exp(0.796)-1). For repeat sales of one- and two-family homes this contrast is even starker. While the number of transactions of repeatedly-sold properties priced in the 10^{th} to the 25^{th} percentile decreases by over 35%($= exp(-0.421) - 1$), the volume of sales of repeatedly-sold homes priced in top 1% of the distribution increases over 175%(≈exp(1.364)-1). Needless to say, this compositional change influences the average sale price observed in a given neighborhood and helps explain the neighborhood-level hedonic COVID-19 price effect estimate.

Table 4: COVID-19 Case Effect on the # of Sales Across the Sale Price Distribution

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	# of Property Sales by Sale Price based on the Distribution of Prices (Jan.-July, 2018 & Jan.-July, 2019)						
	Bottom 10 Percent	10^{th} Perc. - 25^{th} Perc.	25^{th} Perc. - 50^{th} Perc.	50^{th} Perc. - 75^{th} Perc.	75^{th} Perc. - 90^{th} Perc.	Top 10 Percent	Top 1 Percent
Panel A: All Sales							
Cum. Case Rate ('000)	-0.270**	-0.252**	-0.172**	-0.021	0.164*	0.120	0.796***
	(0.120)	(0.101)	(0.072)	(0.071)	(0.088)	(0.115)	(0.304)
N	5,299	5,299	5,299	5,299	5,299	5,299	5,299
Pseudo R^2	0.362	0.437	0.519	0.535	0.455	0.408	0.283
Log-likelihood	-4,723	-5,657	-6,778	-6,975	-5,966	-4,982	-1,415
Deviance Statistic	3,936	4,114	4,197	4,222	4,357	3,973	1,852
Pearson Statistic	3,875	3,844	3,873	3,921	4,040	4,091	3,867
Panel B: Repeat Sales Only							
Cum. Case Rate ('000)	-0.492**	-0.421**	-0.361***	-0.004	-0.121*	0.061	1.017***
	(0.212)	(0.196)	(0.120)	(0.118)	(0.071)	(0.172)	(0.245)
N	5,308	5,308	5,308	5,308	5,308	5,308	5,308
Pseudo R^2	0.341	0.401	0.468	0.475	0.408	0.384	0.276
Log-likelihood	-3,144	-3,799	-4,812	-5,107	-4,277	-3,363	-874
Deviance Statistic	3,106	3,348	3,569	3617	3,540	3,029	1,186
Pearson Statistic	3,388	3,351	3,300	3,257	3,367	3,203	2,796
Avg. Home Characteristics	Y	Y	Y	Y	Y	Y	Y
Time FE	Y	Y	Y	Y	Y	Y	Y
MODZCTA FE	Y	Y	Y	Y	Y	Y	Y

Notes: Standard errors are reported in parenthesis. Across all specifications, we cluster standard errors across MODZCTAs. The dependent variable in Panel A represents the monthly number of sales of all one or two-family homes sold in NYC between January, 2018 and July, 2020, whereas Panel B shows the effects on the number of sales of repeatedly-sold one- or two-family homes between January, 2018 and July, 2020. The underlying estimation samples include the number of sales for 172 or 173 MODZCTAs for up to 31 months, respectively. The COVID-19 cumulative case effects on the monthly number of sales are differentiated across the pre-COVID distribution of sale prices between January and July, 2018 and 2019. Columns (1) and (6), for example, show the COVID-19 cumulative case effect per 100,000 local MODZCTA residents (measured in 1,000 cases) on the number of property sales selling for an amount in the bottom and top 10 percent of all sales (Panel A) or repeat sales (Panel B), respectively. Across all regressions, we control for home characteristics, time and MODZCTA fixed effects. Statistical significance at the conventional 10%, 5%, and 1% thresholds is given by *, **, ***, respectively.

6 Discussion and Limitations

What is the economic significance of these estimates? Focusing on our repeat-sales sample results, our price estimate suggest that the average sale price of a repeatedly-sold NYC home drops by close to $100,000 for every 1,000 novel Coronavirus infections per 100,000 residents. By July 31, 2020 (the end of our sample), the MODZCTA case rates in NYC ranged from 645 to 4,679 (see Figure 2a) and averaged 2,482 infections per 100,000 residents. Combining these statistics with our estimate suggests that the expected price effects may range from close to $65,000 on the lower end in the *'least-infected'* neighborhoods to over $468,000 in neighborhoods with the highest case rates and average around $250,000. A comparison of these figures to the average 2019 NYC sale price listed in Table 1 indicates that COVID-19 has reduced home values in NYC anywhere from 7% to nearly 50% depending on the severity of the local outbreak and 27% on average. For homes that sold at least twice between January, 2003 and December, 2019, our data suggest that the average NYC property appreciated by around $150,000 (around 27%) over the course of 4.5 years between sales. More recently, homes that sold at least twice between 2017 and 2019 appreciated by roughly $100,000 (around 20%) over the course of 3.7 years between sales. Accordingly, a back-of-the-envelope calculation based on our estimate indicates that during a five-month span in 2020 COVID-19 eroded a value equivalent to an expected seven- to ten-year return on investment in residential one- or two-family home properties.

In terms of the volume of the NYC real estate market, our repeat-sales sample estimations point to a notable collapse of the NYC real estate market. Across the range of MODZCTA cumulative infection rates, our estimates suggest that the volume of neighborhood-specific NYC real estate markets fell anywhere from 9% to 66% and 35% on average by July, 2020. In comparison to 5,330 transactions of repeatedly-sold homes in the first seven month of 2019, this implies a loss of nearly 2,000 transactions of repeatedly-sold NYC one- or two-family homes in first seven month of 2020. Moreover, we find that these pandemic-induced volume effects are not uniformly distributed across all types of homes, but instead concentrated among lower-valued properties. The reduction in the number of transactions of properties selling below the median pre-COVID price in a given neighborhood explains the majority of the adverse COVID-19 volume effects, while homes priced at the top 1% of the local price distributions experience a remarkable uptick in the number of sales. The implication of these pandemic-induced compositional shifts is that housing wealth accrued disproportionately to owners of higher valued houses during the pandemic; and is a startling finding. Our results suggest that those homeowners who already started with a high degree of housing wealth saw this wealth move in the opposite direction from those homeowners with relatively little housing wealth.

While our empirical analyses produce consistent results that are in line with some of the early anecdotal evidence reported for NYC, we like to point out a few caveats regarding our findings. First, we note some data limitations. While our NYC real-estate data possess numerous property characteristics, neither the PLUTO™ or NYC Department of Finance data provide detailed home characteristics typically associated with a home's value, such as the number of bedrooms or number of bathrooms. In absence of these attributes, it is possible that our initial hedonic analysis may not be precisely tuned to the nuance of each individual property. The repeat-sales analysis, however, differences out such time-invariant unobservable characteristics and should render unbiased coefficient estimates.[14]

Similarly, apartment-level property characteristics are not available since the data are reported on the borough-block-lot level. In other words, two apartment units in the same building receive the property characteristics of the overall building, rather than the specific details of each unit. Since we focus on residential one- or two-family properties, this does not impact our analysis. And, while the majority of NYC real estate transactions indeed involve one- or two-family properties, it is noteworthy that this is not the case for the Manhattan residential real estate market, where the bulk of transactions involves apartments and condominiums. Consequently, the omission of apartments from our analysis implies that our results related to Manhattan likely comprise only a very small subset of the Manhattan entire real-estate market. Though, as many New York City residents will remind those living in Manhattan, NYC has five boroughs and thus our analysis can still offer a meaningful first glance at the impact of COVID-19 on this major U.S. urban center.

This latter comment also points to the limits of the external validity of our study. First, our analyses pertain to New York City. While this is a key real estate market in United States and our results can produce a useful benchmark that may be indicative of the COVID-19 impact to be expected in other larger urban centers, it may not be reflective of all U.S. real estate markets and their responses to the current pandemic. Moreover, our analyses apply to one- and two-family homes. The estimated pandemic impact on these types of residential homes may be different from that of other residential properties, such as apartments and condominiums, or commercial real estate and leaves room for future investigations.

7 Conclusion

The novel Coronavirus pandemic has been rampant and relentless throughout the U.S. over the past year. While there is some optimism that a safe and effective vaccine may soon be available, there are several uncertainties as to whether this virus will completely disappear any time in the foreseeable future. Immunity may be short-lived, and therefore ongoing regular vaccination (such as annually) may be necessary. It is not clear whether there would be a sufficient number of American residents willing to take a vaccine, which can dramatically diminish the percent of the population that would be immune. Also, a dismal tidbit of

[14] It is possible that the alteration of a property may change the number of bedrooms and bathrooms. If such alterations are officially permitted and change the assessed value of a home, the PLUTO^{TM} dataset reports such changes and we explicitly control for them via an indicator variable. If such alterations are unreported, even the repeat-sales estimator misses the changes in home attributes and it is one weakness of this analysis that we attempt to address via a few robustness tests reported in the Appendix.

history is that the 1918 Spanish Flu pandemic was still around in 2010 in the form of the H1N1 flu. This leads one to ponder: will the novel Coronavirus continue to mutate and linger around for decades?

Even if the novel Coronavirus does not persist for as long as some other viruses have, there are likely to be subsequent waves before the virus is completely eradicated. These ongoing concerns could lead to long-term structural change in how people think about their desired dwelling locations. Density in big cities in the U.S. can facilitate transmission, due to close proximity of other individuals in tight living quarters, use of mass transit due to scarce parking and road traffic, crowded public schools, and houses that are closer together than those in the suburbs. Even within many large U.S. cities, neighborhoods with lower-valued real estate often have residences that are closer together. Therefore, these concentrated neighborhoods may be more prone to spreading the virus than higher-valued homes in more affluent neighborhoods with larger lots of land and plentiful parking available for private vehicles. Neighborhoods with more cases may be more adversely affected and therefore residents may be more likely to choose to move out, and this demand decrease may adversely affect residential real estate prices. These anecdotes underscore the importance of studying the relationships between residential real estate prices and the incidence of the novel Coronavirus. The demographics and real estate markets of New York City facilitate such an analysis for residential real estate sales across the five boroughs. In this paper, we model how individual residential real estate sale prices in New York City have been impacted by growing numbers of cases of the novel Coronavirus in nearby hospitals. We also examine how the growing pandemic has affected the volume of home sales and the composition of properties that are sold in the market.

Our results have shed new light on these issues. In a traditional hedonic specification, where we include the rate of cumulative cases as a regressor, we find a negative statistically significant relationship between case numbers and one- or two-family residential real estate prices across all neighborhoods within a NYC borough. But when zooming in closer to neighborhoods with high priced houses and others with lower priced houses, we see no statistically significant relationship between cases and the average price of sold houses in those neighborhoods. The initial analysis raises the question of whether the estimate implies that COVID-19 has no impact on prices or whether this negligible average price effect at the neighborhood level is the result of a change in the local composition of sold properties.

We drill down deeper to answer this question and explore causality. Our repeat-sales approach for the period 2018-2020 enables us to identify the causal relationships between infections (i.e., through the change in nearby cumulative cases between the two sales dates of a given property) and sale prices (i.e., the change in sales price for a property's two sales) at the property rather than average neighborhood level. Controlling for observable and unobservable time-invariant home and neighborhood characteristics, we find that a given property's sales price falls by an average of approximately $100,000 in response to an additional 1,000 Coronavirus infections per 100,000 residents of the local MODZCTA. Up through roughly the first half of 2020, the MODZCTAs with the least number of infections relative to the local population experienced slightly less than a 7% decrease in property prices due to COVID-19, while the MODZCTAs with the greatest numbers of infections per resident saw prices fall by nearly half.

The third part of our analysis considers the relationship between the number of cases and the number of sales in a neighborhood. Our Poisson process leads us to uncover a negative relationship between case numbers and sales volumes on average and a pandemic-induced compositional shift in terms of the properties that sell in the market. Indeed, the highest value properties saw more sales when case rates rose, while the lowest value properties had relatively fewer sales with more infections per resident. Not only does this result help explain the misleading price effects at the neighborhood level, but it is also a crucial finding because it reveals some indirect evidence on how COVID impacts the distribution of homeowner wealth across different priced houses. Individuals who started with a greater degree of housing wealth before COVID were able to realize further housing wealth during the pandemic, while the opposite was apparent for individuals with the lowest priced houses (and therefore with relatively less housing wealth).

Several important policy implications are implied by our results. First, one could potentially estimate the financial benefits from "shutting down" a large city such as New York City during a pandemic. With fewer cases that are typically associated with a shut-down, house prices would be expected to retain greater value than if the pandemic were allowed to spread more fervently without intervention. Similarly, there could be indirect financial benefits from advances in vaccine development, and this is likely to become a buoyant industry for quite some time, given the need to address mutation and limited timeframes of immunity. There could be a role for government subsidies to pharmaceutical companies that may ultimately lower the case numbers, and in turn, these fewer case numbers could lead to higher property values. Such subsidies could be funded by taxing the homeowners who stand to gain from higher property values due to faster reductions in the number of cases.

Finally, the distributional impacts are critical. With lower-priced houses selling less in response to more cases, perhaps federal and state-level stimulus programs could effectively target homeowners in the neighborhoods of large cities where there are lower-priced houses and increasing numbers of cases.

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Appendix

We conduct a host of robustness analyses to test the sensitivity of our primary COVID-19 price effect (see column (6) of Table 2). We begin by adjusting the restrictions on our repeat-sales sample. While the primary results are based on the more recent transactions of repeatedly-sold properties (i.e. at least one recorded sale since Dec. 31, 2017), we have data on repeat sales since January 1, 2003. In column (1) of Table A1, we report the estimated COVID-19 price effect when we relax this restriction. While the number of observations increases from 20,300 to 98,535, the point estimate remains nearly identical and is statistically significant at

1% level. It appears the pandemic has a notable impact on house prices even in comparison to transactions over the last two decades, including those sold during or shortly after the Great Recession.

Next, we consider the sensitivity of our result against the presence of influential outliers. One criticism against the use of repeat-sales samples has arisen from the literature of price indexes, which have been shown to be more sensitive to outliers when relying on a repeat-sales sample (see, for example, Wallace and Meese (1997)). Although we are not using the repeat-sales sample to construct a price index, we investigate the potential impact of outliers. Excluding transactions that are more or less than three standard deviations removed from the average change in sale prices between repeat sales reduces the number of observations by 262 transactions. The coefficient estimate of interest, however, remains stable and statistically significant at the 1% level (see column (2) of Table A1).

Another potential concern with repeat sales are potential changes in unobservable property characteristics between sales. While the PLUTO^{TM} database indicates whether a home has been altered from the perspective of the assessed value for taxation purposes and we control for this alteration, it is possible that some properties undergo changes that are not necessarily captured by the tax authority and therefore unobservable to us. This may be particularly likely for homes purchased for investment purposes, which may receive a few non-structural updates/renovations and are resold quickly. To avoid the potential influence of such properties, we take two distinct approaches to exclude them. In the first, we restrict the sample to properties for which the duration between sales exceeds five years. We believe that these homes are unlikely to be 'flipped' investment properties and therefore less likely to suffer from the potential bias of unobservable and valued home characteristics that have changed between sales. Column (3) of Table A1 shows that this removes a large number of transactions of repeatedly-sold homes and nearly doubles our coefficient estimate in absolute magnitude. That is, among homes that are less frequently sold the COVID-19 price discount is even larger. An alternative strategy to address the issue of more frequently sold investment properties is to the restrict the sample of homes that have only sold twice since 2003. This excludes roughly half of the observations of repeatedly-sold properties and renders a COVID-19 price effect similar in magnitude to our primary estimate and statistically significant at the 1% level.

Table A1: Robustness Tests of Repeat-Sales COVID-19 Price Effect

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	Sample Restrictions									Alternative Pandemic Measures			
	All Repeat Sales	No Out-liers	> 5 yrs. between Sales	# of Sales < 3	< 5 yrs. between Sales	> 1 Sale since Dec. '17	Sales after Feb. '20	Sales after Feb. '20	Quasi Dif-in -Difs	30-Day Lag	60-Day Lag	Rate of new Cases	Borough Case Rate
Cum. MODZCTA Case Rate ('000)	-1.045***	-0.841***	-1.769***	-1.160***	-0.472**	-0.798***	-0.723**	-0.963**					
	(0.283)	(0.171)	(0.484)	(0.327)	(0.237)	(0.275)	(0.281)	(0.427)					
Quasi Treatment Effect									-0.653**				
									(0.276)				
Lagged Rate Effect										-1.056***	-1.265***		
										(0.276)	(0.382)		
New MODZCTA Case Rate ('000)												-12.057**	
												(5.645)	
Cum. Borough Case Rate ('000)													-2.362***
													(0.648)
N	98,535	20,038	10,256	11,933	9,787	6,691	999	515	644	20,300	20,300	20,300	20,300
adj. R^2	0.081	0.071	0.120	0.118	0.047	0.002	0.226	0.204	0.222	0.119	0.119	0.118	0.120
F	26.7***	73.8***	16.6***	22.9***	22.6***	19.6***	9.2***	3.0*	6.1***	31.7***	30.3***	24.6***	27.4***
Home Charac.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Time-of-Sale FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Time-of-Pre.-Sale FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Standard errors are reported in parenthesis. Across all specifications, we cluster standard errors across MODZCTAs. Depending on the imposed sample restrictions, we observe sales in 105 to 159 MODZCTAs anywhere from as early as January 2003 through July 2020 or as late as March through July 2020. Columns (1) through (8) show the COVID-19 cumulative case effect per 100,000 local MODZCTA residents (measured in 1,000 cases) on the change in sale prices between repeat transactions under varying sample restrictions. In column (9), we estimate the quasi treatment effect of cumulative Coronavirus infections on the change in prices for homes sold after the signing of the New York State on PAUSE executive order. In columns (10) and (11), we report the 30-day and 60-day lagged effect of cumulative MODZCTA infection rates. In column (12), we report the impact of changes in the MODZCTA rate of new Coronavirus infections and in column (13) we show the effect of change in borough, rather than MODZCTA, cumulative infection rates. Across all regressions, we control for home characteristics, time-of-sale and time-of-previous-sale fixed effects. Statistical significance at the conventional 10%, 5%, and 1% thresholds is given by *, **, ***, respectively.

Alternatively, we can reverse the logic and estimate whether the pandemic price effect is notably different for those homes that sold more frequently. To this end, we employ two sample restrictions. We start by restricting the sample to properties that have reported at least two transactions with less than five years between sales, one of which must have occurred since January, 2018 (see column (5) of Table A1). Secondly, we impose an additional restriction that requires at least two of these sales since December, 2017 (see column (6) of Table A1). Under the former restriction we observe 9,787 sales, whereas the more restrictive latter constraint yields 6,691 sales. In both cases, we find that the coefficient estimates fall in absolute magnitude, but remain statistically significant at the 5% or 1% levels. That is, properties that sold more often in recent years and with shorter turn around times experience significant price discounts in response to a worsening of the local outbreak, but appear to be slightly less sensitive to the to effects of COVID-19 than other one- and two-family homes.

In terms of our identification strategy, there two additional potential concerns. First, there may be something inherently and unobservably different about the properties that sell during the COVID-19 period in comparison to those properties that have sold before. If, for example, properties that sold repeatedly before the pandemic experience greater appreciation between sales than the types of properties that report one sale after the pandemic, than we may falsely attribute the price discount as a result of a rise in local case rates. To address this issue head on, we can restrict the sample to only include sales of repeatedly-sold properties after the pandemic. This restriction excludes properties that never sold after the pandemic and avoids the potentially faulty comparison to pre-pandemic changes in price. In other words, under this sample restriction our identification of the COVID-19 price effect is based on the variation in case rates and sale prices after the outbreak and not on the difference in price changes before and after the pandemic. Column (7) shows that this limits the sample to 999 observations and slightly reduces the statistically significant coefficient estimate in absolute magnitude. Specifically, we find that for transactions of repeatedly-sold homes after the initial outbreak of the pandemic (i.e. after February 29, 2020) an additional 1,000 Coronavirus infections per 100,000 MODZCTA residents causes a price discount of over $70,000.

Again, this very restricted sample may include investment-type homes that have sold multiple times during the pandemic and may have undergone some unobservable improvements to offset the anticipated pandemic-induced discount. To avoid this issue, we once again impose a limit on the number of transactions of individual properties and only consider homes that have sold twice since 2003 - once before the pandemic and once after. Controlling for the usual fixed effects, we find that sales of these twice-sold properties, of which we only observe 515, experience a price discount of $96,300 for every 1,000 additional cumulative cases per 100,000 residents (see column (8) of Table A1); an estimate that is nearly identical to our primary result and statistically significant at 5% level.

A final concern is the possibility that we may confound the impact of the local intensity of the pandemic, measured by the cumulative MODZCTA Coronavirus case rate, with the effects of the shutdown of the City. That is, after the total number of Coronavirus infections rose to 7,102 in New York, Governor Cuomo signed the New York State on PAUSE executive order on March 20, 2020 shutting down non-essential business, prohibiting gatherings and imposing social distancing. Since cases rose significantly after the shut down, it is possible that we falsely attribute the price effects of this executive shutdown order to a rise in the rates of infection. To address this concern, we implement a simple quasi difference-in-differences estimator. First, we restrict the sample to transactions of repeatedly-sold one- or two-family homes that sold after the executive order on March 20, 2020. Second, we define a treatment group as those homes sold in neighborhoods experiencing a local infection rate above the median of all MODZCTA cumulative case rates observed at the time of sale. Sales in the control group include homes located in neighborhoods below the median of all MODZCTA cumulative case rates at the time of sale. If the shutdown of NYC, rather than the intensity of the local outbreak, is the cause of the estimated price effect, then our estimate of the quasi treatment effect should be insignificant. If, however, we find that homes sold in neighborhoods with greater infection rates experience significantly larger price discounts after the shutdown executive order, our estimate provides evidence of the COVID-19 price effect (rather than the shutdown effect). Column (9) of Table A1 shows a statistically and economically significant price discount for homes located in neighborhoods with a Coronavirus case rate above the City's median and lends further support to our identification strategy. Specifically, we find that after the signing of the New York State on PAUSE executive order, sales of properties in neighborhoods with a infection rate above the median experience a $55,000 price discount above that of homes sold and located in 'less' affected MODZCTAs.

Combined, these robustness tests based on various sample restrictions produce convincing evidence in support of our primary estimate of the COVID-19 price effect and the proper identification thereof. A final set of robustness analyses considers the timing of the evidenced pandemic-induced price discount and sensitivity of our results against alternative measures of the intensity of the COVID-19 pandemic. Similar to the sample restrictions, these tests produce estimates that reiterate and support our primary finding. The results reported in columns (10) and (11) of Table A1, for example, show that the estimated COVID-19 price discount likely grows with time. We find that 60 days after a rise in local infections the price discount increases to $126,500 for every 1,000 additional cases per 100,000 MODZCTA residents two month ago. If we consider rates of new infections rather than the cumulative count, the estimate remains statistically significant and grows more than three-fold. For every 100 new Coronavirus infections per 100,000 residents house sale prices fall by $120,000 (see column (12) of Table A1). Lastly, we consider case rates at the borough, rather than MODZCTA, level. Again, the effect remains statistically significant and more than doubles in size.