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Housing market volatility under COVID-19: Diverging response of demand in luxury and low-end housing markets

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ABSTRACT

The ongoing pandemic has led to substantial volatility in residential housing markets. However, relatively little is known about whether the volatility is dominated by housing demand or supply, and how different priced markets contribute to the volatility. This article first examines the temporal effect of COVID-19 on house prices, housing demand, and supply in Los Angeles, and second explores the effect heterogeneity in luxury and low-end housing markets within the city. For identification, the article employs a revised difference-in-differences (DID) method that controls more rigorously for unobservables and improves on the traditional DID with smaller prior trends. Using individual level data, the result first shows that, in response to the outbreak, house prices, demand, and supply all decreased in March to May 2020 and increased in July and August 2020, with demand dominating the process. Second, the heterogeneity exploration identifies diverging COVID-19 impacts in higher- and lower-priced markets. Particularly, the decline in overall price and demand before June originates mainly from the lower-priced market while the higher-priced one experienced limited changes in demand. After July, higher-priced markets led housing market’s surge in price, demand, and supply, whereas the lower-priced market has not fully recovered from decreases in house prices and housing demand. Finally, a larger price decline in lower-priced markets is found to be associated with higher service shares and lower homeownership rates. The results not only facilitate market participants in their decision making but also aid local governments in formulating policies and allocating subsidies to mitigate the effects of the outbreak.

1. Introduction

The outbreak of COVID-19 has produced devastating and far-reaching impacts on people’s lives and economic conditions with the severe public health risk, the drastic drop in GDP,\(^1\) and the unprecedented stay home orders. A growing literature has studied the effect of COVID-19, including studies on stock markets, REITs, household spending (Baker et al., 2020a; Ling et al., 2020; Milcheva, 2020; Baker et al., 2020b), and residential housing markets (Del Giudice et al., 2020; Allen-Coghlan and McQuinn, 2021; Zhao and Housing, 2020; Tian, Peng, and Zhang, 2021; Cheung et al., 2021). The current analyses on housing primarily focus on the COVID-19 effect on house prices, and relatively little is known about the underlying driving forces of housing market volatility.

In fact, the transaction volume dropped as far as 50% in Los Angeles (LA) in May 2020. Is this drastic decrease dominated by demand or supply? If it were led by demand, house prices would decrease, and housing markets might mainly suffer from unemployment, income losses, and uncertainties in future house price movements. If otherwise, house prices would increase, and crucial issues in housing markets might lie in the supply side that sellers are reluctant to expose their families amid the high infection risk and new constructions are struggling from persistent delays and rising costs following the pandemic. As situations evolve with ease of stay-at-home restrictions, expansionary monetary policies, and fiscal stimulus packages, whether and when the market is expecting a rebound, and how have housing demand and supply changed over time to result in the rebound?

This article, in an attempt to answer these questions, first examines the temporal effect of COVID-19 on house prices, housing demand, and housing supply. To explore what might have contributed to the overall demand and supply volatility, the study second examines different priced housing markets due to their intrinsic wealth difference that

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might lead to diverging response of housing demand and supply to COVID-19. Specially, the lower-priced might suffer from reinforcing negative impacts from losses in income, instabilities in employment, and lack of health care for households in this market, whereas the higher-priced might not be as negatively impacted. Finally, to investigate what unique negative shocks has COVID-19 brought that help explain the market downturns in LA following the pandemic, the article studies variations in the effect on house prices by service shares (ratios of residents working in Food, Accommodation, and Entertainment) and homeownership rates. Specifically, service industries require face-to-face interactions and can’t be shifted online. They are subsequently devastated the most by the outbreak with higher unemployment rates and larger income losses2 that might lower housing demand; compared to homeowners, renters are more flexible with lower transaction and moving costs. They are consequently able to reduce their housing consumptions by moving to friends’ or relatives’ when facing a sudden fall in income, possibly forcing the landlord with financial difficulties to sell their houses at lower prices.

For identification, the study employs a revised difference-in-differences (DID) strategy, developed from Diamond and Timothy (2019)’s method, to deal with these identification issues. Specifically, the revised DID pairs properties that are within close proximity and are of similar square footage and property types, so that the unobservables in land, neighborhood, and housing features can be more rigorously controlled for. Further, the price difference in treatments is matched with that in controls at the same location and month to better account for how prices of similar homes might trend without the outbreak. Multiple pairs of comparable properties are constructed for each and every property with a transaction record, facilitating more accurate estimations and enabling mapping of the effect as a continuous function of time after the outbreak with non-parametric smoothing.

The research is based in LA, the U.S., which has a large population of 4.085 million, a COVID case number of 0.573 million, and a vibrant and diversified housing market with ample variations in house prices, neighborhood service shares, and homeownership rates.3 Using individual level property data in LA with the revised DID method, the empirical results show that the current pandemic leads to house price declines in March to May 2020 with the largest decreasing rate reaching approximately 3% in May which is the best time to enter markets. That translates to a loss in housing wealth of about $18,750 based on the median house price of $625,000 in LA. After June, house prices started to increase as a result of the pandemic with the appreciation rate reaching approximately 4% in August. Both housing demand and supply experienced decreases in March to May and saw increases after June with changes in demand dominating the price volatilities for the two periods.

The afterwards heterogeneity exploration identifies diverging effects of COVID-19 in the higher- and lower-priced markets—declines in both house prices and housing demand for the general market before June originate mainly from the lower-priced market rather than the higher-priced one that only experienced a slowdown in house price appreciations; in contrast, increases in both house prices and housing demand after June are occurring mostly in the higher-priced market as opposed to the lower-priced one that has not completely recovered from the drop in house prices and housing demand. Finally, both higher service shares and lower homeownership rates are associated with larger house price declines within the lower-priced neighborhood. The largest house price decline of about 9% happens in May 2020, exactly in neighborhoods characterized as low in house prices, high in service shares, and low in homeownership rates. The results are robust across different choices of pre-treatment periods, data sources, and matching standards. A similar result is also identified in New York City (NYC).

The article firstly contributes to provide a new research methodology. Existing studies suffer from limitations in methodology by employing Ordinary Least Squares (OLS), fixed-effects (FE), or a traditional DID method (Del Giudice et al., 2020; Allen-Coghlan and McQuinn, 2021; Zhao and Housing, 2020; Tian et al., 2021; Cheung et al., 2021). Specifically, OLS and FE suffer from lack of controls on housing and neighborhood characteristics, leading to biased estimates when houses transacted after the outbreak differ significantly from those transacted before. Moreover, even if the properties are identical, these two methods fail to account for how house prices would trend without COVID-19. A traditional DID method can partially solve this issue by accounting for house price trends with aggregate level average price differences, but it is in essence a fixed-effect approach that only controls for zip-code, county, or city level fixed effects. The control and treatment properties might thus still differ, tending to violate the parallel trends assumption. The revised DID can improve on the traditional method on the prior trends issue.

The article secondly contributes to the understanding of the underlying driving forces of housing market volatilities under COVID-19, which are under-explored in the literature. This study is among the earliest to reveal the housing demand and supply changes amid the outbreak. After acknowledging that it is the housing demand that dominates the house price volatility, the article further discovers that lower house prices, higher service shares, and lower homeownership rates play a significant role in suppressing the housing demand in LA. Those mechanisms might also contribute to the understanding of housing markets in regions similar with LA in its COVID-19 spread and containment status, public health regulations, industry compositions, and demographic features; for less similar areas, the general mechanism might still apply but the extent of the result similarity depends on how much the area differs from LA.

Thirdly, the findings contribute to the broad literature studying the effect of sudden negative shocks on house prices, like a cholera epidemic in the 19th century, SARS, financial crisis, natural disasters, etc. (Ambrus et al., 2020; Wong, 2008; Ambrus et al., 2020; Shilling et al., 1990; Mian and Sufi, 2011, 2016; Campbell et al., 2011; Zhu et al., 2016; Deng et al., 2015; Skantz and Strickland, 1987; Chiang and Lin-Han, 2021). Specifically, the article contributes to provide the response of house prices and housing demand and supply to the COVID shock, which adds another scenario to the literature where the adversely affected people are forcedly pressured to sell their houses for a discount. Further, the research highlights the unique roles of service shares and homeownership rates that help enlighten future studies on such events. The result also advances the finding that the disadvantaged might be more susceptible both in infection and mortality rates during a pandemic (Wong, 2010) with the new discoveries that larger declines in housing values might also appear in the poor neighborhoods, especially if the homeownership rates are low and the industry shares are high in this neighborhood.

The policy implications are twofold. On the one hand, to mitigate LA’s housing market downturns following the pandemic, housing policies might focus on recovering the housing demand in lower-priced markets with subsidies on rent and mortgage payments. Additionally, the housing market might also benefit from government policies targeting at rebuilding jobs and mitigating income losses for the service industry. The result also justifies policies promoting homeownership, which helps to stabilize housing markets during negative shocks from COVID-19. One thing to add is that financial difficulty is most likely coupled with other social issues like domestic violence and psychological distress, which have increased after the outbreak (Leslie and Wilson, 2020; Daly and Robinson, 2021). Government might thus caution against their lingering adverse effects on the future health, educational, and economic development of the household members (Almond, 2006;
Yilmazer, Babiarz and Liu, 2015; Ma and Kang, 2015). On the other hand, the soaring demand in higher-priced markets seems to be driven by easy monetary policies. This calls for government attentions on the possibility of an overheated higher-priced market. For other regions or countries, local housing policies might also benefit from LA’s experience after taking into account the similarities and differences between the region and LA.

The remainder of this paper is then organized as follows. Section 2 reviews the pertinent literature and discusses the theoretical mechanisms. Section 3 details the methodology of the revised DID method. Section 4 describes the data. Section 5 provides the results and Section 6 concludes.

2. Literature review

2.1. How COVID-19 affects house prices

Theoretically, the effect of COVID-19 on house prices is ambiguous. On the one hand, with an increasing number of people infected, the growing fear to contract the virus discourages people to shop, eat, entertain, buy, or sell houses (Viscusi, 1990; Baker et al., 2020b). This leads to decreases in both housing demand and supply. Additionally, although real estate is categorized as essential during the pandemic, the implementation of stay home orders and social distancing adds to the complexity of transactions and elongates the time needed to close a transaction, exerting downward pressure on both housing demand and supply. For instance, the touring of the open house, the title search, the employment verification, the notary services, and the title recordings are either shifted online or just postponed, especially for the first two months after the outbreak when people were trying to adjust. Lastly, uncertainties about future incomes and house price fluctuations also undermine housing purchase intentions (Zhou and Donald, 2010; Chung and Donald, 2002).

On the other hand, in an effort to combat the negative economic shocks from COVID-19, the Federal Reserve eased money supply, and lowered the interest rates in early March in their monetary policy, which helps boost the housing demand (Harris, 1989; Schwab, 1982; Brueckner and James, 1989; Sommer and Sullivan, 2018). The soaring stock market after March also helps to increase the demand for housing. Besides, the CARES Act provided $150 billion Coronavirus Relief Fund to support people and businesses during the pandemic, which creates inflation expectations that raise the housing demand (Dusansky and Koc, 2007; Hattapoglu and Hoxha, 2014).

2.1.1. Effects of affluence

The COVID-19 effect on house prices can vary with different features. To begin with, the COVID-induced influences probably differ between the higher-and lower-priced housing markets. The housing market in economically advantaged neighborhoods may be less adversely affected due to the higher income or saving of residents and prospective buyers. That is, buyers may still be able to purchase houses and sellers can hold longer to not sell for a discount (Stein, 1995; Genesove and Mayer, 2001). Further, lowered interest rates, rising inflation expectations, and high-rocketing stock prices may also render the higher-priced neighborhood an investment heaven for hedging against risks. The disadvantaged neighborhoods, however, might be more vulnerable to the negative shock with the pre-existing disadvantages in income, savings, and health care. The exploration can thus shed lights on how the two priced markets respond to the COVID-19 shock, and how they might have contributed to the overall housing market volatility.

2.1.2. Effects of service shares and homeownership rates

Second, the COVID-19 effects on housing may also differ in neighborhoods with different industry shares and homeownership rates. Individuals working in industries that require in-person contacts may experience larger income reductions (Baker et al., 2020a). According to the U.S. Bureau of Labor Statistics, the unemployment rate of the service industries is 16.7%, which is the highest among all industries in December 2020. If the individuals employed in service industries are homeowners, they might stay put even when facing unemployment or pay cuts (Gerardi et al., 2017). The reasons are that homeowners not only have higher transaction costs associated with moving but they also are more emotionally attached in their neighborhoods where they plan to settle down. Thus, compared to renters, homeowners are less likely to relocate with a sudden income shock (Green and Patric, 2001; Chan, 2001; Coulson and Lynn, 2002, 2009).

Alternatively, if these individuals working in service industries are renters of lower income, they might be the ones suffering the most. HousingLink Research conducted a survey in July on renters and landlords. This survey painted a picture of the lower-income renters since 90% of the households using their services have an average annual income of $44,000 and pay their rent on a check-to-check basis. The result specified that 28% of the renter respondents were not staying current on rent since the pandemic, 70% either lost their jobs or had working hours reduced, and 44% were unable to pay other bills beyond rent. Under such conditions, some of these renters might move to lower-rent areas or choose to crash with their parents or friends. For the renters who had to stay but could not pay rents, some of them faced evictions by landlords with changing locks, removing trash containers, or being accused of breaching contracts.

For landlords, some are also suffering from the built-up in debts with the rent reduction, delay, and left of tenants. From the survey, over 50% of the landlord respondents said they had rent past due; 12% were having difficulties paying operating costs and financial obligations; 27% were considering putting their houses for sale. Landlords with financial difficulties may end up selling their houses, since besides mortgage payments that can be postponed (but not forgiven), they still need to pay property tax, homeowner association fees, and management expenses. For these landlords, if their houses are at the same time located in lower-priced neighborhoods with less pleasant amenities, they might end up selling at a much lower price than they normally do. This can create negative pressures on house prices in areas of lower homeownership rates, higher service shares, and lower house prices. The factors that can affect the house price effect of COVID-19 in lower-priced neighborhoods might not be limited to service shares and homeownership rates. For instance, the severity of COVID-19 infections in local communities might result in differential house price effects. Unfortunately, this channel cannot be explored in this article since the local level infection data are unavailable at the moment.

2.2. LA’s background

LA has the second-largest population of 3.967 million in 2019 following NYC in the U.S. and has the third-largest GDP of $789.7 billion in 2018 after Tokyo and NYC in the world. The city provides a good research environment for the analyses. Specifically, due to the large population and economic size, LA has a vibrant and diversified housing market that offers sufficient transactions. Additionally, the COVID outbreak has hit LA’s economy dramatically. As home to Hollywood, LA is heavily dependent on service industries that account for 12% of all jobs and constitute 41% of total job losses. The large damage in this industry might then relate to the city’s historically high unemployment rate of 19% in May of 2020. Further, the city has relatively low

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4 https://www.bls.gov/web/empsit/cpseea31.htm
5 https://www.housinglink.org/Research/renter-landlord-pandemic-research
6 Some landlords might make allowances for the renters during such difficult times, especially if the renters could not pay rents at all.
7 https://www.usatoday.com/story/news/investigations/2020/11/20/landlords-use-intimidation-tricks-push-renters-out-amid-pandemic/6284752002/
homeworker rates so that there can be enough renters exercising the downward pressure on house prices. According to the Household Pulse Survey in May 2020, 40.35% adults with household income less than $35,000 in California (where LA locates) either missed or deferred rent payments. The city of LA thus provides a rich sample that enables the heterogeneity exploration by house prices, service shares, and homeowner rates. For instance, there might exist a higher income homeowner who works in industries that can be easily shifted online to purchase a new home during the pandemic; there might also exist a lower income renter who works in service industries, loses their income, and is therefore unable to pay rents and subsequently relocates to their friends’ or relatives’, forcing the landlord to sell their houses at lower prices.

LA’s major characteristics and how it compares to NYC (which serves as an external validity check in the Result Generalizability section) and the national average are shown in Table 3. Specifically, LA and NYC are quite similar in unemployment, service industry damages, homeowner rates, and rent deferment status. Compared to the nation, both cities experienced higher unemployment rates while the damage in service industries and the missing or deferring of rents are quite universal across the country, suggesting that the results identified in LA might also exist in the nation as a whole.

2.3. Former studies on housing market volatilities under COVID-19 and other sudden events

2.3.1. Housing market volatilities under COVID-19

Currently, relatively little is known about the effect of COVID-19 on residential housing markets. Del Giudice et al. (2020) study the COVID-19 effect on Italian housing markets and find an impact of -4.16% in the short run using regional level data with OLS regression. This is one of the earliest to study the Italian housing market response to the outbreak but tends to be more illustrative as opposed to a precise framework. Regional level data can also mask detailed changes in house prices. Allen-Coghlan and McQuinn (2021) examine the effect of COVID-19 on Irish housing markets and find that Irish house prices are set to fall over the next 18 months due to declines in household income and mortgage applications. This research not only studies the house prices but also looks at the mortgage market, but it bases its analyses on observing descriptive summary statistics, which does not provide a precise analysis and can mask the true effects.

Zhao and Housing (2020) identifies increases in both house prices and demand in the U.S. from April to August 2020 using zip-code level data and FE regressions. His article approximates housing demand with views of properties that might overestimate the true demand. The FE improves on the OLS but still suffers from lack of controls on property and neighborhood characteristics. It further fails to account for how the price would trend without COVID-19. Tian et al. (2021) study the effect of the outbreak on housing markets in the Yangtze River Delta in China and find that the house prices rise, and the land prices fall as a result of the pandemic. Cheung et al. (2021) analyze the effect of the pandemic on house prices in 62 areas from 9 districts in Wuhan City and find a decline of approximately 5%. These two studies are one of the earliest in exploring the effect of the pandemic on China’s housing market. They improve the analyses with a DID method and provide valuable insights into the issue. But the traditional DID still uses the average house price changes and controls for regional level fixed effects, which lacks controls on the unobservables of the control and treatment properties.

2.3.2. Housing market volatilities under other sudden events

This research also relates to a broad strand of literature studying housing market volatilities under negative shocks, like a cholera epidemic in the 19th century (Ambrus et al., 2020), the epidemic of SARS (Wong, 2008; Chien, 2010), financial crisis or distressed markets (Shilling et al., 1990; Mian and Sufi, 2011, 2016; Campbell et al., 2011; Aroul et al., 2020), natural disasters of nuclear accidents (Zhu et al., 2016), earthquakes (Deng et al., 2015), and floods (Skanzt and Strickland, 1987; Netusil et al., 2019; Chiang and Lin-Han, 2021). Except the study on the cholera epidemic, which finds a 160-year long difference in house price changes between the affected and unaffected areas, those studies almost all identify an immediate house price decrease right after the event and a recovery thereafter. Specifically, Skantz and Strickland (1987) propose that during a flood event, the house price would firstly decrease and then regain the lost value after people forget the flood. Zhu et al. (2016) find that after one month of the nuclear accident in Japan, land prices in China drop by 18%, but the effect diminishes thereafter. Similarly, Deng et al. (2015) discover that the effect of an earthquake on house values in Wenchuan China eventually decays to zero. This article will then explore whether a similar experience exists for the COVID-19 shock. In terms of the heterogeneity analyses, Wong (2010) specifies that the poor people are the most vulnerable with higher infection and mortality rates during a disease outbreak of SARS. This article will extend this finding by studying how the house price effect of COVID-19 varies in the wealthy and the disadvantaged neighborhoods.

3. Methodology

3.1. Modelling house prices

To start, the following equation describes the log of the house price, $LP_{n,t,h}$ for house $j$ in neighborhood $n$, where house $j$ locates, at time period $t$:

$$LP_{n,t,h} = f_{n,t} + X_{n,t} + T_{n,t} + C_t + \epsilon_{n,t,h}$$ (1)

where $f_{n,t}$ denotes locational neighborhood characteristics, $X_{n,t}$ represents housing features, $T_{n,t}$ captures the effect of time on house prices, and $C_t$ denotes the effect from COVID-19 at time $t$. By model assumption, $f$ includes all the observable and unobservable locational features, such as local transportation, school qualities, environments, and other amenities affecting house prices. $X$ also includes all the observable and unobservable housing characteristics. $T_{n,t}$ represents the normal time trend or the time trend without COVID-19 outbreak. $C_t$ captures all effects associated with the pandemic, including effects of infection risks, stay home orders, interest rate decreases, stock price changes, etc. $T_{n,t}$ and $C_t$ are collectively represented by time dummies. The error term $\epsilon_{n,t,h}$ denotes other factors affecting house prices. The error term is assumed to be independent of the outbreak treatment $C$ after controlling for $f, X,$ and $T$.

The challenge for identification in Eq. (1) is that it is difficult to control for all the unobservable features. For example, if the houses on sale after the outbreak are disproportionately of lower qualities, closer to schools that were closed or other factors, and the dataset used for modeling the outbreak would appear in the error term, making the error term correlate with $C$ and biasing the coefficient. In addition, Eq. (1) is unable to control for how the house price trend if there were no outbreaks.

3.2. The revised DID

The article uses a revised DID method (Diamond and Timothy, 2019)\(^8\) that builds on the traditional DID setting (Zheng et al., 2020;
and improves it by making the control and treatment properties as similar as possible. Specifically, to account for how the price would trend in 2020 if there were no COVID-19, the traditional DID setting subtracts the difference in house prices for the relevant months of the previous year from that of 2020. Specifically, the net COVID-19 effect is calculated as:

$$Net \text{ Treatment } Effect_{\text{Mar-Sep, 2020}} = (\text{APL}_{\text{Mar-Sep, 2019}} - \text{APL}_{\text{Jan-Feb, 2019}}) - (\text{APL}_{\text{Mar-Sep, 2020}} - \text{APL}_{\text{Jan-Feb, 2020}})$$ (2)

where ALP stands for the average house price of the relevant months of 2019 or 2020. The price difference of 2019 therefore serves as a counterfactual of how the price would trend if there were no COVID-19 in 2020. While this counterfactual is not perfect, it is a second optimal choice. As the world is all under the turbulence of COVID-19, it is infeasible to find controls, which exist at the same time with treatment but are unaffected by COVID-19. As to how the second optimal choice may bias the result, it depends on the severity of the pre-existing trends issue. In the Section of Robustness Checks, the article shows that the revised DID can largely improve on the pre-existing trends issue by having a much smaller prior trend than the traditional DID.

The traditional DID setting in essence is a fixed effects approach that only controls for the observable housing characteristics and fixed locational features with zip-code or county level fixed effects. The lack of controls on unobservables subsequently leads to differences not only between the control and treatment groups but also between the properties in the pre- and post-treatment periods within the two groups. This leads to biased estimates and violates the parallel trends assumption when houses transacted after the outbreak in 2020 differ significantly from their counterparts in 2019. Another problem is that the traditional DID method requires the researcher to choose an arbitrary cut-off point for the treatment, which results in a data loss.

The revised DID approach improves the traditional one with the following: first, it selects the comparable properties within close proximity (within 500 m), so that the properties are similar in their land values and neighborhood features. Second, in Diamond and Timothy (2019)’s paper, they assume that the housing characteristics are similar once their locations are controlled for, which might be detached from reality. The article then controls for differences in housing characteristics by matching sizes and housing types of properties. Specifically, the difference in square footage is capped at 15%, and the property types, such as single-families, townhomes, or condos, are kept the same. Then, even if there were significant changes in the composition of properties sold after the outbreak, the estimate would just reflect the net effect on properties of similar qualities. Third, the revised DID method matches the difference of house prices in 2020 with that in 2019 at the same location and month to control for how the price would trend without COVID-19. In this way, the difference-in-differences is based on almost identical properties for the same month of the two years, reducing the prior trends as shown in the Section of robustness checks. Fourth, the revised DID maps the treatment effect as a continuous function of time after the outbreak to make full use of the data and better visualize the effects. This revised DID therefore improves on the traditional DID through controlling more vigorously for the unobservables in locational features, housing characteristics, and time trends.

Specifically, for properties with close proximity and of similar housing features, taking the difference of their house prices specified in Eq. (1) will difference out the locational and housing characteristics and yield the price difference as a function of just time. The time effect includes both the normal time trends over the months and the effect from COVID-19. For the treat and control properties, the price difference will be constructed separately as follows:

$$\Delta L P_{\text{treat}} = L P_{\text{treat post}} - L P_{\text{treat pre}} = T(\Delta t_i) + C_i + \Delta \epsilon_{\text{treat}}$$ (3)

$$\Delta L P_{\text{control}} = L P_{\text{control post}} - L P_{\text{control pre}} = T(\Delta t_i) + \Delta \epsilon_{\text{control}}$$ (4)

where \( \Delta L P_{\text{treat}} \) denotes the difference in the sales price between properties in the post-treatment and pre-treatment periods in the treatment group. \( L P_{\text{treat post}} \) is the log price of treat-property \( a \) with transaction time \( t_b \), which ranges from March to September 2020. \( L P_{\text{treat pre}} \) is the log price of treat-property \( b \) with transaction time \( t_b \), which is January or February 2020. Properties \( a \) and \( b \) are within 500 m and similar in housing characteristics. Thus, the price difference only includes the time trend \( T(\Delta t_i) \), the COVID effect \( C_i \), and the error term difference, where \( \Delta t_i = t_a - t_b \). Similarly, \( \Delta L P_{\text{control}} \) represents the difference in the sales price for houses in the control group between post-treatment and pre-treatment periods with \( L P_{\text{control post}} \) as the price of control-post property \( a \) and \( L P_{\text{control pre}} \) as the price of control-pre property \( d \). \( \Delta t_c \) represents the difference of the transaction time for properties \( c \) and \( d \). The properties \( c \) and \( d \) are also within 500 m and are transacted within the same month of 2020 and 2019 with \( t_e \) equaling \( t_b \). Since the properties transacted in January and February are taken as transacted at the same time, \( t_e \) equals \( t_b \). Then, \( \Delta t_e \) and \( \Delta t_c \) are similar.

Finally, the net treatment effect is obtained as below:

$$\Delta \Delta L P_{\text{t}} = \Delta L P_{\text{treat}} - \Delta L P_{\text{control}} = (T(\Delta t_i) + C_i + \Delta \epsilon_{\text{treat}}) - (T(\Delta t_i) + \Delta \epsilon_{\text{control}})$$ (5)

With \( T(\Delta t_i) \) approximating \( T(\Delta t_i) \),

$$\Delta \Delta L P_{\text{t}} = C_i + (\Delta \epsilon_{\text{treat}} - \Delta \epsilon_{\text{control}})$$ (6)

The net treatment effect is then smoothed with the nonparametric method below:

$$\Psi(t) = \frac{N^{-1} \sum_{i=1}^{N} K_{\tilde{h}_n}(t - \mu(t)) \Delta \Delta L P_{\text{t}}}{N^{-1} \sum_{i=1}^{N} K_{\tilde{h}_n}(t - \mu(t))}$$ (7)

$$K_{\tilde{h}_n}(t - \mu(t)) = \frac{1}{\tilde{h}_n} K \left( \frac{t - \mu(t)}{\tilde{h}_n} \right)$$

\( N \) is the total number of properties in the treatment group for the post-treatment period. \( K(...) \) is the Epichanokov kernel with bandwidths \( \tilde{h}_n \). Since \( \Psi(t) \) is a weighted average of \( \Delta \Delta L P_{\text{t}} \), and the error terms are exogenous to the time treatment effect once the neighborhood, housing, and time features are controlled for, the error term differences are cross out when summing together. The treatment effect is therefore provided by \( \Psi(t) \) with \( t \) as the sold month of the property in the treatment group for the post-treatment period.

4. Data

4.1. Transaction data

The property data are obtained from Redfin, which includes

\footnote{In this DID setting, properties transacted in 2020 and 2019 are referred to as the treatment and the control group, respectively; March to September serve as the post-treatment period, and January to February act as the pre-treatment period. With a reorganization, the net effect could also be expressed as:

\( (ALP_{\text{Mar-Sep, 2020}} - ALP_{\text{Mar-Sep, 2019}}) - (ALP_{\text{Jan-Feb and 2020}} - ALP_{\text{Jan-Feb and 2019}}) \)

\footnote{The distances of 1 kilometer, 800 m, and 200 m are also tested. The results are consistent across different choices.}

\footnote{A robustness check on the different cut-off points is provided in the Robustness check section.}
Fig. 1. Median House Prices and Transaction Volumes in Los Angeles. Note: Panel A shows median house prices with the horizontal axis denoting the months when the contracts are signed and the vertical axis demonstrating the house price in thousands of dollars. Panel B represents transaction volumes with the horizontal axis denoting the months when the contracts are signed and the vertical axis documenting the transaction volume. 2019 denotes January 2019 to September 2019, and 2020 represents January 2020 to September 2020. Since September 2020 includes transactions till 09/14/2020, Panel B deletes data in September.

Table 1
Summary Statistics.
Panel A: Summary Statistics for Housing Characteristics in Los Angeles.
Panel B: Summary Statistics for Housing Characteristics in Treatment Post by Price Levels, Service Shares, and Homeownership Rates.

|                          | Control Pre | Control Post | Treatment Pre | Treatment Post |
|--------------------------|-------------|--------------|---------------|----------------|
| Obs.                     | 1862        | 11,505       | 2340          | 10,791         |
| House Prices             | 852,540     | 912,008      | 918,427       | 1092,522       |
| (703,434)                | (761,008)   | (753,890)    | (753,890)     | (1139,993)     |
| Square Footage           | 1668        | 1713         | 1697          | 1817           |
| (879)                    | (907)       | (914)        | (1049)        |                |
| Beds                     | 2.89        | 2.93         | 2.90          | 3.01           |
| (1.06)                   | (1.06)      | (1.10)       | (1.10)        |                |
| Baths                    | 2.23        | 2.26         | 2.27          | 2.37           |
| (0.97)                   | (0.98)      | (1.03)       | (1.11)        |                |
| Lot Sizes                | 35,838      | 35,244       | 35,086        | 33,476         |
| (78,417)                 | (79,558)    | (76,280)     | (75,228)      |                |
| Built Time               | 1961        | 1963         | 1963          | 1962           |
|                          | (27)        | (28)         | (27)          | (27)           |

Higher Price Lower Price Higher Service Lower Service Lower Price and Higher Service Lower Own Lower Own Lower Price, Higher Service and Lower Own Single-Family Condo/Townhome
| Obs.                     | 5229        | 3644         | 1368          | 1368           | 2276          | 476          | 892          | 475           | 409           |
| House Prices             | 1367,412    | 658,330      | 600,774       | 692,924       | 645,659       | 576,822      | 656,240      | 484,264       |                |
| (1221,845)              | (241,597)   | (216,439)    | (249,258)     | (211,841)     | (215,168)     | (219,494)    | (164,704)    |                |                |
| Beds                    | 2.90        | 3.17         | 2.99          | 3.28          | 3.15          | 2.91         | 2.27         | 2.55          |                |
| (1.11)                   | (1.01)      | (1.00)       | (1.00)        | (0.95)        | (1.03)        | (0.98)       | (0.86)       |                |                |
| Baths                    | 2.37        | 2.35         | 2.21          | 2.43          | 2.24          | 2.20         | 2.22         | 2.18          |                |
| (1.25)                   | (0.80)      | (0.83)       | (0.78)        | (0.81)        | (0.83)        | (0.93)       | (0.75)       |                |                |
| Square Footage           | 1858        | 1761         | 1586          | 1865          | 1702          | 1525         | 1714         | 1299          |                |
| (1207)                   | (702)       | (591)        | (741)         | (643)         | (553)         | (602)        | (395)        |                |                |
| Lot Sizes                | 24,940      | 45,424       | 35,263        | 51,531        | 34,876        | 35,470       | 6573         | 67,844        |                |
| (65,008)                 | (86,923)    | (67,824)     | (96,101)      | (81,836)      | (59,053)      | (9190)       | (72,434)     |                |                |
| Built Time               | 1959        | 1966         | 1961          | 1969          | 1961          | 1963         | 1946         | 1980          |                |
|                          | (29)        | (25)         | (30)          | (20)          | (26)          | (33)         | (34)         | (18)          |                |

Note: the values are the mean of the variables. The standard deviations are in parentheses. We categorize March 2020 to September 2020 as Treatment Post, January and February 2020 as Treatment Pre, March 2019 to September 2019 as Control Post, and January and February 2019 as Control Pre. The full sample includes all transactions in Los Angeles City (LA) and the transactions in adjacent cities that locate close to the city boundary of LA. September 2020 includes transactions till 09/14/2020. The cut-off points for house prices, service shares, and homeownership rates are $725,000, 0.12, and 0.51, respectively.
Angeles city and the transactions in adjacent cities that locate close to transactions with a lot size larger than 1,000,000 square feet or smaller and lot sizes. Property data in LA include all the transactions in Los Angeles county. The homeownership rate data are from the Longitudinal Employer-Household Dynamics groups in LA county. The homeownership rate data are from the cut-off points of service shares and homeownership rates are for all block for all properties transacted from January 2019 to September 2020. The house price cut-off points are ties that fall into different sub-groups categorized by house price levels, respectively.

4.2. Service shares and homeownership rates

In Fig. 2, the article maps the distribution of Treatment Post properties that fall into different sub-groups categorized by house price levels, service shares, and homeownership rates. The cut-off points (25th percentile, 50th percentile, and 75th percentile) to categorize different groups are provided under the figures. The house price cut-off points are for all properties transacted from January 2019 to September 2020. The cut-off points of service shares and homeownership rates are for all block groups in LA county. The homeownership rates data are from the American Community Survey of 2014–2018 and are downloaded from Integrated Public Use Microdata Series (IPUMS). The industry share data are obtained from the Longitudinal Employer-Household Dynamics (LEHD) in 2017.

5. Results

5.1. Discussion of descriptive statistics

Panel A of Table 1 shows that houses sold from March 2020 to September 2020 (Col. (4) in the table) are larger in square footage and older than those sold from January and February 2020 (Col. (3)) as well as those from March 2019 to September 2019 (Col. (2)). The revised DID method can control for these differences by selecting properties with similar home locations and housing characteristics. Thus, the study is investigating houses with comparable attributes as opposed to comparing larger houses to smaller ones. From Panel B of Table 1, there are disproportionally more properties in the area of higher house prices. Within the lower-priced area, there are more properties in the district of lower service shares. Panel A of Fig. 1 shows that the median house price in LA decreased in March and May of 2020 compared to 2019, and it increased dramatically after June 2020. One immediate reason is that disproportionally more houses priced over 2 million were sold after June 2020 (8% compared to 4% for former months), suggesting that the luxury housing market was extraordinarily active after the end of May. For transaction volumes shown in Panel B of Fig. 1, LA went through sharp drops in transaction volumes through February to May 2020 compared to 2019. The decrease might be from declines in housing demand and/or supply. Whether this will lead to a rise or a drop in house prices depends on the relative change in demand and supply. For the overlap of properties in different sub-groups shown in Fig. 2, 47% of higher-priced houses locate in areas of higher service shares, and 54% locate in areas of lower homeownership rates; 62% of lower-priced properties locate in lower service share areas, and 60% locate in areas of higher homeownership rates. The overlaps are thus not overwhelmingly large.

5.2. Results for LA

This section begins by showing how house prices in LA respond to the outbreak. Employing the revised DID method described in preceding sections, the result is shown in Panel A of Fig. 3. The horizontal axis in the figure denotes March to mid-September 2020, which represents when the offer is signed. The vertical axis shows the price impact. Panel A of Fig. 3 specifies that the outbreak leads to house price declines in LA starting in early March, when the virus started to spread in the region. The decreasing rate reached the maximum of 2.7% in late April and gradually returned to zero in early July. Afterwards, the house price started to increase at an accelerating rate in July to early-September in response to the outbreak. This indicates that while the outbreak indeed hurts house prices in March through June, the housing market recovered thereafter and even experienced a surge. The results provide the 95% significance bonds and are significant. To understand what might have happened that leads to the volatility in house prices, the article next investigates changes in housing demand and supply following the outbreak.

5.2.1. Housing demand and supply in LA

The article explores changes in housing demand and supply in a DID setting that can lead to the housing price effect found above. To start, the year-over-year (YOY) growth in transaction volumes and new listings for January to August 2020 are provided in Panel B of Fig. 3; second, the article employs the demand and supply model, shown in Panels C and D of Fig. 3, to derive backwards how the housing demand has shifted to

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12 The transaction time in the original data represents when the transaction closes. Since the transaction takes about 30–45 days to close, we subtract 37.5 days from the original time to better represent the market conditions.

13 The block groups are geographical areas for the U.S. between blocks and census tracts with an average number of 1,200 people.

14 This homeownership rate differs from LA’s average (36.8%) since it is just for the block groups that have transactions in the treatment after period.

15 According to the COVID data released by Johns Hopkins University, the total case number hit 100 in 3/7/2020 in California.
Fig. 2. Distribution of Properties by House Price Levels, Service Shares, and Homeownership Rates in Los Angeles. Note: these three figures display the distribution of Treatment Post properties that locate in the corresponding sub-groups categorized by house price levels, service shares, and homeownership rates. The service share is the share of residents working in Food and Entertainment. The cut-off points are the 25th percentile, 50th percentile, 75th percentile, and the maximum values, which are calculated based on all transactions from January 2019 to 14th September 2020. The cut-off points for service shares and homeownership rates are calculated based on all block groups in LA county.
result in the changes in transaction prices and volumes, conditioning on the movement in the supply (new listings). Specifically, Panel B of Fig. 3 shows that new listings and transaction volumes declined significantly more in March, April, and May than January or February, implying that the supply and transaction volumes decreased on a net basis in March to May in a DID setting. For housing demand, it needs to decrease to a greater extent compared to supply as depicted in Panel C of Fig. 3, such that the price and the transaction volume can both decrease amid a shrinking supply. In July and August, the supply increased on a net basis since their growth rates of new listings are higher than those of January and February as shown in Panel B of Fig. 3. With house prices and transaction volumes both increasing during this period, the demand needs to rise more relative to supply as shown in Panel D of Fig. 3.

Fig. 3. Effects of COVID-19 on Housing Markets in Los Angeles. Note: Panel A shows the effect of COVID-19 on house prices in LA. The horizontal axis denotes the months from March to September in 2020 when the offers are signed. The vertical axis describes the price effect. An effect of 0.02 indicates that the house price increases by 2% as a result of COVID-19. The dotted lines denote the 95% confidence intervals. Panel B provides growth of transaction volumes and new listings from the previous year (year-over-year, YOY) in January to August 2020. Panels C and D present how housing demand and supply change in a difference-in-differences setting as a result of the pandemic. The change is thus directly linked to the effect of COVID-19 on house prices in Panel A.

5.3. Variations within LA by house price levels

The article next explores how effects of COVID-19 on house prices vary in neighborhoods with different house price levels, and how these two markets might have contributed to the overall market volatility. Panel A of Fig. 4 describes that the price impact turns increasingly negative as moving from the fourth to the first price quartile. For the fourth quartile, the outbreak leads to net price appreciations for all the months after the outbreak, although the decreasing rate slowed down in April and May compared to March. In contrast, sellers from the first to the third quartile suffered from net losses in house values due to the outbreak. The article then aggregates the first and last two price quartiles to construct the lower- (Q1 & Q2) and higher- (Q3 & Q4) priced segments to facilitate afterwards explorations. The empirical results

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16 Please note that the demand and supply curves in Panels C and D are just used to illustrate how the demand might have changed. The exact elasticities of the demand and supply curves might differ from those in the figures, and different elasticities do not change the conclusions.

17 As aforementioned, the cut-off point is the median ($725 k) of all the transactions. The higher/lower priced market includes the properties with the house prices being above/below the cut-off point.
show that the lower-priced market experienced price declines in March to August with the largest depreciation rate of approximately 6% occurring in May. This translates to a decline of about $39,500 in housing wealth based on the average house price for the lower-priced neighborhood shown in Panel B of Table 1. The higher-priced market saw price appreciations for the study period. The effects are significant for both markets.

5.3.1. Housing demand and supply for the higher- and lower-priced markets

The former price effects are similar in the shape of the effect curves, which seems to suggest similar responses from the higher- and lower-priced markets to COVID-19. The article next explores housing demand and supply to see what might have happened in these two markets following the outbreak. The previously described backward induction method is applied for this exploration. Panel B of Fig. 4 shows the YOY growth in transaction volumes and new listings in January to August 2020 for the markets of higher and lower house prices. The horizontal axis represents January to August 2020. The vertical axis is the YOY growth rate. A growth rate of $-0.4$ in April for the transaction volume means that the transaction volume decreases by 40% in April 2020 relative to April 2019. Panels C and D discuss the net change in housing demand and supply in response to COVID-19 in a difference-in-differences setting.

Fig. 4. Effects of COVID-19 by House Price Levels. Note: Panel A shows the effect of COVID-19 on house prices for the four price quartiles and the higher (Q3&Q4) and lower (Q1&Q2) priced markets. The horizontal axis denotes the months (March to early September in 2020) when the offers are signed. The vertical axis is the price effect. The dotted lines denote the 95% confidence intervals. Panel B describes the year-over-year (YOY) growth rates of transaction volumes and new listings in January to August 2020 for the markets of higher and lower house prices. The horizontal axis represents January to August 2020. The vertical axis is the YOY growth rate. A growth rate of $-0.4$ in April for the transaction volume means that the transaction volume decreases by 40% in April 2020 relative to April 2019. Panels C and D show that the lower-priced market experienced price declines in March to August with the largest depreciation rate of approximately 6% occurring in May. This translates to a decline of about $39,500 in housing wealth based on the average house price for the lower-priced neighborhood shown in Panel B of Table 1. The higher-priced market saw price appreciations for the study period. The effects are significant for both markets.

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Panel C of Fig. 4 shows analyses for the higher-priced market. In March, April, and May 2020, the supply decreased as shown in Panel B of Fig. 4.\(^{18}\) Given the decrease in supply, in order for the transaction price to increase and the volume to decrease, the demand change should be relatively slight. Namely, the demand could stay constant, increase, or decline by magnitudes that are smaller than that of the supply decrease. In July and August, the supply increased in the higher-priced area, and the demand should rise a lot more to result in increases in both house prices and transaction volumes.\(^{19}\) For the lower-priced market shown in Panel D of Appendix Fig. 1, with the price plummeting and volume soaring, the supply cannot decrease.

As shown in Panel A of Appendix Fig. 1, even if the approximation for the new listing is inaccurate, the supply cannot possibly increase during this period in order for the price to increase and the transaction volume to drop.

As shown in Panel B of Appendix Fig. 1, regardless of whether the supply increases or decreases from last year, the demand needs to increase in larger magnitudes to result in increases in both transaction prices and volumes. Thus, even if the approximation is inaccurate, the conclusion that the demand needs to increase in spades remains unchanged.

As shown in Panel C of Appendix Fig. 1, no matter whether there is a supply decrease or increase during this period, the demand ought to decline in a larger magnitude.

As shown in Panel D of Appendix Fig. 1, with the price plummeting and volume soaring, the supply cannot decrease.
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B. Wang
all industries. The article then explores the effect variations by service shares in the lower-priced market to investigate how they relate to the price decline.

5.4. Variations within the lower-priced market

5.4.1. Service shares

The service share represents the share of residents working in Food and Entertainment and living in block groups where the property locations. The higher (lower) service share group includes properties located in block groups whose service share is above (below) the median service share of all block groups in the county where the property locates. The cut-off point is 12%, and 38% of properties fall into the higher service share category. This part first tests how areas of higher and lower service shares respond to the outbreak shown in Panel A of Fig. 5. The result is significant and differs from that in Panel A of Fig. 4. Specifically, the effect of COVID-19 on house prices for areas of higher service shares falls below that of lower service shares in April and May. Turning to how service shares are related to the price decline in lower-priced markets, Panel B of Fig. 5 displays that neighborhoods with more residents working in service industries indeed experienced a larger house price decline than did the lower service share neighborhood, particularly in April and May.

Table 2
The House Price Effects of COVID-19.

| Month   | Price Impact | Std Errors | Lower House Price (Panel A Fig. 4) | Price Impact | Std Errors |
|---------|--------------|------------|------------------------------------|--------------|------------|
| 3       | -0.0068      | (0.0057)   |                                    |              |            |
| 4       | -0.0259***   | (0.0043)   |                                    |              |            |
| 5       | -0.0254***   | (0.0046)   |                                    |              |            |
| 6       | -0.0071      | (0.0047)   |                                    |              |            |
| 7       | 0.0077       | (0.0042)   |                                    |              |            |
| 8       | 0.0232***    | (0.0051)   |                                    |              |            |
| 9       | 0.0336***    | (0.0086)   |                                    |              |            |

Note: this table provides the average house price impacts and the standard errors from the estimation results in the figures. *** p < 0.01, ** p < 0.05, * p < 0.1.

5.4.2. Service shares and homeownership rates

This section discusses how homeownership rates are related to the price decline in lower-priced areas. The reason that a higher service share is related with larger negative impacts could be that people working in service industries suffered from larger losses in income and employment. For these people who rent, they might not be able to pay the full rent and just downsize or move to their families’ or friends’. According to the Current Population Survey, the share of young adults (18–29) living with their parents or other relatives grew from 46% in May 2019 to 52% in May 2020. And about 40.35% of renters in LA either missed or deferred their rent payments in May 2020 according to the Household Pulse Survey. The landlords, with a lower or zero rent, might become unable to cover the operating and financial costs. The financial costs include not only mortgage payments, which can be postponed temporarily, but also property tax and homeowner association fees. Landlords with financial difficulties might subsequently put their house on sale. Some were then willing to accept a lower price than they would normally do if they had less savings to hold longer, or their houses were not of good qualities or located in less pleasant neighborhoods. Contrarily, homeowners working in service industries are more likely to stay put than renters when losing jobs, due to their higher relocation cost normally do if they had less savings to hold longer, or their houses were not of good qualities or located in less pleasant neighborhoods. The COVID-19 effect by homeownership rates within the neighborhood of lower prices and higher service shares is shown in Panel C of Fig. 5. It describes that a lower homeownership rate is indeed associated with a larger decline in house prices with the largest fall of about 8% occurring in May.

23 https://www.bls.gov/web/empsit/cpsea31.htm
Fig. 6. Distribution of the Hardest Hit Areas in Los Angeles. Note: Panel A provides the distribution of Treatment Post properties by house prices. The cut-off point between lower and higher house prices is $725,000. Panel B describes the distribution of properties by service shares within the area of lower house prices. The cut-off point between lower and higher service shares is 0.12. Panel C denotes the distribution of properties by homeownership rates within the area of lower house prices and higher service shares. The cut-off point between higher and lower homeownership rates is 0.51. Panel D provides the distribution of properties by housing types in the area of lower prices, higher service shares, and lower homeownership rates.
5.4.3. A further test on housing types

If the scenario in our former discussion holds true that the disadvantaged neighborhood with more renters working in service industries suffered from a larger loss in house prices, the situation should be worse for properties with higher rents and for landlords with lower savings. Due to the unavailability of these data for individual properties, the effect difference between condos/townhomes and single-family homes is tested. Condos and townhomes have a lower house price than single-families shown in Panel B of Table 1. According to Zillow, rents for condos/townhomes are also generally lower than those of single-families. Thus, it might be harder for single-family landlords to collect the full rent than landlords of condos/townhomes after the outbreak. Further, according to the 2018 Rental Housing Finance Survey, about 72.5% of single-families occupied by renters are owned by individual investors as opposed to 34.6% of condos/townhomes. Individual investors might be more likely to sell their house at a discount during the outbreak compared to institutional investors of trustees, partnerships, companies, REITs, etc. The result is shown in Panel D of Fig. 5, which specifies that within the neighborhood of lower prices, higher service shares, and lower homeownership rates, the larger decline in house prices happens for single-family homes rather than for condos/townhomes. This is not the case for the effect by housing types for the full sample shown in Appendix Fig. 2. The result in Panel D of Fig. 5 then is consistent with our conjecture that higher rents combined with lower savings of landlords are associated with larger price declines. The point estimates of all results are shown in Table 2.

Finally, the locations of houses with larger price decline are mapped in Fig. 6. Panel C of Fig. 6 describes that neighborhoods of lower prices, higher service shares, and lower homeownership rates locate in the lower east and upper center of LA. Within this neighborhood, single-family homes experienced the largest decline in April and May 2020, the distribution of which is shown in Panel D of Fig. 6.

5.5. Robustness check

5.5.1. The choice of pre-treatment periods

The result in Fig. 3 uses January and February as the pre-treatment period. The article then checks how the result varies with different months chosen for the pre-treatment period, including February 2020, January and February 2020, December 2019 to February 2020, and November 2019 to February 2020, shown in Panel A of Fig. 7. The figure illustrates that these results differ in their effect magnitudes but are similar in the effect patterns and signs, and the conclusion remains unchanged. The reason why February 2020 is not chosen as the pre-treatment period is that there are fewer properties that can be matched to those in the post-treatment period, creating a data loss and making the result relatively unreliable. The entire period between November 2019 and February 2020 is not chosen either. Since our method takes all properties in the pre-treatment period as transacted within the same time, this whole period has too much variation in the transaction time of properties. The article ultimately chooses January and February 2020 as the pre-treatment period since the result does not differ significantly from that of using December 2019 to February 2020, and the properties are transacted within a shorter timeframe.

5.5.2. Prior trends

This part then investigates the prior trends of house prices to explore the validity of the result that uses 2019 as the counterfactual. Studies using the DID approach all involve choosing the counterfactual. The choice and the reliability of the result ultimately depend on whether there is a pre-existing trends issue. In analyzing the effect of Walmart on house prices, Pope and Pope (2015) and Slade (2018) choose two and a half years before the opening of Walmart as the counterfactual since the market already responds before two years of the built. In Diamond and Timothy (2019)’s paper where they analyze how the built of affordable housing affects neighboring house prices, they choose one year before since the developer of the affordable housing cannot foresee when the funding for the project will be available. In our article, since the outbreak of COVID-19 is completely unpredictable that no sellers or buyers can time when the outbreak can happen, the article chooses 2019 – one year before as the baseline counterfactual – when the house price could not be affected by COVID-19.

We then check whether there are differences in the time trends of house prices for the years of 2017, 2018, and 2019 using the data for LA from Redfin,27 shown in Panel B1 of Fig. 7. A perfect scenario is that all these three lines are parallel. The results show that house prices follow a generally similar trend over the months in 2017 to 2019 although the three lines are not exactly parallel. Yet, the conclusion of using 2017 or 2018 as counterfactuels does not differ from that of using 2019. In fact, if using 2018 or 2017 instead, the decrease found in house prices due to COVID-19 before June would be larger in magnitudes since the lines are more steeply sloped from January to June in 2017 and 2018 than that in 2019. After June, the price trend differences among 2017, 2018, and 2019 can be negligible given the high-rocketing house prices for this period in 2020.

Furthermore, the revised DID can mitigate the difference in prior trends. Specifically, the validity of the revised DID result requires the year-over-year (YOY) growth rate of house prices in May 2020 be similar with that in February 2020 if there were no COVID-19. The article then calculates the growth rate in house prices for the respective months in 2019 relative to those in 2018 using the house price averages shown in Panel B1. The revised DID and the individual property data are used to calculate these year-over-year growth rates in house prices. The comparison results are shown in Panel B2 of Fig. 7. It demonstrates that after controlling for the locational and housing characteristics, the variation in the year-over-year growth in house prices among the months of August to December is within 0.5% in the revised DID. This is much smaller than the variation in growth rates when using the averages.

5.5.3. Other data sources

The data from Redfin differ slightly from S&P/Case-Shiller CA-Los Angeles Home Price Index (HPI) and Zillow Home Value Index (ZHVI) which also differ from each other. For our analyses, Redfin’s data provide a more accurate and comprehensive estimate of the effect. The differences among these data will be discussed in detail in the next paragraph. Despite their differences, the change in S&P/Case-Shiller

24 The data from Redfin differ slightly from S&P/Case-Shiller CA-Los Angeles Home Price Index (HPI) and Zillow Home Value Index (ZHVI) which also differ from each other. For our analyses, Redfin’s data provide a more accurate and comprehensive estimate of the effect. The differences among these data will be discussed in detail in the next paragraph. Despite their differences, the change in S&P/Case-Shiller

27 Redfin.com/news/data-center/

28 This is just a variation of the equation in the Method section:

$$\begin{align*}
\text{AL}_{\text{Jan and Feb} 2020} - \text{AL}_{\text{Jan and Feb} 2019} &= (\text{AL}_{\text{Jan and Feb} 2020} - \text{AL}_{\text{Jan and Feb} 2019}) - (\text{AL}_{\text{Jan and Feb} 2020} - \text{AL}_{\text{Jan and Feb} 2019})
\end{align*}$$
HPI also suggests similar effects of COVID-19 on house prices. Specifically, the substantial price appreciation after June is obviously indicative of a positive effect of COVID-19 on house prices. For the negative effect before June, the S&P Shiller HPI of May and June 2020 almost leveled with that of April 2020. In contrast, the HPI was on a steady rise from April to June in 2019.

The difference in the data between Redfin and S&P/Case-Shiller includes but not limited to: (1) Redfin includes transactions of all types of homes, including single-families, condos, townhouses, and multifamilies, whereas S&P/Case-Shiller HPI only includes single-families that are found to experience a smaller negative impact than other housing types shown in Appendix Fig. 2; (2) within the category of single-family properties, the houses used to calculate the S&P/Case-Shiller index also differ from those included in Redfin. The reason is that the S&P/Case-Shiller HPI is calculated based on the resale value of the same single-family properties that do not experience large renovations over time. In contrast, Redfin includes all the transactions in its data. For Zillow’s ZHVI, it is calculated based on Zestimates of homes, including new constructions and homes that have not traded on the open market for many years. The Zestimate is Zillow’s estimate of a home’s market value as opposed to the actual transaction price from Redfin.

5.5.4. Different matching standards
When selecting the control and treatment properties, the article uses the distance of 500 m. Regarding how the result varies with different choices of distances between the control and treatment properties, Panel C1 of Fig. 7 shows that the results of varying distances from 200 to 1000 m are quite similar. When choosing 200 m, the effect turns a little more negative than those of the other three. Additionally, as the distance increases, more properties are included in the treatment and controls, which decreases variation but increases bias since the treatment and controls are more distant. Therefore, as a tradeoff, the article eventually chooses the distance of 500 m. Besides the distance, the housing

Fig. 7. Robustness Checks. Note: Panel A describes the results for Los Angeles with different months chosen in the pre-treatment periods, including February 2020, January and February 2020, December 2019 to February 2020, and November 2019 to February 2020. Panel B describes the prior trends, where Panel B1 shows the average house price levels for the LA metro area from Redfin Data Center, and Panel B2 shows the comparison of YoY growth rates in house prices for months in 2019 between the Average and the Revised DID. The Average represents the YoY growth rates calculated based on the average house prices in Panel B1. Panel C1 contains the results of different distances used for selecting controls and treatments. For these, the house size difference is kept at 15%. Panel C2 includes the results of using various house size differences for selecting control and treatment properties. Only the ones that are within 500 m and have a size difference of within 5%, 10%, 15%, 20%, and 25% are selected for control and treatment properties, respectively. Panel C3 adds matching on the number of beds, baths, and built year with their differences kept at 1 room, 1 room, and 20 years, respectively. For Panel C3, the distance and size differences are 500 m and 15%, respectively.

29 Federal Reserve Economic Data | FRED | St. Louis Fed (stlouisfed.org)

30 https://www.zillow.com/research/zhvi-methodology-2019-highlight-26221/
Table 3

| Features of LA, NYC, the U.S., and the World. | LA | NYC | U.S. | World |
|--------------------------------------------|----|-----|-----|-------|
| Population in Millions | 3.967 | 8.149 | 329.5 | 7900 |
| Unemployment Rate in May 2020 | 19% | 20% | 13.2% | 8.4% |
| Elected Party | Democrats | Democrats | Republicans | – |
| Median Transaction Price | $725,000 | $734,000 | $374,900 | – |
| Median Household Income in 2019 | $79,000 | $72,108 | 67,521 | – |
| Service Industry Share | 12.00% | 10.80% | 11.54% | 6.4% |
| Service Industry Constitute | 41% | 40.30% | 38.2% | 39.2% |
| % of Total Job Losses in May 2020 | – | – | – | – |
| First Stay Home Order in 2020 | 3/19-5/8 | 3/20-5/ | – | – |
| Homeownership Rates | 50.74% | 57.50% | 65.5% | 71.26% |
| Percentage of renters missing or deferring rent payments | 40.35% | 46.25% | 40.74% | – |

Note: this table provides the mean of the features. The Unemployment Rate and Service Industry Constitute % of Total Job Losses are from US Bureau of Labor Statistics. The First Stay Home Order is from County Public Health website where each city locates. Median Transaction Price is the median transaction price for the data in the study period. Median Household Income in 2019 is the median household income for the city in 2019. The Service Industry Share is the share of people that work in the industries of Arts, Entertainment, Recreation, Accommodation, and Food Services from LEHD-RAC 2017. The Homeownership Rates is from American Community Survey. Both the Industry Share and the Homeownership rates are the average for the block groups where there are transactions in the study period for the two cities. The % Missing or Deferring Rent Payments is from Household Pulse Survey in May 2020, the numbers mean that 40.35% adults with household income less than $35,000 in California (where LA locates) either missed or deferred rent payments. And this number is 46.25% in New York state (where NYC locates) and 40.74% for the U.S. The unemployment for the world is the average for OECD countries which have the monthly unemployment data. The homeownership rate for the world is based on 272 countries.

5.6. Result generalizability

The results identified in this article are based on LA which experienced high unemployment following the outbreak that can explain the large demand drop in Figs. 3 and 4. Additionally, LA has a high service share that can lead to an enough number of service industry workers who lost their jobs and couldn’t pay rents, which can explain the result difference associated with service shares shown in Panel B of Fig. 5. Moreover, LA has a low homeownership rate such that a sufficient number of renters can relocate, pressing sizable downward pressures on house prices. This can explain the results by homeownership rates shown in Panel C of Fig. 5.

Regarding result generalizability, similar results might be expected in areas that resemble the features of LA to a large extent. For areas differing from LA, the general mechanism might persist since the outbreak influence is quite universal that almost all areas in the world experienced a certain level of unemployment, have some service industries that are hit the hardest by the outbreak, and have a certain number of renters who can relocate to save on rents. The house price effects might therefore just vary with the degrees of how the area differs from LA in unemployment, service shares, and homeownership rates as well as the pre-existing market conditions (such as the local social, economic, and demographic conditions). Specifically, a lower unemployment and/or a lower service share might lead to smaller effect differences between the two curves in Panel B of Fig. 5, theoretically; yet empirically, the result can be complex since all three factors can vary in different directions in a local economy that at the same time differs in pre-existing conditions from LA. Due to data limitations, the article then provides an empirical check on just New York City (NYC).

NYC is relatively comparable to LA in terms of the city size and diversity. A feature comparison for LA and NYC is shown in Table 3 and the results of NYC31 are shown in Fig. 8. Specifically, Table 3 shows that compared to LA, NYC has a higher unemployment rate that indicates a more negative house price effect, a lower service share suggesting a smaller impact difference associated with service industries, and a higher homeownership rate indicating a smaller impact difference attributable to homeownership. However, it is an empirical question of how exactly those differences, together with other pre-existing differences in the two cities’ social and economic conditions, impact the house price effect. The results in NYC show that lower house prices, higher service shares, and lower homeownership rates are associated with larger house price declines, which are consistent with the results in LA. Further, the price declines in NYC are larger in magnitudes compared to those in LA, possibly due to its larger unemployment.

To sum up, a similar result might be expected in areas that resemble the features of LA to a large extent. However, due to the common shocks from COVID-19, the general working mechanism might still exist, but the extent of the result similarity is subject to how much the area differs from LA. Table 3 shows the feature averages for the U.S. and the world, characteristics of control and treatment properties are also controlled for by firstly selecting homes of the same property types, such as single families, condos, or townhomes, and secondly keeping the difference of the house size within 15%. For the choice of 15%, Panel C2 of Fig. 7 illustrates that the results are quite consistent across varying cut-off points from 5% to 25%. Similar as before, as the cut-off point goes from 5% to 25%, the variation decreases but the bias increases, leading to the middle point choice of 15% for a trade-off. The test also shows how sensitive the result is when adding more housing characteristics for matching treatment and controls in addition to the property types and house sizes. Panel C3 adds the matching on the number of beds, baths, and built year with their differences kept at 1 room, 1 room, and 20 years, respectively. In fact, once the property types and house sizes are matched, the data don’t change much when adding the three more housing characteristic matchings. Panel C3 shows that the result of adding the three more matchings is similar with that without those three. In sum, the revised DID result is robust over different choices of matching standards.

31 One thing to note is that there are 909 observations in Treatment After from NYC since the data in Redfin for eastern areas are not as complete as those in the west. Quite a number of observations in NYC are lacking in transaction time, though the lacking in information does not appear to follow certain patterns and seems to be random. Second, the data is just till July 2020 compared to September in LA. Then the result only represents those observations.

32 Regarding how LA positions in the cities within the U.S. in terms of unemployment rates, service shares, and homeownership rates, LA’s unemployment rate in May 2020 is among the highest in the U.S., and is lower than New Orleans, Buffalo, Fort Wayne, Urban Honolulu, Salinas, Michigan City, Detroit, Atlantic City, Las Vegas, etc. For service shares and homeownership rates, LA stays between the 50th to 75th percentile and the 25th to 50th percentile in the U.S., respectively. For the eight large countries or regions in the world, although the unemployment rate in the U.S. quickly fell to 6.7% in Q4 of 2020, the rate in Q2 stays just below Brazil and is higher than those in China, Japan, Germany, Euro-Zone, France, UK and Russia. As to homeownership status, the U.S. homeownership rate of 65% on average stays between the 25th to 50th percentile of the 68 countries listed in https://en.wikipedia.org/wiki/List_of_countries_by_home_ownership_rate.
which suggests that the U.S. as a whole seems to experience similar economic influences with LA and NYC, while the world appears to see fewer negative impacts than LA.

5.7. Result discussion and limitation

The results specify how the housing market reacts to a pandemic in a region under constant stream of infection cases. Specifically, after the initial housing market downturn that lasts for three months from March to May 2020, people adjusted to the new normal, and some engaged in a home buying frenzy after June. This agrees with the house price movement pattern found after an earthquake, nuclear accidents, and floods (Deng et al., 2015; Zhu et al., 2016; Skantz and Strickland, 1987) that the house price would drop first and then recover. The difference is that this time the house price soared four months after the outbreak, possibly fueled by historically low interest rates and a loosening of credit. The best time to enter housing markets turns out to be May 2020 as the market hit bottom. Contrary to the claim that the adjusting time for COVID-19 might be longer than that for Severe Acute Respiratory Syndrome (SARS),33 which lasts 6 months, LA’s housing market gained its momentum after 4 months. The pertinent concern to the government might lie in the possibility of an overheated higher-priced housing market.

The housing demand and supply analyses suggest that housing demand is the dominant factor in driving housing market changes. Before June, while people probably cancelled or postponed the plans to sell their homes, the dwindling employment and uncertainties about future economies might suppress individuals’ demand on houses to a much greater extent. The decline in demand could be from the fear of contracting the virus, the decline in income, the loss of jobs, and the uncertainty about future economies (Viscusi, 1990; Baker et al., 2020b; Zhou and Donald, 2010; Chung and Donald, 2002). For after June, prospective sellers gradually resumed their selling plans, while the demand skyrocketed. The destruction and increase of demand are then found to be generated from the lower- and higher-priced markets, respectively. Specifically, the disadvantaged neighborhoods have suffered from the major damage in employment and income, and they have yet fully recovered in September 2020. The wealthy households, on the other hand, were not as negatively influenced and were just hesitating on purchasing a home before June due to the uncertainties about future economies. They eventually took advantage of low interest rates and soaring stock markets. Service industries and tenure status are found to be correlated with the house price decline in the lower-priced markets, suggesting that if an area has a high service share and a low homeownership rate, its housing market might be vulnerable to the COVID shock.

The firstly limitation of this study is that due to the lack of data, the article only focuses on LA, and data of broader geographical coverage can help us gain a more comprehensive picture about the impact. Second, as the individual level data in movement, occupation, and demographic features become available, future research can identify the actual personal moving behavior across different places after the pandemic, which can broaden and deepen our understanding about the impact of the outbreak on the housing market.

6. Conclusion

This article examines the effect of COVID-19 on housing markets and investigates what might have contributed to identified housing market volatility. Based in LA, the U.S., the study first explores the effect of COVID-19 on house prices, and then examines whether the price volatility is led by housing demand or supply. Afterwards, the article explores the luxury and low-end housing markets for their differential responses to COVID-19 that might help explain the overall market volatility. Finally, it investigates the potential contributors to the market downturn identified in lower-priced neighborhoods.

Using individual property data and a revised DID method that controls more rigorously for unobservables, the research finds that the outbreak leads to a largest house price decline of approximately 3% in April and May 2020, and it results in a house price increase of almost 4% in September. The price volatility is found to be dominated by demand. In fact, both housing demand and supply decreased in March to May in response to the outbreak, and they afterwards increased in July and August when the market rebounded from the downturn. In both before and after June, the magnitude of changes in housing demand far outpaces that in supply. This suggests that policies targeted at mitigating the negative influence of such a pandemic might focus on the demand side.

Explorations on the effect heterogeneity in higher- and lower-priced markets suggest that the two markets experienced similar changes in supply, which decreased in March to May and increased in July and August. However, the lower-priced market suffered from major negative demand shocks from the pandemic with net decreases identified in both house prices and housing demand in March to June. In contrast, the higher-priced market still experienced net increases in price during this

33 https://www.car.org/en/knowledge/pubs/newsletters/Newsline/Coronavirus
period with only slight changes occurring in demand. The identified increase in price and demand after June for the general market is then found to be originated from the higher-priced area, contrasting with the continued decrease in both price and demand identified in the lower-priced market after June. This justifies financial subsides on rent and mortgage payments for households in lower-priced areas. In addition, governments might be cautious against the risk of an overheating high-end housing market driven by increasing demand fueled by lowered interest rates and surging stock markets in a loosened monetary environment.

The article then delves deep into exploring features that are related to the house price decline in the lower-priced neighborhood. It turns out that the outbreak deals the hardest blow to service industries, which experienced the largest loss in jobs. If people working in these industries are renters, they might not be able to pay the rent in full or they just move out when facing pay reductions or becoming unemployed. The landlords might thus choose to sell the houses at a discount if they are unable to cover the operating and financial costs. The empirical results indeed confirm that houses located in neighborhoods of higher service shares and lower homeownership rates within the lower-priced neighborhood were sold at the largest discount. The study eventually identifies these most vulnerable areas in LA to facilitate the government in allocating the necessary public assistance to households who suffered and will probably continue to suffer from lingering effects of the pandemic in their prospective health, educational, and economic status.

Appendix

See Appendix Figs. 1 and 2.

Appendix Figure 1. Explorations of Result Robustness for Demand and Supply. Note: those figures display the impossible changes in housing demand or supply given the changes in house prices and transaction volumes. It thus tests whether the effect of COVID-19 on housing demand and supply is robust. Panel A indicates even if the approximation for new listing is inaccurate, the supply cannot possibly increase during this period in order for the price to increase and the transaction volume to drop. Panel B describes that even if the housing supply experienced decreases as opposed to the increase estimated from new listings, the demand needs to increase to a much greater extent in order for the transaction prices and volumes to both increase. Thus, the conclusion that the demand needs to tremendously increase remains unchanged irrespective of whether the supply decreases or increases. Panel C describes that even if the supply increases, the demand needs to decrease to a larger degree in order for transaction prices and volumes to both decrease. Thus, the conclusion that the demand needs to significantly decrease also remains unchanged no matter whether the supply decreases or increases. Panel D illustrates that even if the supply decreased in this period, in order for the house price and volume to decrease, the demand needs to decrease in a larger magnitude.
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Appendix Figure 2. Effects by Housing Types in LA. Note: this figure displays the effect of COVID-19 on house prices by housing types in LA.

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