Article
Did the COVID-19 Pandemic Crisis Affect Housing Prices Evenly in the U.S.?

Xinba Li 1 and Chuanrong Zhang 2,*

1 Department of Economics & Department of Mathematics, University of Connecticut, Storrs, CT 06269-4148, USA; xinba.li@uconn.edu
2 Department of Geography & Center of Environmental Sciences and Engineering, University of Connecticut, Storrs, CT 06269-4148, USA
* Correspondence: chuanrong.zhang@uconn.edu

Abstract: While it is well-known that housing prices generally increased in the United States (U.S.) during the COVID-19 pandemic crisis, to the best of our knowledge, there has been no research conducted to understand the spatial patterns and heterogeneity of housing price changes in the U.S. real estate market during the crisis. There has been less attention on the consequences of this pandemic, in terms of the spatial distribution of housing price changes in the U.S. The objective of this study was to explore the spatial patterns and heterogeneous distribution of housing price change rates across different areas of the U.S. real estate market during the COVID-19 pandemic. We calculated the global Moran’s I, Anselin’s local Moran’s I, and Getis-Ord’s G∗i statistics of the housing price change rates in 2856 U.S. counties. The following two major findings were obtained: (1) The influence of the COVID-19 pandemic crisis on housing price change varied across space in the U.S. The patterns not only differed from metropolitan areas to rural areas, but also varied from one metropolitan area to another. (2) It seems that COVID-19 made Americans more cautious about buying property in densely populated urban downtowns that had higher levels of virus infection; therefore, it was found that during the COVID-19 pandemic year of 2020–2021, the housing price hot spots were typically located in more affordable suburbs, smaller cities, and areas away from high-cost, high-density urban downtowns. This study may be helpful for understanding the relationship between the COVID-19 pandemic and the real estate market, as well as human behaviors in response to the pandemic.

Keywords: housing price; COVID-19; real estate; spatial pattern; United States

1. Introduction

The outbreak of the COVID-19 pandemic crisis has brought great socioeconomic effects on our society. Not only has the need for medical supplies significantly increased, but the demand on the food sector also increased, due to panic-buying and the stockpiling of food products. Schools were closed. Social distancing, self-isolation, and travel restrictions led to a reduced workforce across all economic sectors and caused large job losses. Governments around the world implemented lockdown policies in order to ‘flatten the curve’. Yet these lockdown restrictions significantly reduced the production of goods from factories. Quarantine and self-isolation policies decreased the consumption, demand, and utilization of many products and services. Uncoordinated governmental responses and lockdowns led to disruptions in the supply chain of commercial production. In addition to the disruption in the supply chain, the capital market sector was also affected. The pandemic caused economic turmoil in unimaginable ways. The economic recessions worldwide triggered government interventions designed to reverse the economic repercussions. For example, Federal legislators in the U.S. injected USD 2 trillion into the economy with the passage of the Coronavirus Aid, Relief, and Economic Security (CARES) Act of 2020. The U.S. Federal
Reserve recently decreased interest rates by 0.5%, in an attempt to soften the blow of the pandemic on the U.S. economy [1].

As it has done to other productive and commercial sectors, the COVID-19 pandemic has also created an unprecedented disruption in the U.S. housing market. Increased demand and decreased supply created an unprecedented surge in housing prices in the U.S. real estate market. Housing price growth increased substantially after the initial stage of the COVID-19 pandemic in the U.S. The factors contributing to the unusual increase in housing prices could be the historically low mortgage rates and the existence of a ‘fear of missing out’ or fundamental COVID-induced changes in household behavior [2]. In the former, Americans might want to take advantage of the historically low mortgage rates, which make the cost of buying a house much cheaper. The latter implies that Americans might also want to buy a house to live in for health and safety purposes. It may be these reasons that induced the demand for houses. However, during the COVID-19 pandemic the housing supply also decreased, as some Americans were reluctant to list their homes for sale, due to the uncertainty in their lives during the pandemic. The contagious COVID-19 disease also made Americans reluctant to show their homes to strange buyers. These reasons might have caused a shortage of homes for sale. Other important factors driving decreased supply could have been the widespread availability of mortgage forbearance. The COVID-19 pandemic caused many Americans to lose their jobs. Under a normal situation, unemployment may force Americans to sell their house or face foreclosure if they cannot make their mortgage payments. These forced sales can increase the supply of available homes for sale and lower housing prices. However, the widespread availability of forbearance in the U.S. allowed liquidity-constrained households to defer mortgage payments and remain in their homes. This prevented an increase in housing supply driven by the rise of unemployment during the COVID-19 pandemic crisis. In addition to the increased demand and constrained supply, other factors might also have contributed to the unusual housing prices in the U.S. For example, lumber prices have skyrocketed, having nearly tripled in price since 2020. This could have been caused, in large part, by an increased demand from home renovation projects, new home constructions, disrupted transportation, and decreased global production.

While it is well-known that housing prices generally increased in the U.S. during the COVID-19 pandemic crisis, to the best of our knowledge, there has been no research conducted to understand the spatial patterns and spatial heterogeneity of housing price changes in the U.S. real estate market during the COVID-19 pandemic crisis. Based on a literature review, it appears that few studies have been conducted to investigate the spatial dimension of the impact of the COVID-19 pandemic on the housing market. There has been less attention on the consequences of this pandemic, in terms of the spatial distribution of housing price change in the U.S. However, housing prices may be affected unevenly by the COVID-19 crisis across different areas in the U.S. The goal of this study was to explore the impact of the COVID-19 pandemic on housing prices in the U.S. from a spatial perspective. How did the housing price response to the COVID-19 pandemic vary across different areas in the U.S.? We aim to answer this question to fill in the gap in literature.

The rest of this paper is arranged as follows: We first conduct a literature review and reveal the gap in literature and our new contributions in Section 2. In Section 3, we introduce the data used in this study, which came from several different sources. In particular, we show the housing price data in detail. Then in Section 4, we introduce the methods: global Moran’s I for spatial autocorrelation analysis, Anselin’s local Moran’s I for cluster and outlier analysis, and Getis-Ord’s G for hot spot analysis. We show the spatial pattern results of housing price changes across space in the U.S. during the COVID-19 pandemic in Section 5; and then we discuss the major factors causing the housing price changes across space in the U.S. in Section 6. Finally, we conclude this paper by summarizing the study findings, the policy implications, and future studies in Section 7.
2. Literature Review

COVID-19 has changed living and working conditions since its outbreak in early 2020, and it will continue to have consequences on all sectors of the economy, including the real estate market. Therefore, much research has been conducted to investigate the socioeconomic consequences of COVID-19 (e.g., [3–5]). As economic development is closely associated with the housing market and as monetary policies often go in tandem with the housing market cycle, the real estate industry not was immune from the considerable uncertainty brought by COVID-19 [1].

Publications in the literature have investigated the impact of the COVID-19 pandemic upon real estate markets in different countries across the world. Ahsan and Sadak [6] explored the housing market, urban densification, and government policy interventions due to COVID-19 in Turkey. Tanrıvermiş [7] examined the possible effects and impacts of the COVID-19 outbreak on Turkish real estate development and management processes, by making an evaluation of administrative and media records. In Oceania, Hu et al. [8] documented a negative relationship between prior COVID-19 cases and daily housing returns using daily hedonic housing price indices for five Australian state capital cities. They found the daily housing return dropped by 0.35 basis points or 1.26 percentage points annually for every doubling of newly confirmed COVID-19 cases in a state of Australia. They also found an insignificant effect of Australian government lockdown orders on housing returns.

In Europe, Verhaeghe and Ghekiere [9] examined the impact of the COVID-19 pandemic on ethnic discrimination in the housing market of a metropolitan city in Belgium and found that the effects of COVID-19 on discrimination were different for different ethnic groups. Marona and Tomal [10] found that the COVID-19 pandemic had a considerable impact upon the workflow of real estate brokers and their clients' attitudes in the city of Krakow, Poland. Another research work of theirs revealed that the first wave of the COVID-19 pandemic actually led to a 6–7% decrease in prices in the rental market in Krakow [11]. Del Giudice et al. [12] developed a real estate pricing model to evaluate the short and mid-run effects of COVID-19 on housing prices in the Campania Region, Italy. Results of their model indicated a housing price drop of 4.16% in the short-run and 6.49% in the mid-run (late 2020–early 2021) in the region. De Toro et al. [13] found structural changes in the demand for residential properties in the metropolitan area of Naples, Italy, due to new requirements as a result of COVID-19. Based on the study of Blakeley [14], the COVID-19 pandemic could have led to an increase in wealth inequality and a deepening of the housing crisis in the United Kingdom (U.K.). Uchehara et al. [15] provided a wide-ranging insight into the effects of the COVID-19 crisis on the real estate supply chain in the U.K., using a qualitative descriptive research design. To determine the potential recovery pattern of supply chains across the U.K. real estate sector, the economic recovery scenarios with V, U, W, and L shapes were analyzed in their study.

In Asia, Hamzah et al. [16] discussed the future directions of the real estate industrial sector in Malaysia after the COVID-19 pandemic. They argued that the best-case scenario for the Malaysian real estate industry’s recovery would be to undergo a V-shaped recovery, while the worst-case scenario would be a U-shaped recovery, which would take a longer time, due to new waves of the COVID-19 pandemic. Several studies investigated the housing price changes in China during the COVID-19 pandemic crisis. Chong and Liu [17] used a two-way fixed effects model to investigate the non-linear relationship between the death toll of COVID-19 and changes in housing prices. Their results suggested that there was a 'U-shaped' relationship between the monthly death toll of COVID-19 and the percentage changes of housing prices in cities of China. Qian et al. [18] found that the housing prices were reduced by 2.47% in the communities with confirmed COVID-19 cases and that an impact of COVID-19 on housing prices only existed in regions with a high infection level of COVID-19 or poor medical treatment conditions. Cheung et al. [19] found a 4.8% and a 5.0–7.0% year-on-year fall in housing prices immediately after the pandemic outbreak in the COVID-19 epicenter in Wuhan, China, based on hedonic pricing and price
gradient models, respectively. Their price gradient models showed that the price gradient flattened from the epicenter to the urban peripheries, although housing prices rebounded after the lockdown period.

Since the COVID-19 virus has ravaged the U.S. economy [20,21], it has also affected the U.S. housing market. Using west Michigan as an illustrative example, Beard [22] presented an overview of the concerns regarding the ability to pay for houses, springing from the economic impact of the public health shutdowns. Jones and Grigsby-Toussaint [23] suggested that housing crowding in major U.S. metropolitan areas, where multiple families or multiple-generation family members share a relatively small amount of residential space, became hotbeds of risk during the pandemic. Balemi et al. [24] provided a comprehensive literature review of the latest academic insights into how this pandemic has affected the housing, commercial real estate, and mortgage markets in the U.S. Yoruk [25] used daily data from fifty major cities to investigate the early effects of the COVID-19 pandemic on the U.S. housing market. The study showed a broad-based collapse of the housing market, hitting all major U.S. cities, regardless of the intensity of the virus spread or timing of the introduction of state level policies to combat the pandemic during the early stages of the COVID-19 pandemic crisis. Ling et al. [26] studied the effects of COVID-19 on U.S. commercial real estate prices and found a negative relation between the growth of COVID-19 cases and the risk-adjusted return of firms’ individual commercial property holdings. Ramani and Bloom [27] also found that the commercial real estate demand remained relatively flat, while single-family home prices were on the rise. While Bayoumi and Zhao [28] documented that the upward trend of housing prices has not been reversed by the COVID-19 shock; D’Lima et al. [29] found no aggregate pricing effects, but a significant decrease in listings in the shutdown and re-opening periods. Wang [30] studied the effects of COVID-19 on housing prices in Houston, Santa Clara, Honolulu, Irvine, and Des Moines, and found that only Honolulu experienced a noticeable housing price declines from the COVID-19 outbreak. While the COVID-19 pandemic led to housing price decrease in some other countries in the world, as aforementioned, Nicola et al. [1] found that the U.S. real estate market has hitherto shown little sign of distress. The aggregated results from Zhao [2] also demonstrated that the growth rate of median housing prices in the U.S. during the four months (April–August 2020) since the U.S. Federal Reserve’s unprecedented monetary easing have accelerated faster than any four-month period in the lead-up to the 2007–2009 global financial crisis.

Although the aforementioned studies linked COVID-19 and housing prices, there is still uncertainty surrounding the impact of COVID-19 on the housing market [31]. Very few studies in literature have investigated the spatial heterogeneity of the impact of the COVID-19 pandemic on housing markets [32–34]. However, housing prices may be affected heterogeneously across different counties in the U.S., due to the uneven distributions of some socio-economic factors, such as average household size, percentage of households with Internet at home, education, and poverty variables. Housing prices may also exhibit spatial heterogeneity within the larger housing market, due to localized supply and demand imbalances. While scholars found spatial effects of other financial crises on the housing market (e.g., [35–37]), the spatial dimension of the impact of the COVID-19 pandemic crisis on housing price changes in the U.S. still remains unexplored. Therefore, in this study we attempted to fill in this gap in the literature by exploring the spatial patterns and spatial heterogeneity of housing price changes in different areas of the U.S. real estate market during the COVID-19 pandemic.

3. Data

We combined several data sources for the analyses in this study. The housing value dataset was downloaded from the Zillow Research website. We obtained Zillow Home Value Index (ZHVI) data at both county level and zip code level. ZHVI is a smoothed, seasonally adjusted measure of the typical home value and market change across a given region and housing types, including all single-family residences and condo/coops [38]. It
includes monthly data, and the data for a given month is published on the third Thursday of the following month. ZHVI is calculated as the median 'Zestimate' value for a fixed (over time) set of homes in a given area, representing that area's median home value. The 'Zestimate' home valuation is Zillow’s estimate of a home’s market value. A Zestimate is calculated using a sophisticated neural network-based model that incorporates data from county and tax assessor records and direct feeds from hundreds of multiple listing services and brokerages. It incorporates: (1) home characteristics, such as square footage, location, and the number of bathrooms; (2) on-market data, such as listing price, description, comparable homes in the areas, and days on the market; (3) off-market data, such as tax assessments, prior sales, and other publicly available records; and (4) market trends, including seasonal changes in demand. The nationwide median error rate for the Zestimate for on-market homes is 1.9%, which is computed by comparing the final sale price to the Zestimate that was published on, or just prior, to the sale date. ZHVI draws on Zestimates calculated on more than 100 million U.S. homes, including new construction homes and/or homes that have been not traded on the open market for many years. Monthly changes in the index are calculated using a weighted mean of the appreciation of individual homes, as proxied by changes in the Zestimate. ZHVI is Zillow’s flagship measure of both the typical home value, as well as current housing market appreciation and over time.

We used ZHVI data to measure the housing price change rates in different counties or zip-code areas in the U.S. The GIS (Geographic Information System) data include: (1) the U.S. County shapefile; (2) the U.S. Census 5-Digit ZIP Code Tabulation Area (ZCTA5) shapefile; (3) the U.S. major cities shapefile. The U.S. County shapefile and the U.S. Census 5-Digit ZIP Code Tabulation Area (ZCTA5) shapefile were downloaded from the U.S. Census Bureau website. The shapefile of U.S. Major Cities was downloaded from the ESRI ArcGIS hub website. The COVID-19 dataset was downloaded from the USA Facts website. Table 1 lists the details of the data sources. We converted all of the GIS data from the WGS 1984 Geographical Coordinate System to the NAD 1983 (2011) Contiguous USA Albers Projected Coordinate System for spatial data analysis.

**Table 1.** Data names and sources.

<table>
<thead>
<tr>
<th>Data Types</th>
<th>Data Names</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing Price</td>
<td>Zillow Home Value Index (ZHVI) at both County level and Zip Code level</td>
<td>Zillow Research Data: <a href="https://www.zillow.com/research/data/">https://www.zillow.com/research/data/</a> (accessed on 6 June 2021)</td>
</tr>
<tr>
<td>GIS Data</td>
<td>The U.S. County shapefile</td>
<td>the U.S. Census Bureau: <a href="https://www2.census.gov/geo/tiger/TIGER2020/COUNTY/">https://www2.census.gov/geo/tiger/TIGER2020/COUNTY/</a> (accessed on 6 June 2021).</td>
</tr>
<tr>
<td></td>
<td>The U.S. Census 5-Digit ZIP Code Tabulation Area (ZCTA5) shapefile</td>
<td>the U.S. Census Bureau: <a href="https://www2.census.gov/geo/tiger/TIGER2019/ZCTA5/">https://www2.census.gov/geo/tiger/TIGER2019/ZCTA5/</a> (accessed on 16 June 2021)</td>
</tr>
</tbody>
</table>

4. Method

4.1. Global Moran’s I for Spatial Autocorrelation Analysis

The COVID-19 pandemic crisis may have affected housing prices unevenly in the U.S. The housing price changes during the pandemic may have spatial autocorrelations; that is, the housing price change rates may not be independent at different locations, and a rate value in a location may be more similar to other rate values in surrounding locations. The presence of spatial autocorrelations in the housing price data indicates that the data
violates a basic assumption of classic statistics: that the data are independent of each other. If so, the analysis results using classic statistics may not be able to reflect the truth and may hide some real features. Therefore, it is important to test for spatial autocorrelation of housing price data before using the classic statistic methods to perform a housing price change analysis. The measurement of spatial autocorrelation can show the nature and degree to which a fundamental statistical assumption is violated, and, therefore, indicate the extent to which classic statistical inferences are compromised when non-zero spatial autocorrelation is ignored [39]. In addition, measurements of spatial autocorrelation can describe the overall data pattern across a geographic space.

The global Moran’s I was used in this study to measure the overall spatial autocorrelation of the housing price data during the COVID-19 pandemic crisis. The global Moran’s I for spatial autocorrelation is given as:

\[
I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} \sum_{i=1}^{n} (x_i - \bar{x})^2}
\]

(1)

where \(x_i\) and \(x_j\) stand for the housing price change rates of spatial features \(i\) and \(j\) (e.g., counties or zip code areas), \(\bar{x}\) for the mean of the housing price change rates, \(n\) for the number of spatial features (e.g., number of counties or zip code areas), and \(W_{ij}\) is the spatial weight between the spatial features \(i\) and \(j\).

The \(z_I\) score for the \(I\) statistic is computed as:

\[
z_I = \frac{I - E[I]}{\sqrt{V[I]}}
\]

(2)

where

\[
E[I] = -1/(n - 1)
\]

(3)

\[
V[I] = E\left[I^2\right] - E[I]^2
\]

(4)

\[
E\left[I^2\right] = \frac{A - B}{C}
\]

(5)

\[
A = n \left( (n^2 - 3n + 3)S_1 - nS_2 + 3S_0^2 \right)
\]

(6)

\[
B = D \left( (n^2 - n)S_1 - 2nS_2 + 6S_0^2 \right)
\]

(7)

\[
C = (n - 1)(n - 2)(n - 3)S_0^2
\]

(8)

\[
D = \frac{\sum_{j=1}^{n} z_i^4}{\left( \sum_{j=1}^{n} z_i^2 \right)^2}
\]

(9)

\[
S_1 = \left( \frac{1}{n} \right) \sum_{i=1}^{n} \sum_{j=1}^{n} (w_{ij} + w_{ji})^2
\]

(10)

\[
S_2 = \sum_{i=1}^{n} \left( \sum_{j=1}^{n} w_{ij} + \sum_{j=1}^{n} w_{ji} \right)^2
\]

(11)

The expected value of Moran’s I is always a negative value. When the calculated Moran’s I is greater than the \(E(I)\), we can typically claim the existence of a positive spatial autocorrelation or clustered spatial patterns, in which the adjacent or nearby spatial features (counties or zip code areas) show similar housing price change characteristics. In other words, high housing price change rates cluster near other high housing price change rates, while low housing price change rates cluster near other low housing price change rates.

The global Moran’s I is an inferential statistic. Therefore, the results of the analysis always need to be interpreted within the context of its null hypothesis. In this study, the null hypothesis of the global Moran’s I statistic was that the housing price change rates being analyzed were randomly distributed in the study area. The \(z\)-scores and \(p\)-values associated with the test statistic of the inferential global Moran’s I reveal whether or not the
null hypothesis will be rejected. When the \( z \)-score is positive and the \( p \)-value is statistically significant, the null hypothesis may be rejected. This indicates that the spatial distribution of high values and/or low values of the housing price change rates is more spatially clustered than would be expected if the underlying spatial processes were random. When the \( z \)-score is negative and the \( p \)-value is statistically significant, the null hypothesis can still be rejected. This indicates that the spatial distribution of high values and low values of the housing price changes is more spatially dispersed than would be expected if the underlying spatial processes were random. Only when the \( p \)-value is not statistically significant, can the null hypothesis not be rejected. This indicates that it is quite possible that the spatial distribution of housing price change values is the result of random spatial processes.

4.2. Anselin’s Local Moran’s I for Cluster and Outlier Analysis

While the global Moran’s I can measure the overall spatial autocorrelation of housing price change rates, the global statistics assume stationarity or structural stability over space. This may be highly unrealistic for the housing price change variable. A method that focuses on local patterns of association (hot or cold spots), and an allowance for local instabilities in overall spatial associations, is needed for cluster and outlier analysis of housing price changes in the U.S. during the COVID-19 pandemic crisis.

In this study, Anselin’s local Moran’s I (LISA: local indicators of spatial association) was used to identify statistically significant hot spots, cold spots, and spatial outliers of housing price changes in the U.S. during the COVID-19 pandemic crisis. Anselin’s local Moran’s I allows for decomposition of global Moran’s I into the contribution of housing price changes in each individual county or zip code area. The statistics have two purposes [40]: (1) they can identify local non-stationarity or hot spots, similar to the Getis-Ord’s \( G^* \) statistic [41]; (2) they can assess the influence of individual locations on the magnitude of the global Moran’s I statistic to identify ‘outliers’.

The local Moran’s I statistic of spatial association is calculated by:

\[
I_i = \frac{x_i - \bar{X}}{S_i^2} \sum_{j=1, j \neq i}^{n} w_{ij}(x_j - \bar{X})
\]

(12)

where \( x_i \) is the housing price change rate for a county (or a zip code area) \( i \), \( \bar{X} \) is the mean of the corresponding housing price change rates, \( w_{ij} \) is the spatial weight between spatial features (counties or zip code areas) \( i \) and \( j \), and:

\[
S_i^2 = \frac{\sum_{j=1, j \neq i}^{n} (x_j - \bar{X})^2}{n-1}
\]

(13)

with \( n \) equating to the total number of spatial features (counties or zip code areas).

The \( z_i \) score for the local Moran’s I statistics is computed as:

\[
z_{I_i} = \frac{I_i - E[I_i]}{\sqrt{V[I_i]}}
\]

(14)

where

\[
E[I_i] = -\frac{\sum_{j=1, j \neq i}^{n} w_{ij}}{n-1}
\]

(15)

\[
V[I_i] = E[I_i] - E[I_i]^2
\]

(16)

\[
E[I_i]^2 = A - B
\]

(17)

\[
A = \frac{(n - b_z) \sum_{j=1, j \neq i}^{n} w_{ij}^2}{n-1}
\]

(18)

\[
B = \frac{(2b_z - n) \sum_{k=1, k \neq i}^{n} \sum_{h=1, h \neq i}^{n} w_{ik} w_{ih}}{(n-1)(n-2)}
\]

(19)
If Anselin’s local Moran’s $I$ is a positive value, that means that a county or a zip code area has neighboring counties or zip code areas with similarly high or low housing price change rates. This indicates a cluster pattern. If it is a negative value, that means that a county or a zip code area has neighboring counties or zip code areas with dissimilarly high or low housing price change rates. This indicates an outlier pattern. Under both circumstances, the $p$-value for a county or a zip code area must be small enough for the cluster or outlier to be considered statistically significant. Please note that the local Moran’s $I$ is also a relative measure, like the global Moran’s $I$, and can only be interpreted within the context of its computed $z$-score or $p$-value.

4.3. Getis-Ord’s $G^*_i$ for Hot Spot Analysis

A county or a zip code area with a high housing price change rate is interesting but may not be a statistically significant hot spot. To be a statistically significant hot spot, a county or a zip code area with a high housing price change rate must be surrounded by other counties or zip code areas with high housing price change rates. In this study, the statistically significant hot spots and cold spots of the housing price change rates in the U.S. were also identified using the Getis-Ord’s $G^*_i$ statistic.

The Getis-Ord’s $G^*_i$ statistic is calculated by:

$$G^*_i = \frac{\sum_{j=1}^{n} w_{ij} x_j - \bar{X} \sum_{j=1}^{n} w_{ij}}{S \sqrt{\frac{\sum_{j=1}^{n} w_{ij}^2 - (\sum_{j=1}^{n} w_{ij})^2}{n-1}}}$$  \hspace{1cm} (21)

where $x_j$ is the housing price change rate for a spatial feature (county or zip code area) $j$, $w_{ij}$ is the spatial weight between spatial features (counties or zip code areas) $i$ and $j$, $n$ is equal to the total number of spatial features and

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n}$$  \hspace{1cm} (22)

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\bar{X})^2}$$  \hspace{1cm} (23)

The $G^*_i$ statistic returned for each spatial feature (a county or a zip code area) in the housing price change data is a $z$ score. Therefore, no further calculations are required. For statistically significant positive $z$ scores, the larger the $z$ score is, the more intense the clustering of high values (hot spots) of the housing price change rates. On the other hand, for statistically significant negative $z$ scores, the smaller the $z$ score, the more intense the clustering of low values (cold spots) of the housing price change rates.

5. Results

To determine whether or not the COVID-19 pandemic crisis had effects on housing price change in the U.S., we first compared the general housing price change rate trend during the past nine normal years with the general housing price change rate trend during the COVID-19 pandemic year (from May 2020 to May 2021). We calculated the annual housing price change rates of 2856 U.S. counties in the month May for the past ten years (from 2011 to 2021), using Zillow Home Value Index (ZHVI) data to make the comparison. We chose the month of May because the impact of the outbreak of the COVID-19 pandemic on housing prices began to appear in May 2020. Although the COVID-19 pandemic crisis started to occur in late 2019 and the COVID-19 cases started to spike in the latter half of March 2020 in the U.S. [42], its impact on housing price had a delayed effect. The price changes, in fact, lagged by a couple months, so May should be a good representative month.
in 2020 for studying housing price change during the pandemic. Table 2 shows statistics of the housing price change rates of the 2856 U.S. counties for the past ten years for the month May. It can be seen that the minimum housing price change rate in the 2856 U.S. counties during the COVID-19 pandemic year (2020–2021) was −8.8, which is much higher than most of the minimum housing price change rates during the other nine years (2011–2020), before the pandemic crisis. The maximum, median, mean, and standard deviation values of the housing price change rates during the COVID-19 pandemic year (2020–2021) are 37.85, 7.52, 8.56, and 5.41, respectively. These values are also much higher than their corresponding values during the other nine normal years. They indicate that the COVID-19 pandemic may have had an effect on housing prices and may have caused housing prices to increase. Figure 1 shows the trend of the mean values of housing price change rates in the 2856 U.S. counties during the nine normal years and the COVID-19 pandemic year. It can be seen that the general trend of housing price change rates during the COVID-19 pandemic year is quite different from the trends during the none-pandemic years, and the mean value has a sharp increase during the COVID-19 pandemic year. Figure 2 illustrates the histograms of housing price change rates during the normal year of 2019–2020 and the COVID-19 pandemic year 2020–2021. It can be seen that the distributions of housing price change rates during the two periods are quite different. The distribution of the housing price change rates during the normal year of 2019–2020 tends to be more normally distributed compared to that of the housing price change rates during the COVID-19 pandemic year of 2020–2021, which is positively skewed. The skewness may have been caused by the different effects of the COVID-19 pandemic crisis on housing prices in different counties. There are more counties that had housing price increase rates less than the mean value during the COVID-19 pandemic crisis. The range of the distribution shape of housing price change rates during the normal year of 2019–2020 is smaller than the width of the distribution shape of housing price change rates during the COVID-19 pandemic year of 2020–2021. This indicates that the spread range of the housing price change rates for the 2856 U.S. counties during the COVID-19 pandemic year of 2020–2021 was wider, and the COVID-19 pandemic may have had different effects on housing prices in different counties. In general, the statistics in Table 2, and the graphics in Figures 1 and 2, may indicate that the outbreak of the COVID-19 pandemic crisis had obvious effects on U.S. housing prices and that the effects may vary strongly across different counties.

Table 2. Statistics of the housing price change rates for May in the past ten years (2011–2021).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>29.94</td>
<td>30.81</td>
<td>37.8</td>
<td>26.02</td>
<td>26.98</td>
<td>28.33</td>
<td>24.81</td>
<td>30.43</td>
<td>22.31</td>
<td>37.85</td>
</tr>
<tr>
<td>Median</td>
<td>−0.29</td>
<td>2.26</td>
<td>3.49</td>
<td>4.05</td>
<td>4.21</td>
<td>4.88</td>
<td>5.45</td>
<td>4.63</td>
<td>3.28</td>
<td>7.52</td>
</tr>
<tr>
<td>Mean</td>
<td>−0.51</td>
<td>3.18</td>
<td>4.46</td>
<td>4.31</td>
<td>4.37</td>
<td>5.0</td>
<td>5.5</td>
<td>4.67</td>
<td>3.4</td>
<td>8.56</td>
</tr>
<tr>
<td>S.D.</td>
<td>3.63</td>
<td>4.79</td>
<td>4.62</td>
<td>3.37</td>
<td>3.54</td>
<td>3.33</td>
<td>3.2</td>
<td>2.75</td>
<td>2.94</td>
<td>5.41</td>
</tr>
</tbody>
</table>

To test whether or not the housing price change rates were inconsistent across different counties in the U.S., we first visualized housing price change rates across different counties. We mapped the housing price change rates of the 2856 U.S. counties during the normal year of 2019–2020 and the COVID-19 pandemic year of 2020–2021, using the same graduated color symbols, as shown in Figure 3. Blue colors indicate negative housing price change rates, while yellow and red colors indicate positive housing price change rates. Please note that the white colors in the maps indicate that some counties had no available house price data. It can be seen that for the majority of U.S. counties the housing prices increased much more in the COVID-19 pandemic year of 2020–2021 than in the normal year of 2019–2020. Although the housing price change rates were positive for the majority of the U.S. counties during the COVID-19 pandemic year of 2020–2021, there are still some counties that had negative housing price change rates. In general, while the COVID-19 pandemic crisis brought negative effects to most economic sectors, it facilitated the increase of housing
prices in most U.S. counties. The housing market, however, did not boom equally. There were indeed some counties where housing prices decreased. Table 3 lists the top ten counties with decreased housing prices. Table 4 lists the top ten counties with increased housing prices. From these, it can be seen that, while the top ten counties for housing price increases surged more than 29%, the top ten counties for housing price decreases declined more than 5% during the COVID-19 pandemic year of 2020–2021.

![Mean of Housing Price Change Rates (2011-2021)](image)

**Figure 1.** Mean values of housing price change rates during the nine normal years and the COVID-19 pandemic year.

![Histogram of Housing Price Change Rates (2019-2020)](image)

(a)

**Figure 2.** Cont.

To test whether or not the housing price change rates were inconsistent across different counties in the U.S., we first visualized housing price change rates across different counties. We mapped the housing price change rates of the 2856 U.S. counties during the normal year of 2019–2020 and the COVID-19 pandemic year of 2020–2021, using the same graduated color symbols, as shown in Figure 3. Blue colors indicate negative housing price change rates, while yellow and red colors indicate positive housing price change rates. Please note that the white colors in the maps indicate that some counties had no available house price data. It can be seen that for the majority of U.S. counties the housing prices increased much more in the COVID-19 pandemic year of 2020–2021 than in the normal year of 2019–2020. Although the housing price change rates were positive for the majority of the U.S. counties during the COVID-19 pandemic year of 2020–2021, there are still some counties that had negative housing price change rates. In general, while the COVID-19 pandemic crisis brought negative effects to most economic sectors, it facilitated the increase of housing prices in most U.S. counties. The housing market, however, did not boom equally. There were indeed some counties where housing prices decreased. Table 3 lists the top ten counties with decreased housing prices. Table 4 lists the top ten counties with increased housing prices. From these, it can be seen that, while the top ten counties for housing price increases surged more than 29%, the top ten counties for housing price decreases declined more than 5% during the COVID-19 pandemic year of 2020–2021.

Figure 3. Maps of the housing price change rates during the normal year of 2019–2020 and the COVID-19 pandemic year of 2020–2021.
Table 3. Top ten counties with decreased housing prices during the COVID-19 pandemic year of 2020–2021.

<table>
<thead>
<tr>
<th>Rank</th>
<th>House Price Change Rate</th>
<th>County</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>−8.8%</td>
<td>Clinton</td>
<td>Iowa</td>
</tr>
<tr>
<td>2</td>
<td>−8.65%</td>
<td>Ector</td>
<td>Texas</td>
</tr>
<tr>
<td>3</td>
<td>−7.89%</td>
<td>Hansford</td>
<td>Texas</td>
</tr>
<tr>
<td>4</td>
<td>−7.61%</td>
<td>Sullivan</td>
<td>Missouri</td>
</tr>
<tr>
<td>5</td>
<td>−7.11%</td>
<td>Mason</td>
<td>Illinois</td>
</tr>
<tr>
<td>6</td>
<td>−6.62%</td>
<td>Green</td>
<td>Kentucky</td>
</tr>
<tr>
<td>7</td>
<td>−6.23%</td>
<td>Red River</td>
<td>Louisiana</td>
</tr>
<tr>
<td>8</td>
<td>−5.72%</td>
<td>Okeechobee</td>
<td>Florida</td>
</tr>
<tr>
<td>9</td>
<td>−5.52%</td>
<td>Lafourche</td>
<td>Louisiana</td>
</tr>
<tr>
<td>10</td>
<td>−5.09%</td>
<td>Jefferson Davis</td>
<td>Mississippi</td>
</tr>
</tbody>
</table>

Table 4. Top ten counties with increased housing prices during the COVID-19 pandemic year of 2020–2021.

<table>
<thead>
<tr>
<th>Rank</th>
<th>House Price Change Rate</th>
<th>County</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>37.85%</td>
<td>Canyon</td>
<td>Idaho</td>
</tr>
<tr>
<td>2</td>
<td>36.03%</td>
<td>Ada</td>
<td>Idaho</td>
</tr>
<tr>
<td>3</td>
<td>33.76%</td>
<td>Williamson</td>
<td>Texas</td>
</tr>
<tr>
<td>4</td>
<td>33.41%</td>
<td>Camden</td>
<td>Missouri</td>
</tr>
<tr>
<td>5</td>
<td>31.94%</td>
<td>Ulster</td>
<td>New York</td>
</tr>
<tr>
<td>6</td>
<td>31.76%</td>
<td>Phillips</td>
<td>Kansas</td>
</tr>
<tr>
<td>7</td>
<td>31.74%</td>
<td>Watauga</td>
<td>North Carolina</td>
</tr>
<tr>
<td>8</td>
<td>29.96%</td>
<td>Sullivan</td>
<td>Texas</td>
</tr>
<tr>
<td>9</td>
<td>29.89%</td>
<td>Travis</td>
<td>Texas</td>
</tr>
<tr>
<td>10</td>
<td>29.19%</td>
<td>Flathead</td>
<td>Montana</td>
</tr>
</tbody>
</table>

As previously mentioned, while visualizing counties or zip code areas with high or low housing price change rates is interesting, it may not be able to show clearly the statistically significant hot or cold spots and indicate the spatial autocorrelation of housing price changes across space. To test whether the housing price changes in the U.S. counties were randomly distributed or not, and measure the overall spatial autocorrelation of the housing price changes during the COVID-19 pandemic year of 2020–2021, we calculated the global Moran’s I of the housing price change rates in the 2856 U.S. counties. Table 5 summarizes the calculated global Moran’s I results. It can be seen that the calculated Moran’s I index (0.403586) is much greater than the expected Moran’s I index (−0.000350). Based on this result we can claim the existence of positive spatial autocorrelation or clustered spatial patterns of the housing price change rates in the 2856 U.S. counties during the COVID-19 pandemic year of 2020–2021. This means that the high housing price change rates typically cluster near other high housing price change rates, while low housing price change rates cluster near other low housing price change rates. The positive z-score (44.644315) and the almost zero p-value indicate that the calculated Moran’s I inference statistic is significant. The spatial distribution of housing price change rates was not the result of random spatial processes and has some spatial autocorrelation.
Table 5. The global Moran’s I results.

<table>
<thead>
<tr>
<th>Names</th>
<th>Moran’s Index</th>
<th>Expected Index</th>
<th>Variance</th>
<th>z-Score</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Values</td>
<td>0.403586</td>
<td>−0.000350</td>
<td>0.000082</td>
<td>44.644315</td>
<td>0.000000</td>
</tr>
</tbody>
</table>

While the global Moran’s I measured the overall spatial autocorrelation of the housing price change rates, it cannot determine where the spatial autocorrelation occurs, or the local patterns of the spatial autocorrelation. To reveal the local cluster patterns of association, we calculated both the Anselin’s local Moran’s I and Getis-Ord’s $G^*_i$ statistic of the housing price change rates in the 2856 U.S. counties during the COVID-19 pandemic year of 2020–2021. Figure 4 shows the local Moran’s I cluster and outlier analysis results. Figure 5 illustrates the $G^*_i$ statistic analysis results. It can be seen that the spatial distribution patterns of hot spots (high-high housing price change rate clusters) and cold spots (low-low housing price change rate clusters) calculated by the local Moran’s I and the $G^*_i$ statistic are almost the same. The major differences between the local Moran’s I results and the $G^*_i$ statistic results are the following: First, the local Moran’s I results show spatial outliers of housing price change rates, while the $G^*_i$ statistic results only show hot and cold spots. Second, the $G^*_i$ statistic results show the different confidence levels of hot spots and cold spots, while the local Moran’s I results cannot show this and treat hot and cold spots with the same confidence level. It also can be seen that the hot spots are mainly located in the Northeast and West coastal regions, but the cold spots are mainly located in the Midwest, Southwest, and Southeast regions. To find out what caused these spatial patterns, we overlaid the $G^*_i$ statistical results with the major U.S. cities, as shown in Figure 6. It can be seen that the hot spots are mainly located in the areas around some of the U.S. major cities. This indicates that the places with large housing price increases are located around the major cities with dense population. Although there are many cold spots located in some rural areas in the Midwest, Southwest, and Southeast regions, there are still some hot spots around major cities in the Midwest, Southwest, and Southeast regions, such as those around Milwaukee, Chicago, Cleveland, Charlotte, Atlanta, Kansas City, Denver, Dallas, and Austin.

![Cluster and Outlier Analysis Results](image)

Figure 4. Anselin’s local Moran’s I results.
such as those around Milwaukee, Chicago, Cleveland, Charlotte, Atlanta, Kansas City, Denver, Dallas, and Austin.

Figure 4. Anselin’s local Moran’s $I$ results.

Figure 5. Getis-Ord’s $G^*_i$ statistic results.

To determine the general trend of the COVID-19 pandemic crisis’s effects on housing prices in the major cities of the U.S., we drew the trend of housing price changes of the 12 most populous U.S. cities in the past two years (2019–2021), as shown in Figure 7. It can be seen that the housing price changes in these most populous cities all have a generally increasing trend. The housing prices in some of these populous cities had some temporary slowdowns or dips around April or May 2020. Then the housing prices in these populous cities all bounced back quickly. The increase rates accelerated faster during the COVID-19 pandemic year than in the year before.

Although Figure 7 displays the general trend, this figure alone does not show whether or not the COVID-19 pandemic affected housing prices uniformly in these cities. To find out whether or not the COVID-19 pandemic crisis affected housing prices evenly in these cities, we made maps of the housing price change rates in these populous cities during the year 2019–2020 (before the COVID-19 pandemic crisis) and the year 2020–2021 (during the COVID-19 pandemic crisis), as shown in Figures 8 and 9. It can be seen that the housing price change rates vary across different zip code areas within these populous cities. Although the general trends in housing prices in Figure 7 were shown to increase for all of the 12 most populous cities, there are many zip code areas in these cities that had decreasing housing prices before, and even during, the COVID-19 pandemic year, as shown in Figures 8 and 9. There are more zip code areas with housing price decreases before the COVID-19 pandemic year than in the COVID-19 pandemic year. For example, although the housing prices in New York City had a generally increase trend during the COVID-19 pandemic year, housing prices in many zip code areas in the Brooklyn borough of New York City actually decreased during the COVID-19 pandemic year. More places in New York City had housing price decreases before the COVID-19 pandemic year. In addition, from Figures 8 and 9, it can also be seen that housing price changes during the COVID-19 pandemic year of 2020–2021 had different spatial patterns compared with those in the year of 2019–2020 (before the COVID-19 pandemic crisis). The housing price change rates had a relatively clearer ‘ring’ (i.e., changing radiantly from an urban center to the suburbs) pattern during the COVID-19 pandemic crisis year of 2020–2021, compared with in the year of 2019–2020. The places with large increases in housing price change rates were typically located in suburban areas, while the places with no or small housing price increases were normally located in urban downtown areas, during the COVID-19 pandemic crisis year of 2020–2021.
Figure 7. The trends of housing price changes (2019–2021) in the 12 most populous U.S. cities.
Although Figure 7 displays the general trend, this figure alone does not show whether or not the COVID-19 pandemic affected housing prices uniformly in these cities. To find out whether or not the COVID-19 pandemic crisis affected housing prices evenly in these cities, we made maps of the housing price change rates in these populous cities during the year 2019–2020 (before the COVID-19 pandemic crisis) and the year 2020–2021 (during the COVID-19 pandemic crisis), as shown in Figures 8 and 9. It can be seen that the housing price change rates vary across different zip code areas within these populous cities. Although the general trends in housing prices in Figure 7 were shown to increase for all of the 12 most populous cities, there are many zip code areas in these cities that had decreasing housing prices before, and even during, the COVID-19 pandemic year, as shown in Figures 8 and 9. There are more zip code areas with housing price decreases before the COVID-19 pandemic year than in the COVID-19 pandemic year. For example, although the housing prices in New York City had a generally increase trend during the COVID-19 pandemic year, housing prices in many zip code areas in the Brooklyn borough of New York City actually decreased during the COVID-19 pandemic year. More places in New York City had housing price decreases before the COVID-19 pandemic year. In addition, from Figures 8 and 9, it can also be seen that housing price changes during the COVID-19 pandemic year of 2020–2021 had different spatial patterns compared with those in the year of 2019–2020 (before the COVID-19 pandemic crisis). The housing price change rates had a relatively clearer ‘ring’ (i.e., changing radiantly from an urban center to the suburbs) pattern during the COVID-19 pandemic crisis year of 2020–2021, compared with in the year of 2019–2020. The places with large increases in housing price change rates were typically located in suburban areas, while the places with no or small housing price increases were normally located in urban downtown areas, during the COVID-19 pandemic crisis year of 2020–2021.

To determine statistically significant hot or cold spots in these most populous cities during the COVID-19 pandemic year of 2020–2021, we conducted a cluster and outlier analysis by calculating the local Moran’s I. Figure 10 shows the cluster and outlier analysis results for the ten most populous cities during the COVID-19 pandemic year of 2020–2021. It can be seen that the urban downtowns of the six most populous cities (New York City, Philadelphia, Dallas, Houston, Los Angeles, and San Jose) belong to the low-low clusters or cold spots. Only the urban downtowns of two cities, Chicago and Phoenix, belong to the high-high clusters or hot spots. When zoomed in, one can find that the urban downtowns of another two cities, San Antonio and San Diego, belong to the low-high outlier patterns or cold spots with lower confidence levels. Although the housing price change rates in most of the urban downtowns of these cities belong to cold spots, the housing price change rates in the suburban areas of the nine most populous cities, except Houston, belong to the high-high clusters or hot spots.

To find out whether or not housing price change rates have similar ‘ring’ patterns in other relatively small cities, we also conducted cluster and outlier analysis for several relatively small cities. Figure 11 shows the analysis results for some such cities with ‘ring’ patterns, such as Boston, Washington, Atlanta, Indianapolis, Denver, Las Vegas, Portland, and Seattle. It can be seen that the housing price change rates in the urban downtowns of these cities typically belong to either cold spots or spots with no significant housing price change, while the housing price change rates in their suburban areas normally belong to hot spots.

As previously mentioned, although housing price change rates in most places in the Midwest, Southwest, and Southeast regions belong to either cold spots or spots with no significant housing price change, there are still some hot spots around certain major cities in these regions. Figure 12 shows some cluster and outlier analysis results for housing price change rates in various example cities in the Midwest, Southwest, and Southeast regions with hot spots. These example cities include Cleveland, Akron, Columbus, Detroit, Milwaukee, Charlotte, Cincinnati, Jacksonville, Boise City, and Salt Lake City. Although the housing price change rates around major cities in the Midwest and Southwest regions...
belong to hot spots, the housing price change rates in rural areas far away from these cities belong to cold spots. Figure 13 shows the cluster and outlier analysis results for example cities with such a ‘ring’ spatial pattern. The example cities include Memphis, Oklahoma City, St. Louis, and Pittsburgh. It can be seen that the housing price change hot spots in the urban areas are normally surrounded by cold spots (a ‘ring’) in the rural areas.

Figure 8. Maps of housing price change rates in some of the most populous U.S. cities (New York, Philadelphia, Chicago, Houston, San Antonio, Austin) during the year 2019–2020 and the year 2020–2021.
price change rates in the suburban areas of the nine most populous cities, except Houston, belong to the high-high clusters or hot spots.

Figure 9. Maps of the housing price change rates in some of the most populous U.S. cities (Dallas, Las Vegas, Phoenix, San Jose, Los Angeles, and San Diego) during the year 2019–2020 and the year 2020–2021.
Figure 10. Cont.
To find out whether or not housing price change rates have similar 'ring' patterns in other relatively small cities, we also conducted cluster and outlier analysis for several relatively small cities. Figure 11 shows the analysis results for some such cities with 'ring' patterns, such as Boston, Washington, Atlanta, Indianapolis, Denver, Las Vegas, Portland, and Seattle. It can be seen that the housing price change rates in the urban downtowns of these cities typically belong to either cold spots or spots with no significant housing price change, while the housing price change rates in their suburban areas normally belong to hot spots.

**Figure 10.** The cluster and outlier analysis results for the 10 most populous cities (New York City, Philadelphia, Chicago, Dallas, Houston, San Antonio, Phoenix, San Diego, Los Angeles, and San Jose) during the pandemic year.

**Figure 11.** Cont.
Figure 11. Some cluster and outlier analysis results for the relatively small-sized example cities (including Boston, Washington, Atlanta, Indianapolis, Denver, Las Vegas, Portland, and Seattle) during the COVID-19 pandemic year.
Figure 11. Some cluster and outlier analysis results for the relatively small-sized example cities (including Boston, Washington, Atlanta, Indianapolis, Denver, Las Vegas, Portland, and Seattle) during the COVID-19 pandemic year.

As previously mentioned, although housing price change rates in most places in the Midwest, Southwest, and Southeast regions belong to either cold spots or spots with no significant housing price change, there are still some hot spots around certain major cities in these regions. Figure 12 shows some cluster and outlier analysis results for housing price change rates in various example cities in the Midwest, Southwest, and Southeast regions with hot spots. These example cities include Cleveland, Akron, Columbus, Detroit, Milwaukee, Charlotte, Cincinnati, Jacksonville, Boise City, and Salt Lake City. Although the housing price change rates around major cities in the Midwest and Southwest regions belong to hot spots, the housing price change rates in rural areas far away from these cities belong to cold spots. Figure 13 shows the cluster and outlier analysis results for example cities with such a 'ring' spatial pattern. The example cities include Memphis, Oklahoma City, St. Louis, and Pittsburgh. It can be seen that the housing price change hot spots in the urban areas are normally surrounded by cold spots (a 'ring') in the rural areas.

Figure 12. Cont.
6. Discussions

The outbreak of the COVID-19 pandemic crisis has had an effect on housing prices in the U.S. This impact can be seen by comparing the general housing price change rate trend for the past nine normal years with the general housing price change rate trend during the COVID-19 pandemic year. In general, housing prices in the U.S. had an increasing trend during the COVID-19 pandemic year.

The housing prices in many major cities had some temporary slow-down or dip trends in the early part of the COVID-19 pandemic crisis (April or May 2020). A possible reason may be that, at the beginning of the COVID-19 pandemic crisis, social distancing precautions reduced intention for house viewing, which is a key part of the selling process, and both buyers and sellers had to reconsider their plans. Sellers increasingly looked...
6. Discussions

The outbreak of the COVID-19 pandemic crisis has had an effect on housing prices in the U.S. This impact can be seen by comparing the general housing price change rate trend for the past nine normal years with the general housing price change rate trend during the COVID-19 pandemic year. In general, housing prices in the U.S. had an increasing trend during the COVID-19 pandemic year.

The housing prices in many major cities had some temporary slow-down or dip trends in the early part of the COVID-19 pandemic crisis (April or May 2020). A possible reason may be that, at the beginning of the COVID-19 pandemic crisis, social distancing precautions reduced intention for house viewing, which is a key part of the selling process, and both buyers and sellers had to reconsider their plans. Sellers increasingly looked for reassurance regarding the health of potential buyers coming to view properties. As the pandemic began to spread in mid-March 2020, the amount of homes for sale in the U.S. housing market decreased, as sellers delisted their homes to prevent the risk of contracting COVID-19. At the same time, homebuyers were reluctant to visit prospective homes due to stay-at-home orders. Many areas in the U.S. experienced a noticeable drop in home sales during the initial phases of the pandemic in early 2020, due to health concerns, extensive lay-offs or furloughs, stay-at-home orders, and economic uncertainty. In April and May 2020, nationwide home sales dropped to their lowest levels since the housing and financial crisis that began in 2007. Americans preferred to have cash to hand and personal financial security. This created a general trend of a cautious pause, to see how the pandemic would play out before spending money on hard assets such as houses. Normally, a large decline in demand for new home sales would be accompanied by a drop in prices. However, the COVID-19 pandemic turmoil in Spring 2020 did not lead to large price declines in the U.S. housing market. The combination of low supply and historically low mortgage rates allowed housing prices to remain steady throughout April and May 2020 in the U.S. housing market.

Surprisingly, housing prices bounced back quickly and had a sharp increase during the later COVID-19 pandemic period. The reasons may be that over the course of the last few months in 2020, with hopes of ‘normalizing’ back to pre-pandemic life growing, as well as the increasing hope of vaccination and ‘reopening’ business policies, economic growth and consumer spending followed a positive trajectory. Under such a situation, investment in the stock market quickly escalated. Accordingly, the U.S. housing market followed a similar trend, with relatively low mortgage rates and more positive consumer sentiments fueling a sudden interest in home buying. In addition, real estate brokers began to utilize digital technologies and online services to a greater extent in running their businesses. For example, some U.S. brokers offered virtual house tours via Skype and FaceTime. Brokers also asked potential buyers to preregister for viewings in order to gauge their level of interest and likelihood of purchase [1]. Potential buyers started to increase their housing search and purchase activity by the end of May 2020. Home showings per listing rose from their low levels in March and April 2020, and were well above pre-pandemic levels by May 2020, aided by the increase in online and socially distanced viewings. Home sales in the U.S. housing market rebounded in the summer 2020. Potential homebuyers rushed to the housing market to take advantage of the historically low mortgage rates. Americans valued homeownership more than before and were more capable of affording the down payments, due to higher forced savings during the COVID-19 pandemic. The U.S. household budgets changed during the pandemic, probably because savings rates increased as vacations were canceled, big-ticket purchases were waylaid, and retail spending plummeted. Based on a recent Zillow survey, more than half of young adults plan to use their pandemic savings for buying a home, which could worsen the housing crisis [43].

In addition, the U.S. Federal Housing Finance Agency loosened its national appraisal standards to allow households to qualify for larger mortgages, as housing values had grown. Most importantly, the improving economy and the approaching peak home-buying years of millennials are driving a residential housing boom in the U.S. Millennials and
baby-boomers are the two largest age segments of the U.S. population. A recent Zillow study found that about half of all buyers are under the age of 36 and about half of sellers are under 41 [44]. Housing supplies are now at their lowest level since the 1970s, due to millennial homeownership and other factors, such as rising building prices and real estate speculators snapping up starter homes.

While housing demand made progress by the end of May 2020, housing supply did not recover at the same pace. There was a lower inflow of sellers to the real estate markets. New listings, despite improving from their April lows in 2020, were only slightly higher than a year before. Homeowners were reluctant to list their homes for sale. Generous mortgage forbearance programs and the foreclosure moratorium may also have helped to reduce supply. As a result, housing inventories declined. The foundational forces in the housing market are supply and demand. During the late COVID-19 pandemic period, new demand exceeded even pre-pandemic levels of supply, and the gap was too large to be realistically filled by new construction, in the short term. In addition, the housing price data used in this study included the prices of newly built homes. Due to the limited available data, it is impossible to separate the newly built home prices from the old home prices in this study. Higher building costs, longer delivery times, and general unpredictability in the construction supply chain during the COVID-19 pandemic period could have had great impacts on new home prices. Builders could not afford to produce cheaper houses, owing to rising building material prices. Therefore, housing prices in many places greatly increased during the later COVID-19 pandemic period.

However, the effects on housing prices from the COVID-19 pandemic crisis were not uniform or random across different areas in the U.S. Not everywhere saw housing prices soar in the U.S. real estate market. While many places, especially many coastal areas in the Northeast and West regions, saw a sharp housing price rise during the COVID-19 pandemic, other places, particularly some rural areas in the Midwest, Southwest, and Southeast regions, experienced a housing price decline. In spite of the hot real estate market during the COVID-19 pandemic year, there were still many housing price cold spots in some rural areas in the Midwest, Southwest, and Southeast regions. Of course, not all the places in the Midwest, Southwest, and Southeast regions showed cold spots. Some housing price hot spots existed around the major cities in these regions. A common spatial ‘ring’ pattern can be seen from many of the housing price change rate maps of the major cities, no matter if they are located in the Northeast and West coastal regions or in the Midwest, Southwest, and Southeast regions. Houses in the urban downtowns typically had either lower prices or no significant price increase, while houses in the suburban areas (around the cities) normally had significantly increased prices.

The spatial patterns could be related to the COVID-19 pandemic crisis. During the COVID-19 pandemic crisis, Americans might have become more concerned about living in urban areas with a high population density, due to fears about the contagious disease. Americans might have perceived that in places with a high-density population, COVID-19 disease transmission is easier, due to overcrowding. For the health and safety purposes, Americans might have felt safer living in a less crowded place, such as suburbs, or even rural areas, during the pandemic period. Therefore, this may be the reason that brought a decline in the demand for houses located in urban downtowns. The reduced demand for urban downtowns property may also have been partially driven by the diminished need for living close to jobs in urban downtowns. The COVID-19 pandemic reshaped the nature of work and home in the U.S. Owing to the contagious nature of COVID-19, some office workers no longer commuted to crowded urban locations for work and were able to work from home. Some companies even started to allow their employees to permanently work remotely. Americans began to conduct businesses at home virtually. As urban cores have soared in popularity, so have urban home prices. To afford bigger homes and to find shared amenities, such as community gyms and pools, many Americans, especially many millennials, are willing to live farther out of a city and live in the suburbs.
Due to the COVID-19 pandemic, many households reconsidered their housing needs and their homes became substitutes for offices, restaurants, schools, and recreation facilities. COVID-19 forced Americans to spend more time at home and reduced the value of urban amenities, when restaurants, indoor gathering, cultural exhibits, etc. were unavailable. These factors pushed Americans into moving to suburban environments and into opting for yards and extra space to accommodate work and schooling simultaneously. While Americans still wanted to be within commuting distance of large employment centers, they were willing to extend the distance from urban downtowns during the COVID-19 pandemic crisis. The reduced demand for houses in urban downtowns and the increased demand for houses in suburban areas could have been the factors that led to the aforementioned spatial patterns of housing price changes across different geographical locations in the U.S. housing market.

7. Conclusions

Remote working, irrational and millennial buying, jittery markets, and the desire to obtain more home space for less money in the middle of the ongoing pandemic created one of the most unpredictable real estate markets in a generation in the U.S. The reduced supply and the increased demand, with a higher inflow of millennial buyers to the U.S. real estate market, caused a significant housing price increase during the COVID-19 pandemic crisis. Although many studies have been conducted to investigate the impact of the COVID-19 pandemic crisis on real estate markets, the geographies or spatial patterns of housing price changes have been little studied in the literature. This study provided a spatial analysis of housing price changes in the U.S. during the COVID-19 pandemic crisis. We found that the influence of the COVID-19 pandemic crisis on housing price changes varied across space in the U.S. The patterns not only differed from metropolitan areas to rural areas, but also varied from one metropolitan area to another. It seems that COVID-19 made Americans more cautious about buying property in densely populated urban downtowns that had higher levels of virus infection. Therefore, during the COVID-19 pandemic year, the housing price hot spots were typically located in more affordable suburbs, smaller cities, and areas away from high-cost, high-density urban downtowns. These results are consistent with the findings from Liu and Su [33] and Ramani and Bloom [27]. While COVID-19 could have forced some Americans to move away from high-priced, high-tax, and high-lockdown urban locations, such as the downtowns of New York City, there were also many hot spots around the coastal cities in the Northeast and West regions. Although the housing price change cold spots, and spots with no significant housing price changes, were most located in various rural areas in the Midwest, Southwest, and Southeast regions, there were many housing price change hot spots around major cities in these regions. Apparently, many Americans wanted to buy houses located in warmer and safer places with lower taxes, less regulations, and fewer lockdowns; in the Southeast and Southwest regions.

The findings from our study imply that governments, policymakers, and/or related businesses should consider local situations or local economic activities when they form their real estate market policies or take action to fight recession due to the heterogeneous impacts of the COVID-19 pandemic on the housing market. Although we explored the spatial patterns of housing price changes in the U.S. before and during the COVID-19 pandemic year (2020–2021) in this study, further studies are needed to investigate the spatially non-stationary causal relationships between the housing price changes and the COVID-19 pandemic crisis. Many factors could have caused housing price changes, and the COVID-19 pandemic crisis is only one of them. To further examine the spatial heterogeneity of housing price changes caused by the COVID-19 pandemic crisis, future studies may focus on modelling the spatial causal relationships of housing price changes with COVID-19 cases and other factors, such as population, employment, education, poverty, and other socio-economic data in different counties in the U.S. Furthermore, geographical inequalities in housing price changes may increase the wealth gap between the poor and the rich. The
varied influence of the COVID-19 pandemic crisis on minority ethnic groups in the U.S. real estate market also needs further studies. In addition, there are still many uncertainties about the impact of COVID-19 pandemic on housing prices in U.S. We still do not fully understand many aspects of the pandemic itself, such as the infectiousness, prevalence, and lethality of the COVID-19. There are many uncertainties about the near-term economic impacts of the pandemic and policy responses in the real estate market. Future studies could investigate the impact of pandemic-induced shifts in consumer spending patterns and government intervention policies on housing price changes. We may also conduct some comparison studies to examine the spatial patterns of price changes across different real estate types, such as residential real estate, commercial real estate, and vacant land.

Author Contributions: Conceptualization, X.L. and C.Z.; methodology, X.L.; software, X.L.; validation, X.L. and C.Z.; formal analysis, X.L.; investigation, X.L.; resources, C.Z.; data curation, X.L.; writing—original draft preparation, X.L.; writing—review and editing, C.Z.; visualization, X.L.; supervision, C.Z.; project administration, C.Z.; funding acquisition, C.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research is partially supported by USA NSF grant No. 2022036. Authors have the sole responsibility to all of the viewpoints presented in the paper.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References
7. Tanrıvermiş, H. Possible impacts of COVID-19 outbreak on real estate sector and possible changes to adopt: A situation analysis and general assessment on Turkish perspective. J. Urban Manag. 2020, 9, 263–269. [CrossRef]


35. Li, H.; Wei, Y.D. Spatial inequality of housing value changes since the financial crisis. *Appl. Geogr.* 2020, 115, 102141. [CrossRef]


