

THESIS

MARSHALL FIRE'S IMPACT ON COLORADO HOUSING MARKET

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ABSTRACT

MARSHALL FIRE'S IMPACT ON COLORADO HOUSING MARKET

The devastation caused by wildfires not only results in the loss of human lives and property but also significantly impacts the residential housing real estate market in the United States. With the rise in urban and suburban wildfires and brushfires, as well as increased human settlement across the Wildlife Urban Interface (WUI) zone, it is imperative to analyze how wildfires in less rural areas impact the housing market. While previous studies have explored the impact of disasters on the housing market, only a few studies have focused specifically on how wildfires affect the residential housing market in the United States. Out of those, there are only limited studies about wildfires in suburban and urban communities. This research focuses on examining the aftermath of the Marshall Fire, a brushfire that occurred in a suburban region near Boulder, Colorado, in December 2021, causing damage to over 1,000 residential homes. The study investigates the impact of the Marshall Fire on the residential housing market in Colorado, aiming to achieve two primary objectives: 1) determine the extent and timing of changes in housing values following the Marshall Fire, and 2) assess how geographical proximity to the fire zone affected housing values. The study collects secondary data on the monthly housing values for Marshall Fire-affected zip codes and surrounding areas in Colorado from Zillow. Data from before and after the wildfire was analyzed to identify the extent of the impact of the Marshall Fire on home values. Results indicate a significant increase in median housing values in the fire-affected region. Housing values spiked two months post-fire, remained inflated for six months post-fire, and gradually returned to pre-fire trends after six months. Before the Marshall Fire, housing values in fire-affected zip codes

consistently lagged behind surrounding and other Colorado zip codes for 14 months. Statistical tests, including paired t-tests and repeated measures ANOVA tests, indicate that the changes in housing values pre-fire and post-fire are statistically significant. The geographic proximity of a home to the Marshall Fire also played a statistically significant role in housing value changes. This surge in housing values could be attributed to supply and demand dynamics in the real estate market. The research contributes valuable insights into the effects of suburban fires on the residential housing market, aiding stakeholders in making informed decisions for the future. The study's findings offer valuable guidance for homebuyers, sellers, and the general public in predicting housing market trends in the event of similar incidents, facilitating informed decision-making.

TABLE OF CONTENTS

ABSTRACT.....	ii
LIST OF TABLES.....	vii
LIST OF FIGURES.....	viii
CHAPTER 1: INTRODUCTION.....	1
1.1 Research Questions.....	3
CHAPTER 2: LITERATURE REVIEW.....	4
2.1 Overview of Marshall Fire.....	4
2.1.1 Trends in Colorado Wildfire.....	5
2.1.2 Impact of Marshall Fire on Communities (Marshall Fire Damage Assessment)	6
2.2 How the Residential Housing Market Responds to Disasters	7
2.2.1 Disaster Studies in Global Context.....	8
2.2.2 Wildfire Studies in Colorado	9
2.4 United States Housing Market.....	12
2.4.1 Housing Market Trend in the United States	12
2.4.2 Housing Supply Elasticities	13
2.4.3 Post-Covid Housing Market	14
2.5 Relationship Between Housing Price and Rental Price	16
2.5.1 Price to Rent Ratio.....	16
2.5.2 Post Disaster Rental Market.....	17
2.6 Effect of Disaster on Labor Market	18

CHAPTER 3: DATA COLLECTION AND METHODOLOGY	20
3.1 Data Collection	21
3.1.1 Fire-affected Zip Codes	21
3.1.2 Monthly Typical Home Values.....	24
3.1.2.1 ZHVI (Zillow Home Value Index)	24
3.1.3 Housing and Rental Vacancy.....	26
3.2 Data Preparation.....	26
3.2.1 Time Frame	28
3.3 Data Analysis	28
CHAPTER 4: RESULTS.....	30
4.1 Residential Housing and Rental Vacancy Rates in the United States	30
4.2 Monthly Typical Housing Value Analysis	32
4.2.1 Quarterly Analysis of Home Values	32
4.2.1.1 Pre-Fire	33
4.2.1.2 Post-Fire.....	33
4.2.2 Monthly Analysis of Housing Values.....	35
4.2.3 Rate of Percentage Change of Housing Values	36
4.2.4 Implications.....	36
4.3 Average Typical Home Value 14 months Pre and Post-Marshall Fire.....	39
4.4 Statistical Test Results	40
4.4.1 Normality Test	41
4.4.2 Paired T-Tests	41

4.4.3 ANOVA Test Results	43
4.4 Limitations and Future Work.....	45
CHAPTER 5: CONCLUSION	47
5.1 Discussion.....	47
5.1.1 Risk Perception	48
5.1.2 Rental Market Influence	48
5.1.3 Practical and Theoretical Contributions.....	49
REFERENCES	51

LIST OF TABLES

Table 1. Total number of structures impacted by Marshall Fire.....	8
Table 2. The effect of Natural Hazards on the Housing Market.....	11
Table 3. Zip Codes Categories.....	27
Table 4. Housing and rental unit vacancy rates (in percentage) for 2021	31
Table 5. Tabulated quarterly percentage change in housing values	34
Table 6. ZHVI Mean Housing Values Before & After the Marshall Fire	40
Table 7. Shapiro-Wilk Normality Test Results.....	41
Table 8. Paired Samples T-Test Results: Pre- and Post- Fire	42
Table 9. Repeated Measures ANOVA Results: Between Subject Effects.....	44
Table 10. Repeated Measures ANOVA Results: Pre-Fire Analysis of Variance	44
Table 11. Repeated Measures ANOVA Results: Post-Fire Analysis of Variance	45

LIST OF FIGURES

Figure 1. Damage caused by Wildfires in United States from 1984 to 2020 (US EPA, 2022)	2
Figure 2. Marshall Fire map (Boulder County, 2022)	7
Figure 3. U.S. National Home Price Index from 1995 to 2022 (FRED Economic Data, 2024)...	13
Figure 4. Shift in housing demand within and across MSAs (Liu & Su, 2021)	16
Figure 5. Research Methodology	20
Figure 6. Marshall Fire map within the fire-affected zip codes.....	22
Figure 7. Fire-affected and fire- adjacent ZIP Codes	23
Figure 8. Quarterly typical home value 14 months pre and post fire	32
Figure 9. Quarterly percentage change in housing values pre and post fire	33
Figure 10. Monthly percentage change in housing values (14 months pre and post fire)	35
Figure 11. Rate of percentage change in housing values (14 months pre and post fire)	37
Figure 12. Monthly percentage change in housing values (pre fire)	39

CHAPTER 1: INTRODUCTION

The devastation caused by wildfires has reached an alarming level, making them more than simply a regional or seasonal issue. Every year, records are broken for the number of homes destroyed, acres burned, and containment costs related to wildfires. According to the annual wildland fire statistics provided by the National Interagency Coordination Center (NICC), the average number of acres burned annually in the United States increased by 197% between the 1980s and the 2010s. NICC wildfire statistics indicate that in the last decade, the United States experienced an average of 61,410 wildfires each year burning an average of 7.2 million acres impacted per year (NICC, 2022).

In 2022, more than 68,000 separate wildfires have burned 7.6 million acres in the United States (NICC, 2022). Figure 1 below illustrates the damages caused by wildfires in the United States from 1984 to 2020. The chart displays the extent of areas burned by wildfires categorized by severity, measured in million acres. The data reveals an overall increasing trend in the burned area over the period from 1984 to 2020. Wildfires also pose a direct threat to the lives of people living in fire-risk areas, as well as the environment, communities, and property. The United States' wildland-urban interface (WUI) has grown beyond its original size because of the nation's expanding population, increasing housing demands, and desire to live closer to natural areas. The Wildland Urban Interface (WUI) is the transitional area where human development and structures meet or intermingle with undeveloped wildland or vegetative fuels (U.S. Fire Administration, 2024).

The effects of these wildfires extend across different industries including supply chains, skill shortages, and the real estate market. According to Verisk Analytics, a company that evaluates

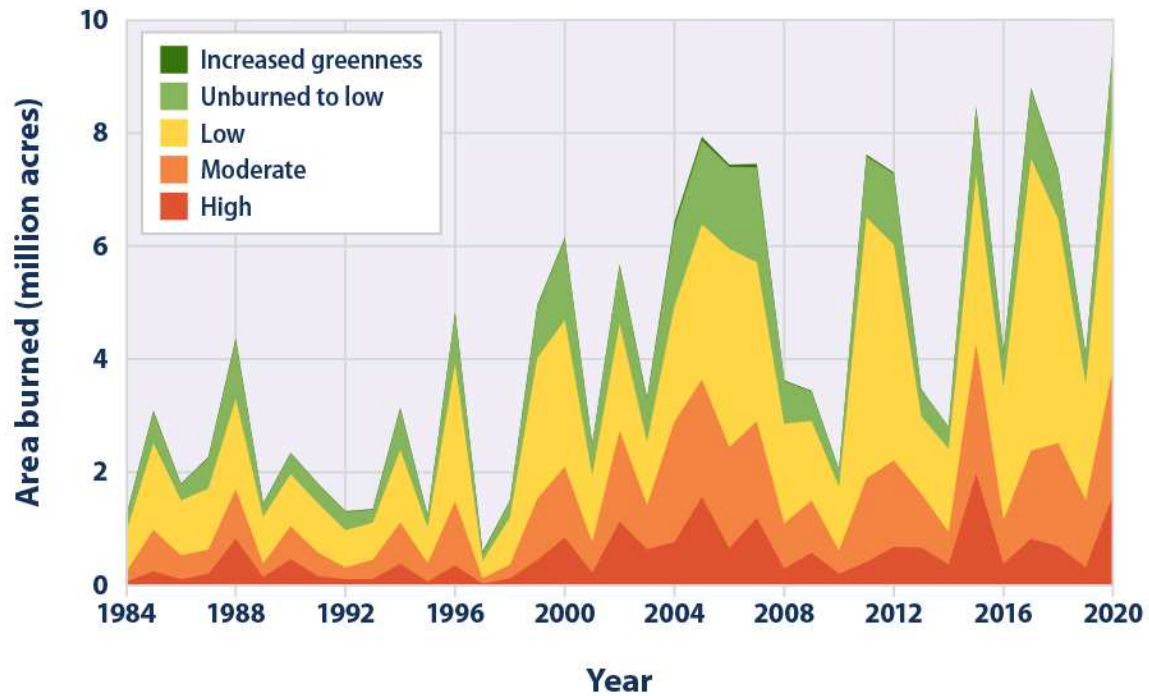


Figure 1. Damage caused by Wildfires in United States from 1984 to 2020 (US EPA, 2022)

insurance risk, over 4.5 million houses in the United States are at high or extremely high wildfire risk (Metz & Masterson, 2022). Houses located within WUI areas or in densely populated urban and suburban regions are at higher risk of wildfire-related damages. The United States experienced an average annual loss of over 3,000 structures to Wildland-Urban Interface (WUI) fires between 2002 and 2016 (U.S. Fire Administration, 2024).

Following a wildfire, the reduced desirability of living in a now-identified hazardous location may be reflected in the housing market. Initially, households might accept the risk, perceiving a net benefit of living in the forested environment because of the amenity value associated with it. However, after a 'near miss,' such as a nearby forest fire, homeowners' risk perception rises, diminishing the net benefits of living in the forested environment, which should be mirrored in a decline in house prices (Loomis, 2004). With the occurrence of a wildfire, the public's perceived risk of such an event also increases. This increased risk perception may lead

buyers and sellers to devalue homes in high fire risk areas, resulting in a decline in housing values. Additionally, the post-disaster landscape may reduce amenity levels, affecting the desirability of a neighborhood or community vulnerable to wildfires.

1.1 Research Questions

This research focuses on examining the aftermath of the Marshall Fire, a brushfire that occurred in a suburban region near Boulder, Colorado, in December 2021, causing damage to over 1,000 residential homes. The study investigates the impact of the Marshall Fire on the residential housing market in Colorado, aiming to achieve two primary objectives: 1) determine the extent and timing of changes in housing values following the Marshall Fire, and 2) assess how geographical proximity to the fire zone affected housing values.

The research aims to address the following research questions.

How is Marshall fire affecting the residential housing market in Colorado?

- By how much are the typical home value changing?
- When does this home value shift occur?
- How does the geographical proximity to the wildfire affect the housing price change?

CHAPTER 2: LITERATURE REVIEW

While previous studies have explored the broader impact of disasters on the residential housing market, there is a notable gap in the literature regarding the effects of wildfires, particularly those occurring in suburban and urban communities. Limited research exists that compares home values before and after wildfires (J. M. Mueller & Loomis, 2014). Most existing fire studies primarily focus on wildfires in the Wildland-Urban Interface (WUI) zone or rural areas, as most wildfires in the United States occur near forested areas. Consequently, there is a scarcity of studies concentrating on wildfires in suburban and urban regions. This chapter explores the background of the Marshall Fire and the general wildfire trends across Colorado and the United States. It introduces several studies that have analyzed post-disaster residential housing market dynamics. The latter portion of this chapter provides additional insights into housing market patterns in the United States, exploring the impact of the post-COVID era on the housing market and examining the role of rental vacancies in disaster recovery.

2.1 Overview of Marshall Fire

On December 30, 2021, the Marshall Fire sparked in Boulder County and burned 6,026 acres of land. Boulder County, with a population of 326,000 residents, is located in north-central Colorado, spanning 740 square miles across the western plains and the Rocky Mountains. The devastating wildfire raged through the City of Louisville, the town of Superior, and unincorporated Boulder County, resulting in the destruction and damage of more than 1,000 homes and over 30 commercial structures (Case, 2022). Initially starting in the sparsely developed Wildland-Urban Interface (WUI) southwest of the City of Boulder, the fire rapidly spread to areas of suburban sprawl, engulfing various structures such as tract homes, shopping plazas, and other commercial

businesses. The lack of snow that winter, coupled with high winds and parched grass, created favorable conditions for the rapid escalation of wildfire (Fovell et al., 2022). The fire occurred in the heavily populated suburbs between Denver and Boulder, causing damages of around \$2 billion. According to the number of structures destroyed and damaged, this fire is said to be the most destructive fire in Colorado history. Two people were also found dead in the aftermath of the Marshall Fire (KUSA, 2022).

The United States has experienced a rise in wildfires due to climate change, as indicated by the fourth National Climate Assessment, which attributes the increase to heightened temperatures, prolonged drought, and insect infestations (USGCRP, 2018). Experts point to the increasing frequency of such events, attributing them to the effects of climate change warming the planet and the expansion of suburbs into fire-prone areas (Rebecca, 2022). As a result, events like the Marshall Fire are projected to become more commonplace in the future.

2.1.1 Trends in Colorado Wildfire

Colorado is one of the fastest growing states in the United States with an annual population growth rate of 1.4% and a current population of over 5.8 million (US Census Bureau, 2023e). In recent years, Colorado has experienced an increase in the frequency and severity of wildfires due to warmer and drier climate conditions (Wright & Roy, 2022). The number of people living in the wildland-urban interface (WUI) - an area where structures or other human developments meet or intermingle with wildland vegetation or other fire fuels - has grown tremendously in recent years. Data from the Colorado Wildfire Risk Assessment shows that people residing in WUI in Colorado increased by nearly 50% from 2012 to 2018 (Colorado State Forest Service, 2022). Approximately 2.9 million residents of Colorado, which is half of Colorado's population live in these vulnerable areas as of 2018 (Colorado State Forest Service, 2022), whereas this number was 2 million

residents just five years ago. Wright & Roy (2022) analyzed the spatial patterns and trends of fire occurrences in Colorado from 2001 to 2020. The authors found a seasonal variation in the size and dispersion of Colorado wildfires over the past 20 years, with the fires traveling in a circular pattern from the southeast in the winter to the northwest in the summer. However, there have been more wildfire incidents reported in recent years and their locations have grown more unpredictable with the potential to spread further north, likely due to climate change.

2.1.2 Impact of Marshall Fire on Communities (Marshall Fire Damage Assessment)

The day after the Marshall Fire, President Biden declared the Marshall Fire as a federal major disaster (FEMA-4634-DR, Colorado – Wildfires and Straight-line Winds), under the authority of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, 42 U.S.C. 5121 *et seq.* (the “Stafford Act”). On January 6, 2022, the damage assessment report was published on the Boulder County webpage after a comprehensive inspection of all damaged buildings within the fire perimeter (FEMA, 2022). The report categorized the status of impacted properties as damaged or destroyed. Properties classified as destroyed included those with a complete failure of major structural components which were not economically feasible to repair whereas properties categorized as damaged included those with minor to major structural damages that were habitable or could be made habitable with repairs. Figure 2 shows the fire map of the Marshall Fire with the fire boundary and the position of damaged and destroyed structures.

According to the Boulder County Assessor, the value of residential housing damages was more than \$513 million. Over 97% of the buildings affected by the Marshall Fire were identified as destroyed, with only a handful listed as damaged (e.g., capable of being repaired). The report shows that 1,084 residential and 7 commercial properties were destroyed and 149 residential and 30 commercial properties were damaged countrywide (Boulder County, 2022).

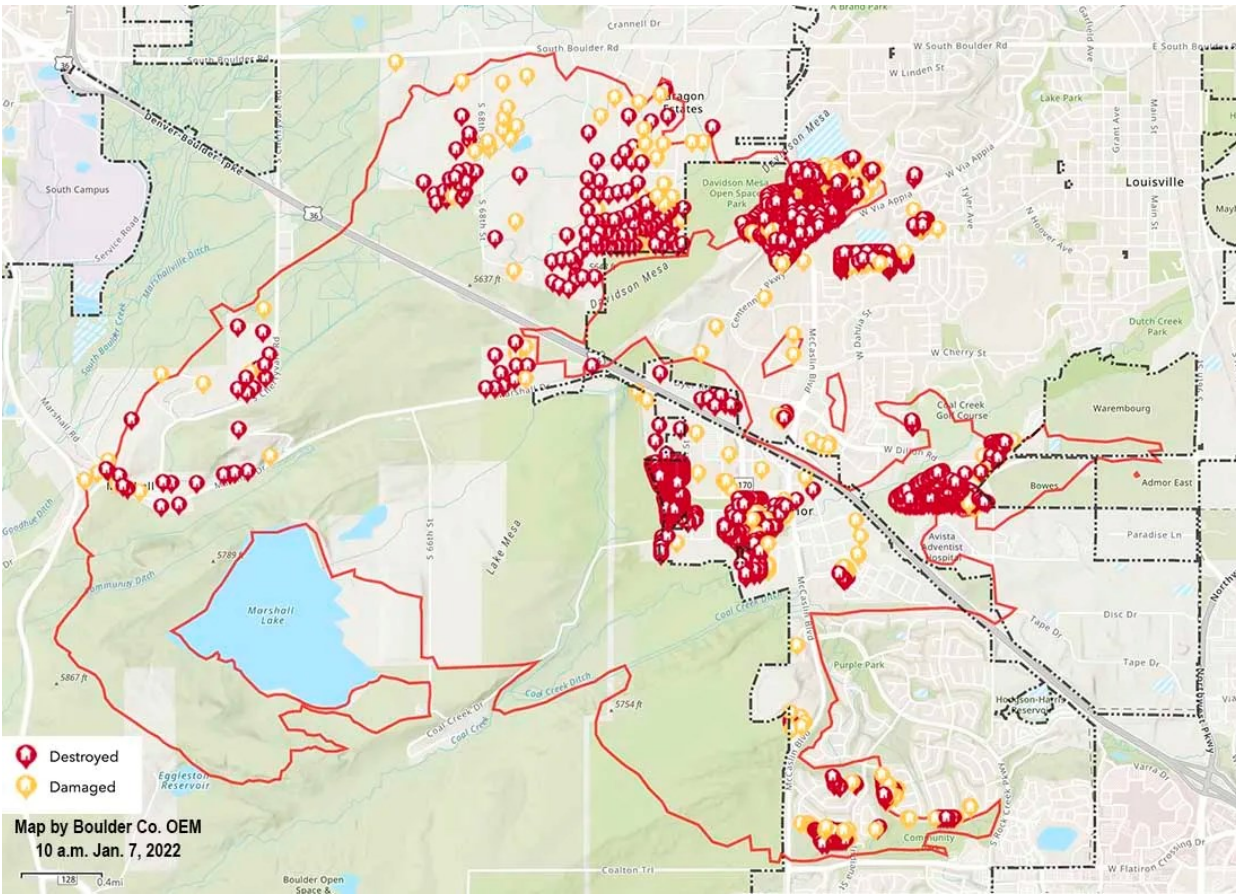


Figure 2. Marshall Fire map (Boulder County, 2022)

In terms of the number of structures lost, the Marshall Fire is considered to be the most destructive fire in Colorado's history (Dougherty & Johnson, 2023). The fire raged through the city of Louisville, the town of Superior, and unincorporated Boulder County. The fire resulted in the destruction and damage of 4.95% of structures in zip codes 80303 and 80027. Table 1 below shows the total number of damaged and destroyed structures in Louisville, Superior, and Unincorporated Boulder County.

2.2 How the Residential Housing Market Responds to Disasters

This section explores the impact of disasters on the residential housing market, discussing immediate responses in global contexts, including studies on bushfires, floods, and hurricanes. The

Table 1. Total number of structures impacted by Marshall Fire

	Louisville	Superior	Unincorporated Boulder County	Total
Residential (Destroyed)	550	378	156	1084
Residential (Damaged)	43	58	48	149
Commercial (Destroyed)	4	3	0	7
Commercial (Damaged)	14	14	2	30
Total	611	453	206	1270

focus then narrows the focus to wildfire studies specifically in Colorado. This includes studies that have examined housing costs and sales rates in Wildland Urban Interface (WUI) regions of the Colorado Front Range.

2.2.1 Disaster Studies in Global Context

Athukorala et al. (2019) used a hedonic pricing approach to examine how bushfires impacted residential housing market prices and whether residents in bushfire-prone areas were substantially affected by the bushfire risk. The study was conducted in the city of Brisbane, Australia, and showed home values decreased as proximity to bushfire-prone areas (open grassland spaces) rose. Due to suburban sprawl and environmental amenities associated with living near a forest, individuals are willing to pay extra to live close to forested areas, despite the increased risk of fire. Using a sample of repeated wildfires in Southern California, Mueller et al. (2009) looked into the home values of single-family residences located within 1.75 meters of the wildfire zone and found that the housing values dropped approximately by 9.7% after one wildfire and 22.7% after a second wildfire.

Housing values consistently decreased following other natural hazard events like floods and hurricanes as well. Bin & Landry, (2013) examined the risk premium of houses located in

flood zones in North Carolina after multiple storm events. They compared the prices of residential housing for properties located in FEMA-designated flood zones to properties located outside of flood zones, before and after two major hurricanes in Pitt County. The result showed a 5.7% drop in housing sales prices following Hurricane Fran and an 8.8% hurricane-induced flood-risk discount after Hurricane Floyd. These discounts lasted for 5 to 6 years before recovering and matching sales trends for homes outside the flood zone.

Following a major flood event in Dougherty County, Georgia in 1994, Atreya et al. (2013) conducted a similar analysis to determine how the flood affected home sales prices. They reported a post-flood property discount between 25% to 44% which lasted for 4–9 years. Similarly, Atreya & Ferreira (2015) used a hedonic property model and analyzed the change in risk perception following the same flood event in Dougherty County. They found that the homes located in flood inundated areas had a significant discount in listing prices as compared to other properties in the same floodplain that did not get fully inundated by the floodwaters. This supports their hypothesis that homeowners respond more to what they have experienced directly (“seeing is believing”) over other forms of disaster risk data such as floodplain maps.

2.2.2 Wildfire Studies in Colorado

Although wildfires are growing in frequency and severity across the United States, only a handful of studies have examined Colorado fire events. For example, McCoy & Walsh (2018) performed an empirical analysis of wildfires that occurred in WUI (Wildland Urban Interface) regions of the Colorado Front Range (COFR). They examined how wildfires affected housing assessed values and sales rates in the COFR region and found that disasters cause immediate but transient increases in risk perceptions. They observed that there is a temporary sales price drop for houses located in high fire-risk areas immediately after a wildfire, corresponding with a short-lived

increase in the sales rate of houses in these areas. However, housing sales prices in low fire-risk areas continue along the pre-wildfire trendline. Since this effect is only temporary, prices of homes in high-risk areas quickly reverted to baseline levels two to three years after the fire. In other words, homeowners who have directly experienced a recent wildfire are more likely to list their homes for a reduced rate – which temporarily drives up home-buying in high-risk area.

Loomis (2004) examined the effect of a wildfire in Buffalo Creek, Colorado on the residential housing market of the closest nearby town of Pine, located 2 miles from the fire zone. The author found a 15% drop in house prices in the town of Pine following the fire, based on housing transaction data 5 years after the fire. According to this study, a higher perceived fire risk and a lower level of amenities in the town of Pine may have caused a decrease in the town's desirability as a place to live, lowering Pine's home values.

Donovan et al. (2007) evaluated the impact of an online educational campaign on wildfire risk perceptions, made available to residents residing in WUI areas near Colorado Springs, Colorado. This website enabled homeowners living in the WUI areas to know their parcel-level wildfire risk ratings. The authors compared the relationship between wildfire risk and housing prices before and after the launch of the website. Results showed that residents had a higher perception of desirable community amenities and positive neighborhood characteristics in the WUI areas, despite the elevated wildfire risks. There was a premium price attached to the houses in the fire risk zone because of the positive amenity value of being located in an area closer to the green, a great view, and a ridge line (McCoy & Walsh, 2018). These positives offset the perceived loss from wildfire risk before the website was made public, but not after. Residents reported being more aware of the risk of wildfires after the website was launched, and housing prices within the WUI areas dipped temporarily but soon recovered.

Table 2 summarizes the findings of existing disaster studies by natural hazard. Based on the literature, there is a trend of an immediate decrease in housing assessed values and sales prices after a disaster, across multiple types of natural hazard events (wildfire, flood, etc.). Most existing

Table 2. The effect of Natural Hazards on the Housing Market

Disaster type	Location	Author	Findings
Bushfire	Brisbane, Australia	(Athukorala et al., 2019)	home values decrease as proximity to bushfire-prone areas (green space) rises
Wildfire	Southern California	(Mueller et al., 2009)	housing prices of single-family residences located within 1.75 m of wildfire zone dropped by 9.7% after one wildfire and 22.7% after a second price
Flood and Hurricane	North Carolina	(Bin & Landry, 2013)	result shows a 5.7% drop in housing prices following Hurricane Fran and a 8.8% hurricane-induced flood-risk discount after Hurricane Floyd
Wildfire	Colorado Front Range	(McCoy & Walsh, 2018)	temporary price drop of the properties located in high-risk area after a fire corresponding with a short-lived increase in the sales rate of houses in these areas
Wildfire	Buffalo Creek, Colorado	(Loomis, 2004)	15% drop in house prices in town of Pines (located 2 miles from the fire zone) following the fire
Wildfire	Colorado Springs	(Donovan et al., 2007)	positive amenity value of homes in higher risk zone offset the perceived loss from wildfire risk before the website was made public, but not after

studies related specifically to wildfires focus solely on case studies within WUI areas. Urban and suburban environments have historically been safe from wildfires because they are less likely to be near forest areas or WUIs – where the majority of wildfires occur in the United States. However, climate change and suburban sprawl are creating new high risk wildfire zones, as highlighted by the Marshall Fire in Colorado.

2.4 United States Housing Market

This section provides an overview of the United States housing market, explaining its historical trends. The housing market's response to economic downturns and unforeseen events, such as the Great Recession and COVID-19, has triggered shifts from urban to rural and Wildland-Urban Interface (WUI) areas, impacting suburban housing prices. The availability of rental vacancies during housing shortages emerges as a key factor influencing the speed of the housing market recovery. Exploring these links is crucial for understanding the broader impact on housing dynamics and urban resilience.

2.4.1 Housing Market Trend in the United States

Over the 23 years from 1975 to 1998, the average home sales price in the United States increased by 18%. The average (mean) income per worker increased by 12% during this time, whereas income per capita increased by nearly 40%. This shows that, on average, home prices increased in accordance with income throughout this time. The years from 1998 to 2006, however, were particularly noteworthy. Despite an almost 50% increase in home prices, income growth was only between 5% and 11% (Wheaton & Nechayev, 2008). While changes in housing prices have typically been influenced by local factors, Del Negro & Otrok (2007) mentioned that the overall increase in housing prices during this period was a national phenomenon. During the Great Recession of 2007–2009, the national real house price growth factor collapsed. The housing

market leveled off around 2010 and has since substantially recovered through 2019. According to Gupta et al. (2022), the national housing component has been isolated from the recognized macroeconomic shocks (fundamentals) since 2014, which raises the possibility that another "national bubble" is again developing in the United States housing market.

Figure 3 shows the graph representing the S&P/Case Shiller National Home Price Index from 1995 to 2022 published by the St. Louis Federal Reserve. This data is based on the existing house sales and is not seasonally adjusted. House prices increased significantly from the late 1990s to the mid-2000s. The Great Recession caused the residential housing market to plummet, and prices fell, losing nearly 27% of their national value. Prices have increased steadily since the Recession, but recovery has been slow (FRED Economic Data, 2024).

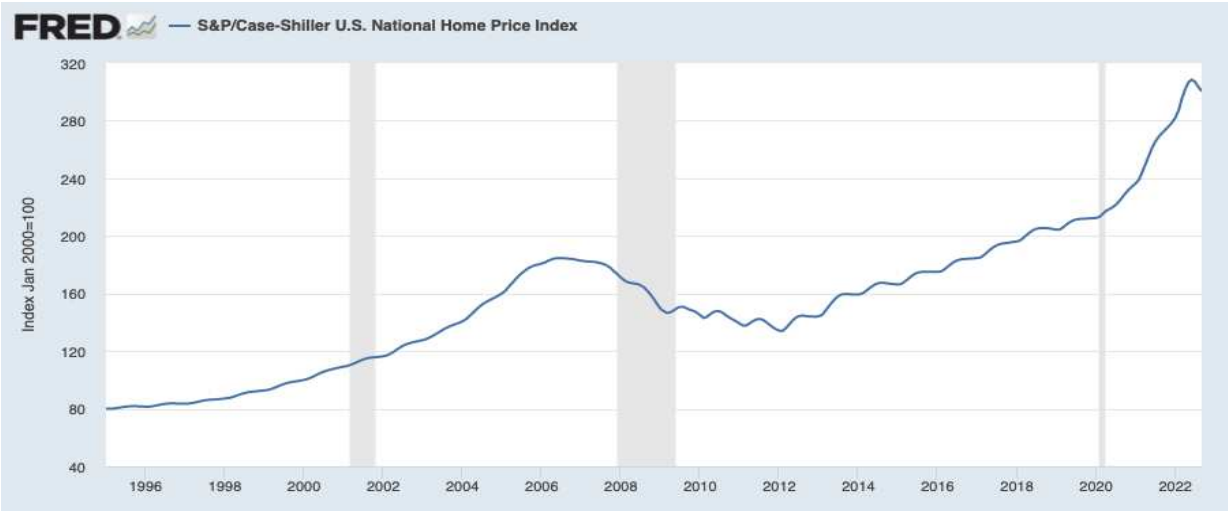


Figure 3. U.S. National Home Price Index from 1995 to 2022 (*FRED Economic Data, 2024*)

2.4.2 Housing Supply Elasticities

Geographically varying housing prices can be attributed to housing supply elasticities, which measure how much the quantity of housing (new houses being built) responds to changes in house prices (Green et al., 2005). Since the Great Recession of 2008, the housing supply in the United States has become more inelastic, particularly in areas where land-use regulations have

become more restrictive and in regions that experienced significant price declines during the recession (Albuquerque et al., 2020). Any increase in demand for housing leads to higher prices without leading to meaningful increases in housing unit construction due to the inelastic price elasticity of supply. When demand rises, areas with more elastic housing supply tend to have more stable or moderate price increases because builders can respond more readily to changes in demand. Conversely, areas with more inelastic housing supply may experience sharper price increases when demand rises since builders cannot quickly increase the housing supply to meet the demand. Since the residential housing market recovery began in mid-2012, home values across the United States have risen by about 30%, closely reflecting the pattern of the 1996–2006 housing boom. Despite the similar price development, the housing supply has not kept pace with demand due to population growth. While the overall rise in building permits from 1996 to 2006 was about 86%, building permit growth has only been around 20% since the Great Recession, representing a much weaker recovery in construction during the second boom. This shows that the United States' housing supply has become more inelastic (Albuquerque et al., 2020)

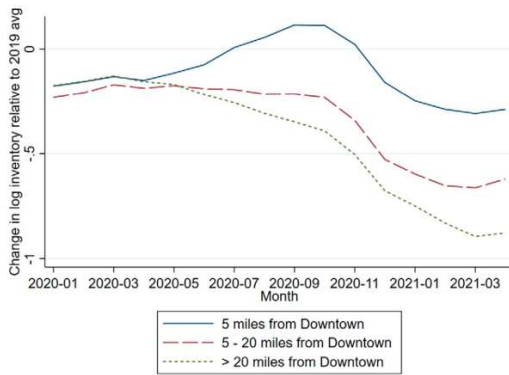
2.4.3 Post-Covid Housing Market

Liu & Su (2021) found that the COVID-19 pandemic reduced the housing demand in central cities and dense neighborhoods shifting the demand to the suburbs and neighborhoods with lower population density. Many offices adopted work-from-home policies following the COVID-19 pandemic in March 2020, which reduced the number of employees attending the offices (Bartik et al., 2020). After the first few days of the shutdown orders, the distance people traveled to the “non-essential” businesses such as restaurants dropped by 24%, and the number of visits to these places dropped by 40% (Alexander & Karger, 2021). With the remote arrangements, the desirability of living in dense neighborhoods and big cities, where amenities for consumption and

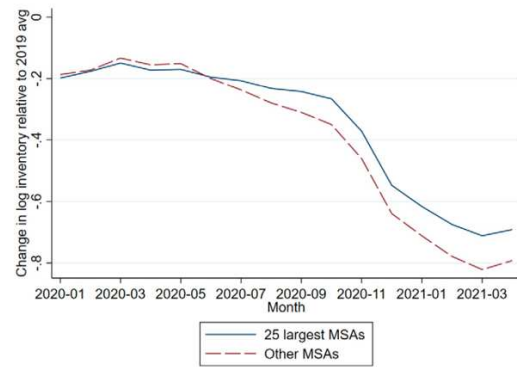
employment are concentrated, has decreased. The central cities and dense neighborhoods with higher pre-COVID-19 home values also witnessed an increase in home inventory and a relative decline in housing prices and rents after the pandemic. Because housing supply elasticities are generally lower in dense neighborhoods, housing costs there tend to be higher (Baum-Snow & Han, 2019). As the housing demand in these locations diminishes, the housing prices also drop. The COVID-19 pandemic has indeed influenced residential migration patterns, leading to some notable shifts from denser urban areas to suburban areas, Wildland-Urban Interface (WUI) zones, or rural communities. As of December 2022, the relative prices of suburban homes compared to urban homes in major US metropolitan areas remained elevated compared to pre-pandemic levels, sustaining the trend of increasing suburban house prices relative to urban centers observed during the pandemic (Biljanovska & Dell'Ariccica, 2023).

Figures 4(a) and 4(c) plot the growth of inventory and housing prices relative to the 2019 average for each month by distance to downtown for the 25 largest MSAs. Following the pandemic, the home inventory in central cities grew significantly faster than the inventory in suburban. Figures 4(b) and 4(d) plot the growth of housing inventory and prices in relation to the 2019 average for each month by the size of MSAs. The figures show a shift in housing demand away from larger cities to smaller ones. D'Lima et al. (2022) analyzed the property transaction data of more than two million residential properties in the United States between January 2019 and December 2020 and found that the shutdowns due to the pandemic were followed by a decrease in housing prices in dense areas but a price increase in less dense areas. In areas with a high population density (like downtown), the average price of a three-bedroom home decreased by around 1.4% but increased by about 1.5% in areas with a low density (like the suburbs). The size and structural density of properties also have an impact on post-shutdown pricing. The average

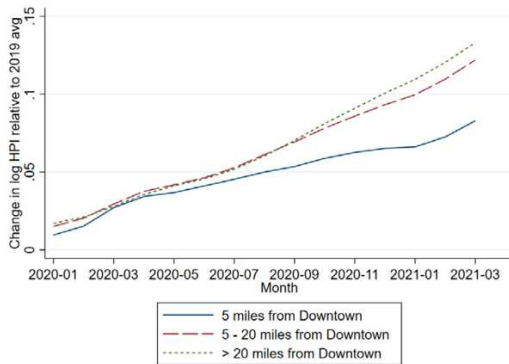
value of properties with low structural density grew particularly in areas with low population densities. The results imply that the pandemic has changed people’s behavior and preferences regarding the value of living close to one's place of employment as well as the cost that households are prepared to pay for extra space or rooms in various places.



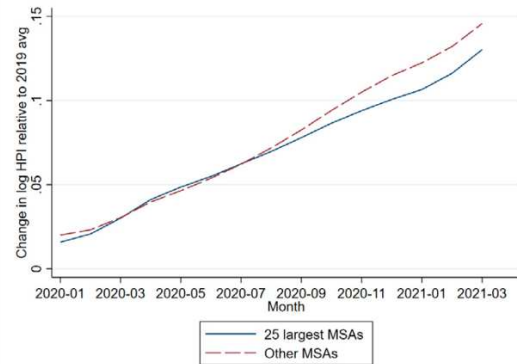
(a) Inventory (Within MSAs)



(b) Inventory (Across MSAs)



(c) HPI (Within MSAs)



(d) HPI (Across MSAs)

Figure 4. Shift in housing demand within and across MSAs (Liu & Su, 2021)

2.5 Relationship Between Housing Price and Rental Price

2.5.1 Price to Rent Ratio

The nominal home prices in the United States have doubled from 1994 to 2005. Gallin, (2008) used a price-to-rent ratio to predict changes in the housing market over the period of three years. The price-to-rent ratio is the ratio of home prices over the annualized rent within a given

location. This ratio serves as a standard for determining whether it is more affordable to rent or buy a home (Webb-Alexander et al., 2020). According to Gallin (2008), periods of high price-to-rent ratios (e.g., when house prices are higher relative to rent) are typically followed by periods of faster real rent growth and slower house price growth. Although the price-to-rent ratio can be used as an indicator of housing market valuation, it cannot be relied on to predict housing values with precision.

A price-to-rent ratio between 1 to 15 suggests it is much preferable to buy than rent; a price-to-rent ratio of 16 to 20 suggests it is typically better to rent than buy, and a price-to-rent ratio of 21 or more indicates it is much better to rent than buy (Pancak, 2017). According to an analysis of P/R ratios In Colorado (data set from 2010 Census), the majority of the counties in the state have P/R ratios that are higher than the 16 national average, which suggests it is financially a better idea to rent than buy across much of Colorado (Webb-Alexander et al., 2020).

In theory, when a housing market is in equilibrium, individuals are indifferent to buying or renting. If house prices become too high compared to rents, potential buyers may opt to rent, reducing demand for buying and increasing demand for renting. This shift leads to a decline in house prices and an increase in rents until equilibrium is restored. Conversely, if house prices are too low relative to rents, potential renters may choose to buy, increasing demand for buying and decreasing demand for renting. This results in a rise in house prices and a decrease in rents until a balance is achieved (Pancak, 2017).

2.5.2 Post Disaster Rental Market

The availability of rental vacancies plays a crucial role in urban recovery after a housing market-related disaster (Comerio, 1997). Comerio (1997) emphasizes that concentrated losses in multi-family housing within densely populated urban areas, as observed in the cases of Mexico

City, Loma Prieta, and Kobe, can lead to housing crises. Even if the percentage of total urban housing stock affected was small, the lack of alternative temporary housing for victims and the absence of insurance or governmental aid systems exacerbated the situation. In contrast, areas with high rental vacancy rates, such as in the cases of Hurricane Hugo and Andrew, allowed victims to find alternative temporary housing more quickly. The comparison underscores the importance of considering rental vacancy rates and the availability of alternative housing options when assessing the potential impact of urban disasters on housing markets (Comerio, 1997).

2.6 Effect of Disaster on Labor Market

The need for early reconstruction after the disaster causes a positive labor demand shock. Groen et al. (2020) studied the effect of two major hurricanes of the 2005 Atlantic Hurricane seasons, Hurricane Katrina and Hurricane Rita on individual's employment and earnings over the short and long term. Following Hurricane Katrina, Louisiana and Mississippi saw severe unemployment and high mass layoffs (Brown & Carey, 2006). The result shows that for the first year after the storm events, the affected people's earnings were negatively impacted, primarily because they lost their jobs. Individuals whose workplaces were impacted suffered higher temporary earnings losses that can be linked to business closing or migration. However, the storm-affected areas experienced a positive labor demand shock and a boost in wages for the workers in the construction sector. The increase in wages can be explained by the labor shortage, high reconstruction work, and increase in housing costs due to storms' destruction of residences.

Belasen & Polachek (2009) conducted a study on the local labor market following hurricane events by comparing a hurricane-hit county with other non-affected counties in Florida and reported a similar finding. The result showed a labor shortage in the hurricane-hit county and an increase in labor supply in the neighboring counties because of out-migration. As a result, the

hurricane-affected counties experienced up to a 4.35% increase in labor wages, while surrounding counties saw decreases in wages of up to 4.51%.

Chang-Richards et al. (2017) studied major earthquakes in Christchurch, New Zealand, and examined the effects of these events on the skills shortage in the construction industry. The country's already-existing skills shortages were exacerbated by the Christchurch earthquakes due to increased demand for reconstruction. Major skill shortage was identified in project management, site supervision, certain trades, and seismic assessment and design for buildings. Some of the main reasons for the skills shortages in undertaking reconstruction work were identified including, limited technical capacity nationwide, lack of temporary housing to accommodate additional workers, the time required for trainees to become skilled workers, lack of information about reconstruction workloads and lack of operational capacity within construction companies were identified as. Though this study is specific to New Zealand, the findings show the nature of the skill challenge the construction industry might face in the wake of a major disaster as well as the potential problems that may exacerbate skills shortages.

CHAPTER 3: DATA COLLECTION AND METHODOLOGY

This section details the proposed methodology for addressing the study research questions. The methodology for this study constituted a multistep process. Initially, secondary data related to the Marshall Fire and the American residential housing market were collected from publicly available datasets. The subsequent phase involved cleaning, preparing, and analyzing the data to derive results. Following the data collection and preparation phase, the first step involved analyzing the data and examining descriptive statistics related to housing and rental availability. The second step included analyzing the monthly and quarterly housing value growth trends pre- and post the fire, while the third step focused on determining the statistical significance of these growth trends using paired t-tests and repeated measures ANOVA. The proposed methodology for this research is illustrated in Figure 5.

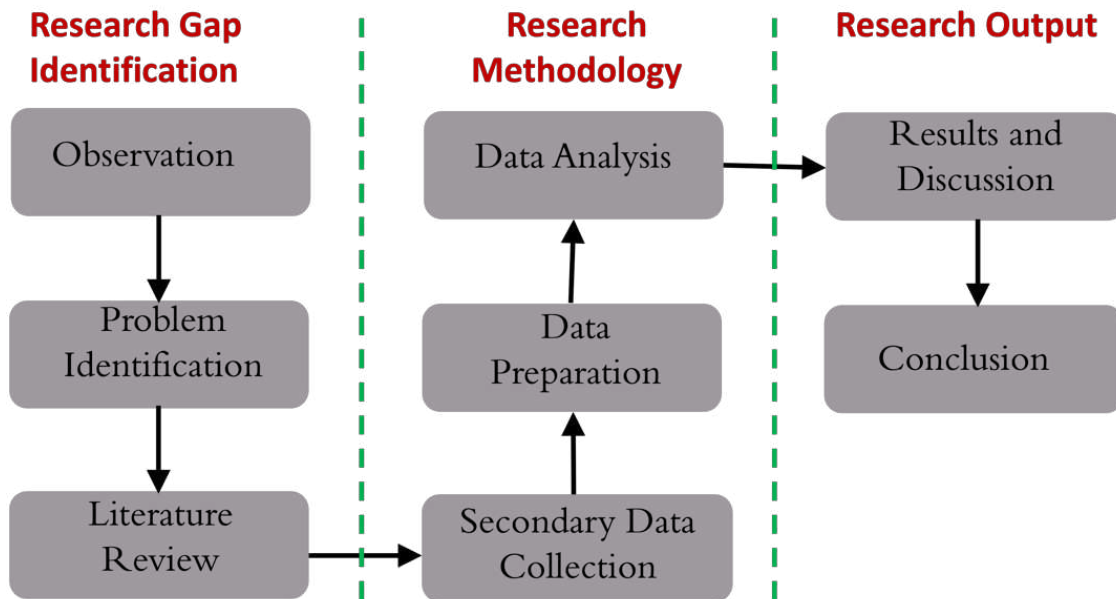


Figure 5. Research Methodology

3.1 Data Collection

Secondary data were collected to identify: (1) Zip codes affected by the Marshall Fire; (2) adjacent zip codes to the fire-affected areas; and (3) the monthly typical home values of all zip codes in Colorado pre and post-fire. Data on housing and rental availability were also collected. A comprehensive search of datasets was conducted, given that a significant part of the research relied on the availability of data for quantitative analysis. The data was gathered from publicly available datasets published by Boulder County (Boulder County, 2022), Zillow (Zillow, 2023), and Census Bureau (US Census Bureau, 2023a). The first part of the following section covers the parameters obtained to collect information about fire-affected zip codes, and the latter part includes the data collection process for assessing any changes in home values.

3.1.1 Fire-affected Zip Codes

To identify which zip codes were affected by the fire, first the fire map from “Marshall Fire – Damage Assessment Map released by the Boulder Office of Disaster Management (ODM)” was referred to. This map displays the perimeter of the Marshall Fire, along with the precise locations of affected houses (Boulder County, 2022). The zip code map of Colorado was overlaid onto this Marshall Fire Damage Assessment map in ArcGIS to identify the fire-affected zip codes. The fire incident primarily occurred in two zip codes: 80027 (which includes the cities of Louisville and Superior) and 80303. Figure 6 illustrates the Marshall Fire map with the fire boundary and damaged and destroyed structures overlaid on top of the Colorado zip code map. Referring to Figure 6, the fire map falls within two fire-affected zip codes: 80027 and 80303.

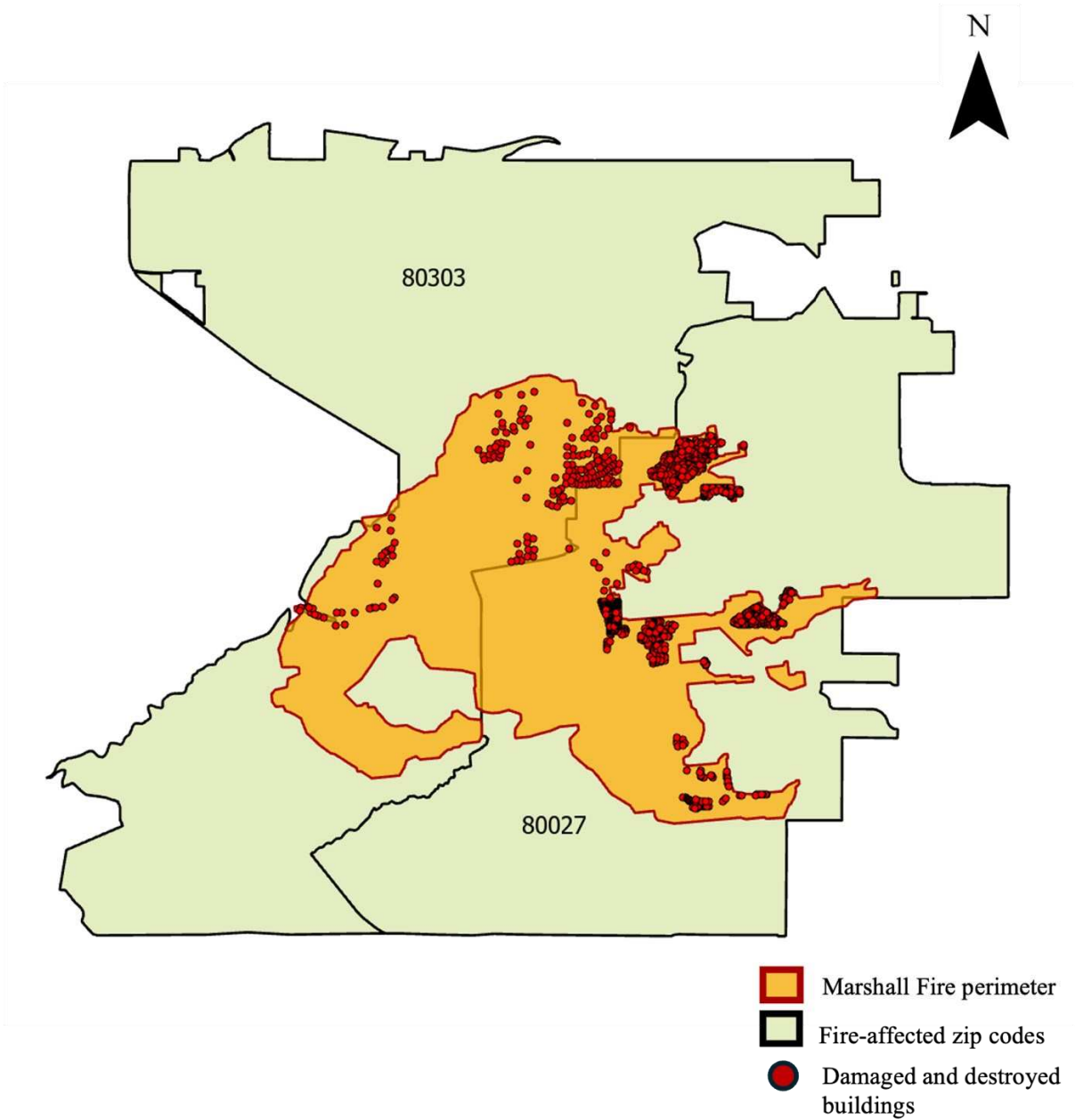


Figure 6. Marshall Fire map within the fire-affected zip codes

The impact of the fire also extended to the immediately adjacent zip codes. The fire-adjacent zip codes comprised ten zip codes surrounding the two affected ones: 80020, 80021, 80025, 80026, 80301, 80302, 80304, 80305, 80403, and 80007. Figure 7 shows the map of two fire-affected zip codes and adjacent ten zip codes.

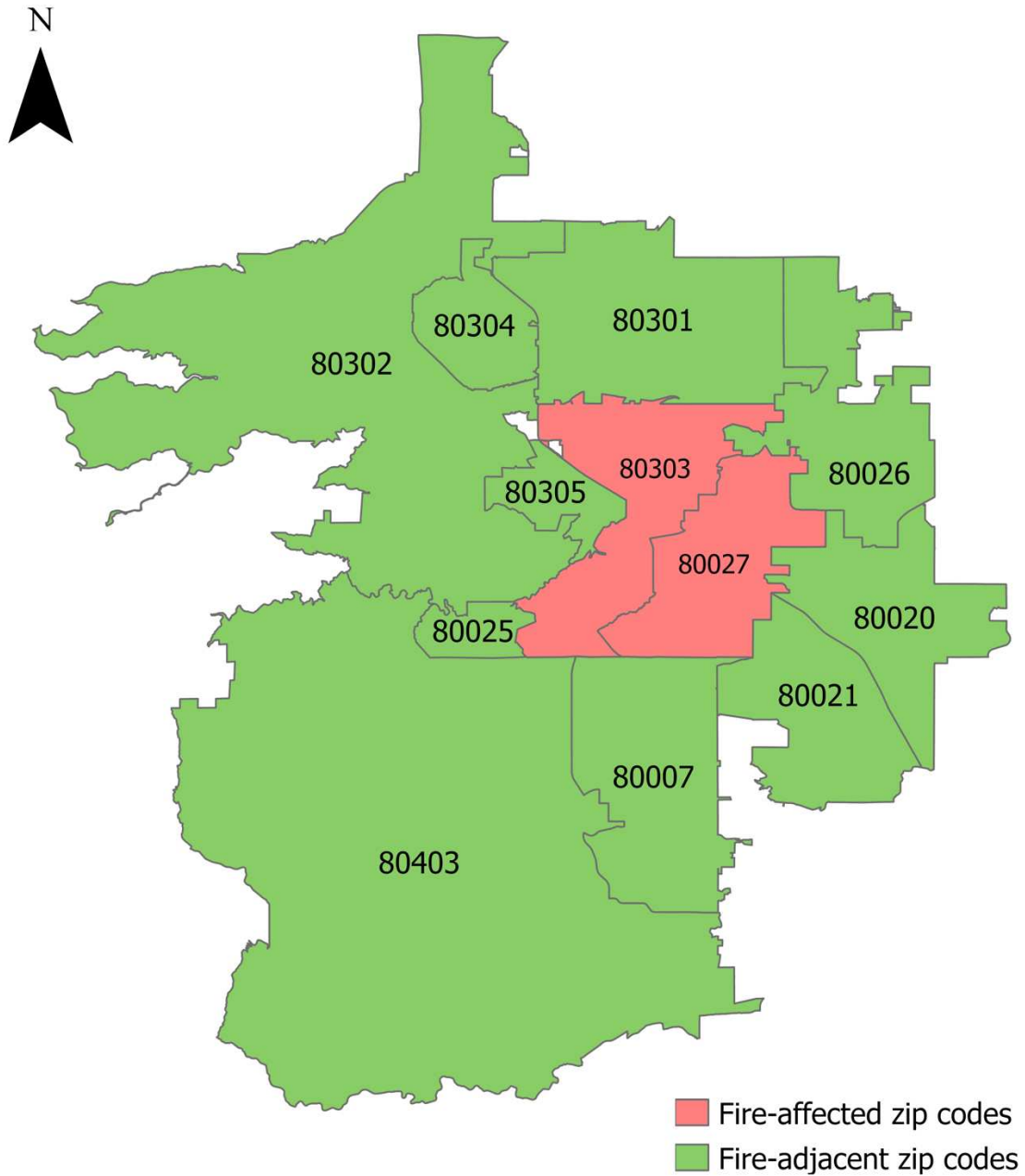


Figure 7. Fire-affected and fire- adjacent ZIP Codes

3.1.2 Monthly Typical Home Values

The data on typical home value for the required zip codes in Colorado was collected from the Zillow website. Joshi (2016) used Zillow Home Value Index (ZHVI) monthly county data as a proxy for local house prices. Similarly, our study uses zip-code level ZHVI data published by Zillow to determine typical home value in the given zip code in the given month.

The Zillow website has information on over 100 million homes across the United States. Among its various features, Zillow provides value estimates for homes, known as "Zestimates", tracks value changes for each home over time, offers aerial views of properties, and provides insights into typical home values within specific regions. The Zestimate, Zillow's value estimate for individual homes, is generated using a combination of property characteristics and publicly available data, including recent sales of nearby homes with similar features (Hryniw, 2019). Using Zestimate, Zillow also publishes data on typical home values at a regional level, referred to as the ZHVI, Zillow Home Value Index (Zillow, 2023).

3.1.2.1 ZHVI (Zillow Home Value Index)

Zillow Home Value Index (ZHVI) serves as a measure of typical home values and market trends within a specified region and housing type. It is calculated as a weighted average of the middle third of homes in a given area (Melissa, 2022). ZHVI offers a more comprehensive perspective by incorporating Zestimates for newly constructed homes and properties that have not been recently traded in the market. ZHVI claims to offer a number of advantages over other housing indices, including better timeliness, better coverage of the market, and more visibility into changes in small market segments (Hryniw, 2019).

ZHVI dataset is available for various geographic levels, including the nation, state, metro area, county, city, neighborhood, and ZIP code. ZIP code-level data was selected for the research

because it provides the most localized and finer level of geographic granularity compared to other available geographic levels such as state, metro area, county, or city. This helps to assess the distinct impacts of the Marshall Fire on housing markets within the directly affected areas, their immediate surroundings, and the broader Colorado context. ZHVI uses a unique method by combining Zestimates for numerous individual properties and putting together these estimates on a monthly basis. This approach allows to gain valuable insights into neighborhoods and housing segments that might otherwise be overlooked by other methods due to data limitations.

ZHVI is available in two forms: as a smoothed, seasonally adjusted measure and as a raw measure (Zillow, 2023). For this research, the ‘Time Series, Smoothed, Seasonally Adjusted’ dataset was chosen because it includes a variety of housing types, such as single-family homes and condominiums, within its mid-tier, all of which are seasonally adjusted. This means that it encompasses properties falling within the 35th to 65th percentile of home values, excluding extreme outliers (Zillow, 2023).

The term ‘seasonally adjusted’ refers to the process of accounting for seasonal fluctuations, such as price variations that occur at specific times of the year. ZHVI is seasonally adjusted, which means that it eliminates the impact of seasonal factors on home values, such as increased demand during the summer and reduced demand in late fall and winter. This adjustment is achieved through a method known as LOESS-based seasonal decomposition, allowing us to discern the genuine underlying trends in the data (Hryniw, 2019). Seasonally adjusted data provides a more accurate representation of the long-term trajectory of home prices, revealing a relatively stable value over the year with minor fluctuations. This approach offers a clearer understanding of true changes in home values over time, free from the influence of seasonal variations. Furthermore, the resulting seasonally adjusted data are smoothed using a 3-month moving average, enhancing the

interpretability of the dataset (Hryniw, 2019). These techniques collectively enhance the accuracy and utility of ZHVI data.

In essence, out of all the available datasets published by Zillow, the seasonally adjusted, smoothed ZHVI data was chosen. This data represents an estimate of the typical home value in a specific area at a given point in time while accounting for seasonality and employing smoothing techniques to provide a more nuanced view of housing market trends. Throughout this study, the term 'housing value' refers to the ZHVI home value as reported by Zillow.

3.1.3 Housing and Rental Vacancy

The data for the available housing and rental vacancy rates for the year 2021 were collected from the Census Bureau website. In addition to the fire-affected region and all the zip codes in Colorado, these data were also collected for the Denver Metropolitan Statistical Area (MSA), Colorado, and the United States as a whole. This broader scope was undertaken to gain a comprehensive understanding of housing and vacancy availability in larger regions, allowing for a comparison of fire-affected areas with the entire United States.

3.2 Data Preparation

The raw typical housing data obtained from various sources were refined before being used for quantitative analysis. Data was prepared in three phases. The first phase included dividing the Colorado geographical region into three categories to analyze the housing value change in each group. Table 3 shows the three categories of zip codes.

The "Fire-affected Zip codes" group includes the two zip codes that are directly affected by the fire: 80027 and 80303. The "Fire-adjacent Zip codes" category includes the zip codes that immediately surround the above two fire-affected zip codes. This group includes ten zip codes: 80020, 80021, 80025, 80026, 80301, 80302, 80304, 80305, 80403, and 80007. The "Rest of CO"

Table 3. Zip Codes Categories

Categories	ZIP Codes
Fire-affected ZIP Codes	80027, 80303
Fire-adjacent ZIP Codes	80020, 80021, 80025, 80026, 80301, 80302, 80304, 80305, 80403, 80007
Rest of CO	All other ZIP Codes in CO excluding above two groups

group includes all the other zip codes in Colorado, excluding the fire-affected and fire-adjacent zip codes. This approach ensures that the groups are independent of each other and allows for meaningful comparisons without overlapping zip codes.

The second phase involved filtering and grouping the typical home value data collected from the Zillow website. Some of the zip codes in Colorado were missing in the ZHVI data. The reason was found to be either low population density, a very low number of housing units, or simply being in a forested area. Out of the ten ZIP Codes grouped under the "Fire-adjacent ZIP Codes" category, ZHVI data for 80025 was missing, which could be attributed to it being in a forested area with very low housing units, population, and land area (United States Zip Codes, 2023). Data was analyzed for the "Fire-adjacent Zip Codes" group with just nine zip codes, including 80020, 80021, 80026, 80301, 80302, 80304, 80305, 80403, and 80007.

The third phase included calculating the average of housing value data for the three groups. Fire-affected zip codes encompassed the average value of data from two zip codes directly affected by fire. For example, regarding housing values, it constituted the average of the typical home values in these two zip codes for a given month. Adjacent zip codes comprised the average of nine typical home values from the zip codes surrounding the affected areas for a specific month.

Similarly, the rest of Colorado constituted the average of typical home values for all zip codes within the state of Colorado, excluding the fire-affected and fire-adjacent areas.

3.2.1 Time Frame

Data was examined over a 14-month period, both before and after the fire. This timeframe was divided into quarterly segments. The fire event occurred on December 30, 2021. Therefore, data was collected from November 2020 to February 2023. Using a 14-month period allowed for a comprehensive analysis that covers a substantial period both before and after the fire event. Collecting data from November 2020 to February 2023 also provided ample time to capture changes in housing values and their recovery after the fire, as well as any longer-term trends or effects.

3.3 Data Analysis

This process involved multiple steps. The initial step was to analyze the descriptive statistics of rental and housing availability in the year 2021 across various regions, starting from the United States, Colorado, and Denver MSA to fire-affected and surrounding fire-adjacent zip codes.

The second step involved analyzing the monthly and quarterly housing value growth trends before and after the Marshall Fire. During this phase, the percentage change in housing values and the rate of percentage change were calculated and analyzed. The average of three months' data represented each quarterly period. Raw housing value changes, percentage changes in housing values, and the rates of percentage change in the three groups of zip codes were analyzed in each quarter, both pre and post-fire. The quarterly data represents the average of housing values over three months, while each month's data represents the average of housing values in zip codes within that group.

The third step was to assess the statistical significance of the housing value data before and after the Marshall Fire, using the Excel data analysis add-on software XLSTAT. To achieve this, several statistical tests were conducted. First, normality tests were performed to determine if the data sets followed a normal distribution, and which statistical tests were appropriate. The second step involved conducting separate two-sample paired t-tests (two-tailed) for each of the three different groups of zip code locations (fire-affected, fire-adjacent, and the rest of CO) for the 14 months pre- and post-fire. In other words, the t-tests were used to determine if the average ZHVI housing values within each of the three zip code groups changed pre- and post-fire, and if those changes within each geographic location were statistically significant. The third step included conducting a repeated measures ANOVA test to determine if the differences in mean ZHVI housing values within and between the three zip code locations (fire-affected, fire-adjacent, and the rest of CO) were statistically significant pre- or post-Marshall Fire.

CHAPTER 4: RESULTS

This chapter presents the results of the above-mentioned analysis. It provides descriptive statistics for residential housing and rental vacancy rates across Colorado and the United States, including an analysis of the monthly typical housing values pre- and post-fire. The latter part involves the use of statistical tests to assess the statistical significance of any differences in pre- and post-fire housing values.

4.1 Residential Housing and Rental Vacancy Rates in the United States

Although this study examines the impact of the Marshall Fire on residential housing values, the existing vacancy rates of privately owned housing and rental units can also influence the housing market following a disaster (Pancak, 2017). Previous studies found that post-disaster housing values fluctuated less in areas where pre-disaster rental vacancy rates were high – providing easily accessible local housing options for people with damaged or destroyed homes – particularly in more urban settings (Comerio, 1997). Housing vacancies can also provide overflow temporary housing following a disaster. Therefore, housing and rental unit vacancy rates provide some insight into how the residential housing market responded to the Marshall Fire in Colorado.

In 2021, the year of the Marshall Fire, the rental vacancy rate for the entire United States was 6.10% (US Census Bureau, 2023c). Notably, at the time of the fire, Colorado already exhibited a lower availability of rental spaces in comparison to the overall United States average for the year. Colorado reported a lower rental vacancy rate of 4.50% for the same year (US Census Bureau, 2023b). The surrounding fire-adjacent zip codes in Colorado had an availability of 3.23% of rental units, whereas the fire-affected zip codes recorded a slightly higher rate of 4.95% (US Census Bureau, 2023d). These rental vacancy rates indicate that Colorado collectively had a sizeable lack

of rental units readily available before the Marshall Fire (approximately 20% less than the national average), and a severe shortage of rental units in the fire-adjacent zip codes (about 50% less than the national average)

Additionally, the housing vacancy rate for the United States in 2021 was 0.90% (US Census Bureau, 2023c). In Colorado, the housing vacancy rate was lower than the national average, at 0.70%, and the Denver metro area reported a housing vacancy rate of only 0.60% (approximately 33% less available housing than at the national level) (US Census Bureau, 2023b). These statistics indicate that Colorado was experiencing a housing shortage even before the Marshall Fire. Table 4 presents housing and rental unit vacancy rates for 2021, including the: fire-affected zip codes, fire-adjacent zip codes, the Denver metro area, Colorado as a whole, and the entire United States. Collectively, the residential housing and rental unit vacancy rates before the Marshall Fire indicate a shortage of housing availability for purchase or rent across Colorado zip codes, including zip codes within or adjacent to the fire perimeter. These shortages were then exacerbated by the Marshall Fire that destroyed over 1,000 homes, spiking post-disaster demand for housing or rental units.

Table 4. Housing and rental unit vacancy rates (in percentage) for 2021

	Housing vacancy rate	Rental vacancy rate
Fire-affected	0.90	4.95
Fire-adjacent	0.54	3.23
Denver MSA	0.60	4.60
Colorado	0.70	4.50
United States	0.90	6.10

4.2 Monthly Typical Housing Value Analysis

This section includes the analysis of monthly typical home values collected for three different groups: Fire-affected Zip codes, Fire-adjacent Zip codes, and Rest of CO, spanning 14 months pre- and post-Marshall Fire. The initial part includes the quarterly analysis, and the latter part focuses on the monthly analysis of typical home values.

4.2.1 Quarterly Analysis of Home Values

When examining the typical home value data, it is evident that all three groups display a similar trend. Figure 8 shows the graph of raw housing values, which alone does not reveal significant differences. Notably, the Fire-adjacent zip codes exhibit the highest range of housing values, followed by the Fire-affected zip codes, with the rest of CO showing the lowest price range. To gain deeper insights, the analysis of percentage change was done.

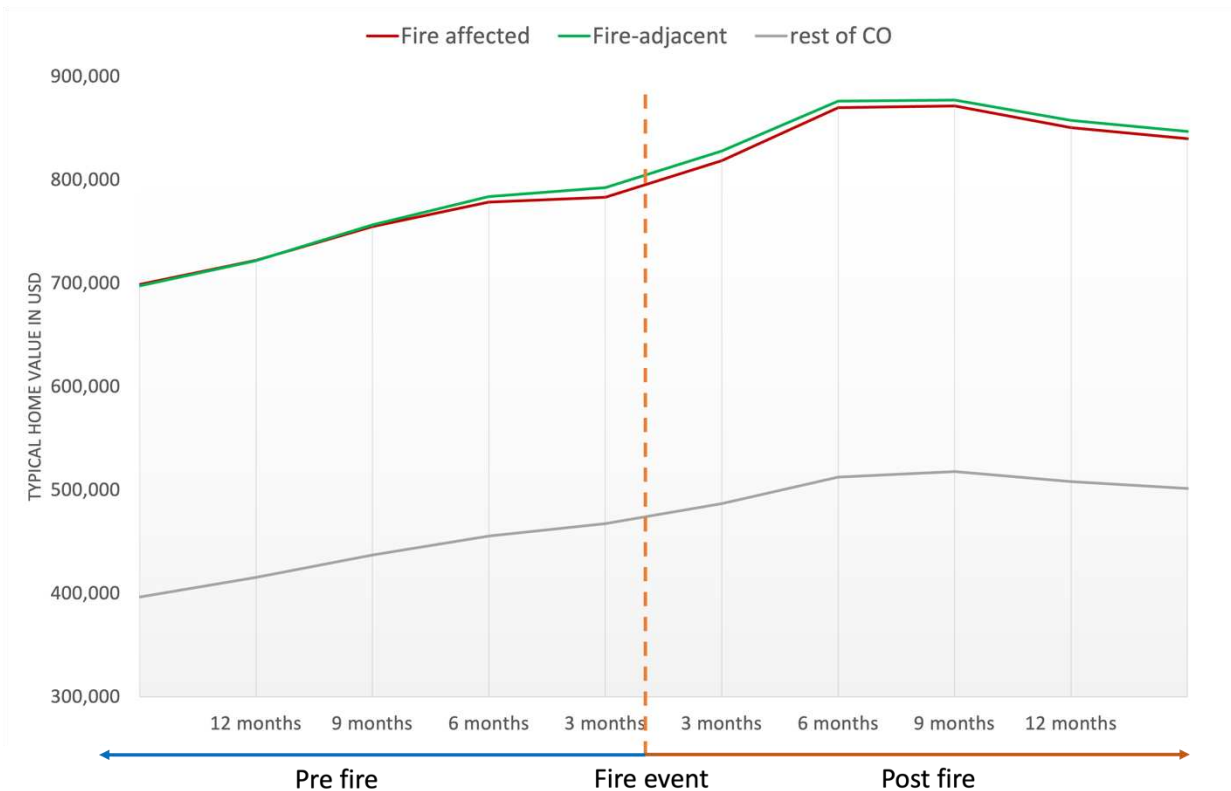


Figure 8. Quarterly typical home value 14 months pre and post fire

4.2.1.1 Pre-Fire

Figure 9 shows the quarterly percentage change in housing values pre and post-fire. A consistent trend was observed over the 14 months leading up to the fire. The average percentage increase in housing values for zip codes in the rest of Colorado (excluding fire-affected and fire-adjacent areas) was found to be the highest, followed by Fire-adjacent zip codes, and finally, fire-impacted areas (Fire-affected zip codes). The average percentage difference between fire-affected zip codes and the rest of Colorado was found to be statistically significant, with a 0.43% difference 14 months pre-fire. In the three months immediately before the fire, housing values were found to have increased by 1.02% in the rest of Colorado, 0.59% in fire-adjacent zip codes, and 0.44% in fire-affected zip codes.

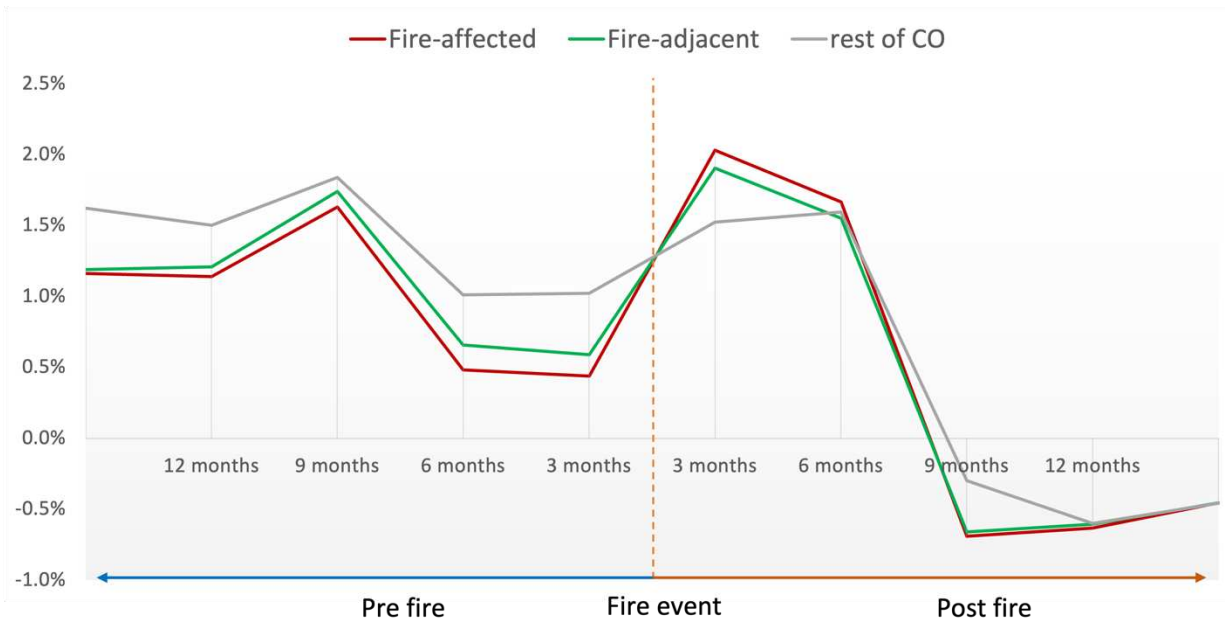


Figure 9. Quarterly percentage change in housing values pre and post fire

4.2.1.2 Post-Fire

In the first three months following the fire, this pattern was reversed. The highest home value percentage increase was observed in fire-affected zip codes at 2.03%, followed by fire-

adjacent zip codes at 1.91%, while the rest of Colorado displayed the lowest increase at 1.52%. Between three to six months post-fire, housing values continued to rise the most in fire-affected zip codes at 1.67%, with fire-adjacent zip codes and the rest of Colorado experiencing similar increases at 1.55% and 1.6%, respectively. Between 6-9 months after the fire, the housing value percentage decreased in all over Colorado. The rest of Colorado displayed the lowest average decrease at 0.30%. This was followed by fire-adjacent zip codes with 0.70% decrease and fire-affected zip codes with 0.70% decrease. At this point, the percentage change started following the pre-fire trend. Between 9-12 months post-fire, the rest of CO has the lowest decrease in housing value percentage (0.60%) followed by fire-adjacent zip codes (0.61%), and fire-affected zip codes had the highest decrease (0.63%). This sequence also aligns with the pre-fire sequence. By the 12-14 months mark post-fire, no significant differences were observed in the percentage change among the three types of zip codes. Table 5 shows the quarterly percentage change in housing values in these three geographical categories (Fire-affected zip codes, Fire-adjacent zip codes, and the rest of CO) pre and post-fire.

Table 5. Tabulated quarterly percentage change in housing values

	Time frame	Fire-affected zip codes	Fire-adjacent zip codes	Rest of CO
Pre-Fire	12-14 months	1.161%	1.189%	1.622%
	9-12 months	1.141%	1.208%	1.501%
	6-9 months	1.631%	1.740%	1.838%
	3-6 months	0.483%	0.659%	1.012%
	0-3 months	0.439%	0.588%	1.023%
Post Fire	0-3 months	2.030%	1.905%	1.524%
	3-6 months	1.665%	1.551%	1.595%
	6-9 months	-0.691%	-0.659%	-0.298%
	9-12 months	-0.634%	-0.606%	-0.600%
	12-14 months	-0.456%	-0.454%	-0.457%

4.2.2 Monthly Analysis of Housing Values

Figure 10 shows the monthly percentage change in housing values pre- and post-fire. In individuals 14 months leading up to the fire, the lowest increase in housing values was consistently observed in fire-affected zip codes compared to the other two groups. However, although the average for the first quarter of post-fire percentage change shows the highest values in fire-affected zip codes, it was only in the second month following the fire (February) that the percentage change began to increase significantly in this area (2.06%), surpassing the other two groups. In the first month immediately after the fire (January), the percentage change remained highest in the rest of Colorado zip codes at 1.63%, followed closely by the fire-affected zip codes and the fire-adjacent zip codes, which exhibited similar values.

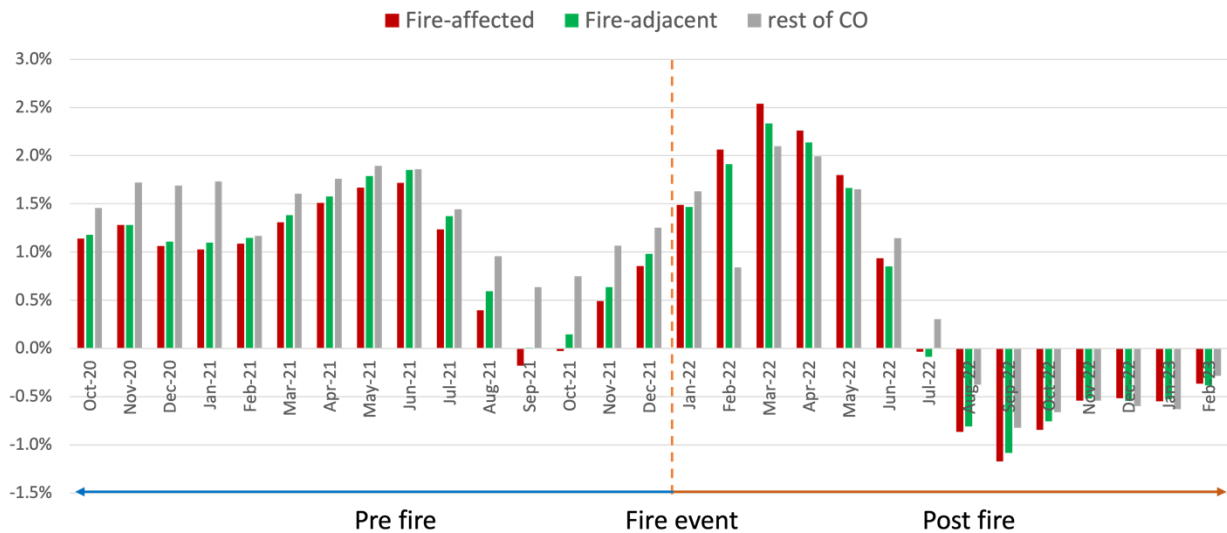


Figure 10. Monthly percentage change in housing values (14 months pre and post fire)

From February through May of 2022, the percentage change was highest in the fire-affected zip codes, followed by fire-adjacent zip codes, with the lowest values observed in the rest of Colorado. During June and July of 2022, the highest increase in percentage change was observed in the rest of Colorado, followed by the fire-affected zip codes and then the fire-adjacent zip codes.

Remarkably, during this period, the observed trend was in line with the pre-fire pattern with the rest of CO group having the highest percent increase. In August through October, a significant percentage decrease was noted, with the highest decline occurring in the fire-affected zip codes, followed by the fire-adjacent zip codes and then the rest of Colorado which also aligns with the pre-fire pattern. From November through February, the percentage decrease in housing values remained consistent across all three groups, showing minimal variation.

The highest percentage increase in housing values post-fire was observed in March 2022 (3 months after the fire), with 2.54% in fire-affected zip codes, 2.34% in fire-adjacent zip codes, and 2.10% in the rest of Colorado, likely reflecting a potential surge in demand in whole Colorado. The highest percentage decrease post-fire was observed in fire-affected zip codes at 1.17% in Sept 2022. The highest percentage increase pre-fire in fire-affected zip codes was noted in June 2021, with 1.72%.

4.2.3 Rate of Percentage Change of Housing Values

The rate of percentage change calculates the difference between the housing value percentage change in one month and the percentage change in the subsequent month. It shows how fast housing values are increasing or decreasing. The rate of percentage change is highest for fire-affected zip codes in the first month after the fire which can be referred to in Figure 11. This probably signifies the greater demand in that area.

4.2.4 Implications

In individuals 14 months leading up to the fire, the lowest increase in housing values was consistently observed in fire-affected areas compared to the other two groups. This suggests that the areas affected by the fire were already experiencing smaller price growth before the incident as compared to surrounding and the rest of CO. In the first three months following the fire, a

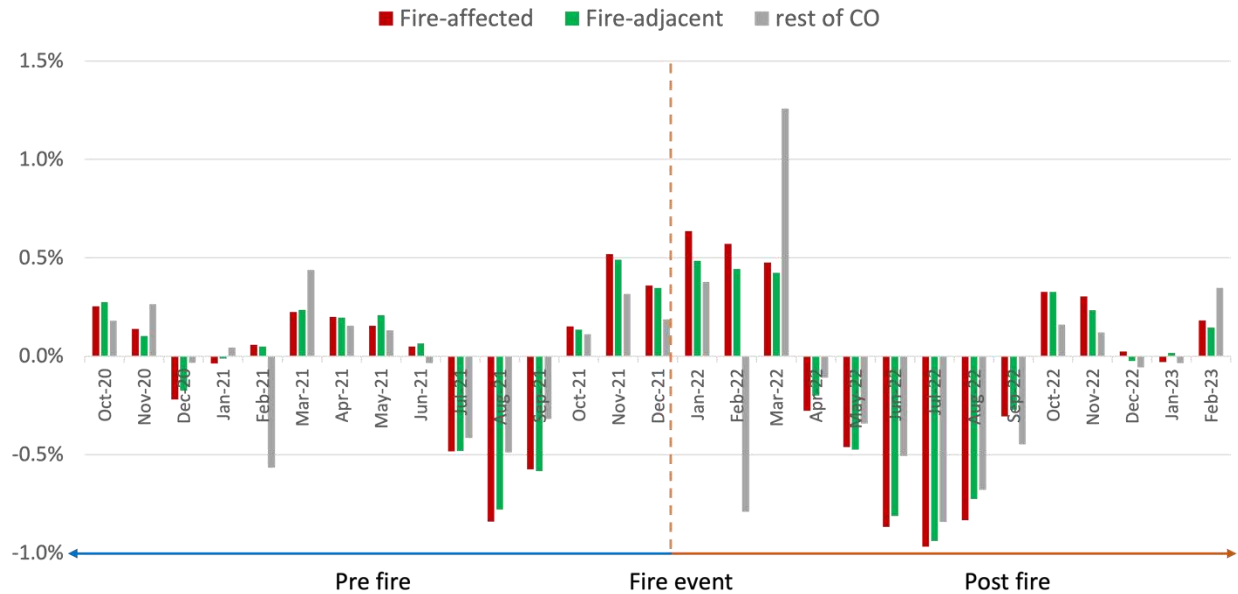


Figure 11. Rate of percentage change in housing values (14 months pre and post fire)

reversal of the trend was noticed. Fire-affected zip codes experienced the highest percentage increase, while the rest of Colorado had the lowest. This suggests a significant shift in the market dynamics post-fire.

This situation can be attributed to the supply and demand dynamics within the housing market in the affected area. The Marshall Fire burned more than 1,000 homes at a time when there were already too few homes on the market in Colorado. Removing 1,000 houses from the market and reintroducing 1,000 people who needed homes instantly created an intense demand and supply issue. Immediately after the fire, the supply of houses in the affected area decreased, causing available properties to become more expensive. Colorado was already facing a housing shortage at that time, and the sudden occurrence of the fire event exacerbated the competition for the limited housing stock in the fire-affected zip codes. Given that the fire primarily affected densely populated areas rather than rural regions, residents were likely hesitant to relocate due to the intrinsic value of amenities such as proximity to commute routes and schools in that area.

Additionally, surrounding areas like Boulder, Broomfield, Denver, and Longmont were already densely populated with high rental rates, and low rental vacancy (refer to Table 1) discouraging people from moving away. Relocating to these areas would have incurred higher costs. Also, the rental vacancy in the fire-affected zip code was not high (US Census Bureau, 2023d), and right after the fire, renters started price gouging (boulderbeat., 2022), which could have prompted people to explore alternative housing options. Consequently, the demand for housing in the same area increased.

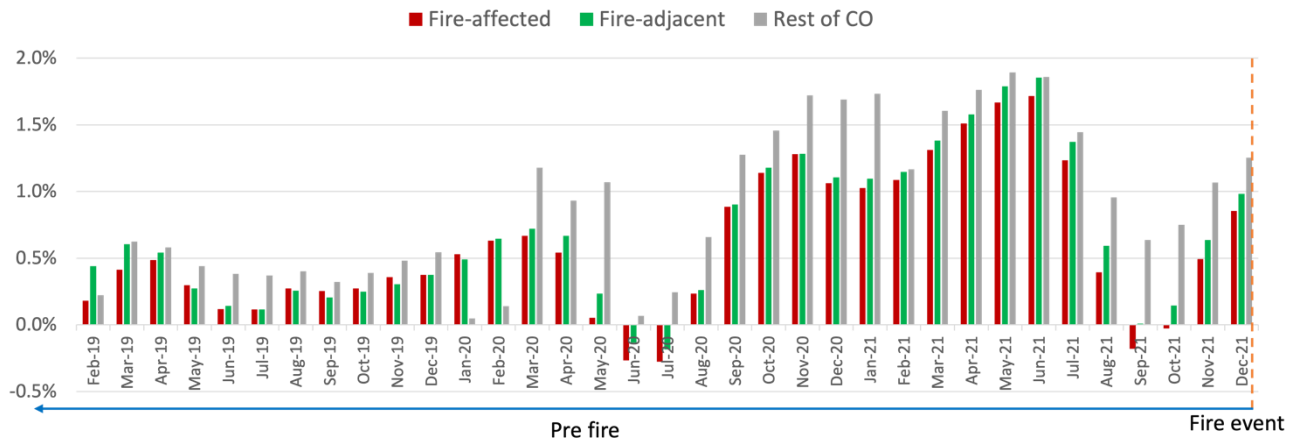
Between 3-6 months post-fire, the trend continued, with housing values in fire-affected zip codes rising the most. However, from 6-9 months post-fire, all areas experienced a decrease in housing values and at this point, the percentage change started following the pre-fire trend. This implies after June 2022, the initial shock of the fire had subsided and the pattern started following the pre-fire trend. By 12-14 months post-fire, not much significant differences were observed among the three types of zip codes, indicating a return to a more stable market. The extended recovery period of 6-9 months post-fire indicates a gradual subsiding of the initial shock. This prolonged recovery phase aligns with the time needed for the housing market to stabilize after the surge.

The findings suggest that the Marshall Fire had a significant short-term impact on the housing market, with fire-affected areas experiencing a surge in housing values immediately after the event. In the second month following the fire (February), the percentage change began to increase significantly in fire zip codes (2.062%), surpassing the other two groups. Over the long term, the market appears to stabilize.

Also, looking at the pre-fire trend from February 2019 till December 2021 (refer to Figure 12), it is apparent that the percentage change in housing values within the fire-affected zip codes

consistently lagged the percentage change in the surrounding area and the rest of Colorado in any given month. However, a significant shift occurred in the second month (February) following the fire, with the percentage change peaking in the fire zip codes, marking the beginning of their recovery after June 2022; six months after the fire event.

Figure 12. Monthly percentage change in housing values (pre fire)



Since the Marshall Fire was a brush wildfire that swept through a major suburban subdivision, it makes sense that it acted differently than the findings in the literature review, where there would typically be a significant decrease in housing values post-disaster. The community it serves includes Denver and Boulder, which are densely populated areas, unlike any rural community in the woods. This study represents one of the first examinations of the impact of a brush wildfire (like a grassfire) in a more densely populated area.

4.3 Average Typical Home Value 14 months Pre and Post-Marshall Fire

Table 6 below illustrates the percentage change in average housing values 14 months pre- and post-Marshall Fire for fire-affected zip codes, fire-adjacent zip codes, the rest of Colorado, and the Denver metro area. All these groups experienced an increase in housing values post-fire.

The Denver metro area witnessed a 15.78% increase in housing values post-fire, closely aligning with the rest of the Colorado region, which recorded a 15.55% increase. The "rest of CO" group comprises all zip codes in Colorado except for the eleven fire-affected or fire-adjacent zip codes. The average post-fire percentage increase for the fire-affected and fire-adjacent zip codes was 13.21% and 13.64%, respectively. These values are slightly lower than the increase observed in the "rest of CO" and the Denver metro area. Evidently, the fire-affected and fire-adjacent groups exhibit different behavior compared to the "rest of CO" and Denver metro groups. These areas are not growing as fast as the Denver metro or the rest of CO in the long run. It was immediately after the fire event that these groups exhibited a higher percentage change in housing value compared to the "rest of CO" group.

Table 6. ZHVI Mean Housing Values Before & After the Marshall Fire

Zip Code Location	Mean ZHVI Housing Value (\$USD)	Mean ZHVI Housing Value (\$USD)	Difference (\$USD)	Difference (%)
	<i>Pre-fire</i>	<i>Post-fire</i>		
Fire-affected	\$ 751,615	\$ 850,870	\$ 99,254	13.21%
Fire-Adjacent	\$ 754,907	\$ 857,879	\$ 102,972	13.64%
Rest of CO	\$ 437,689	\$ 505,739	\$ 68,050	15.55%
Denver MSA	\$ 495,115	\$ 573,228	\$ 78,113	15.78%

4.4 Statistical Test Results

First, normality tests were performed to determine which statistical tests were appropriate for the analysis of pre- and post-Marshall Fire ZHVI housing values. Second, t-tests were performed to assess if changes in ZHVI housing values within each geographic zip code location (fire-affected, fire-adjacent, and the rest of CO) were statistically significant pre- and post-fire.

Lastly, a repeated measures ANOVA was performed to assess if differences in ZHVI housing values within or between the three geographic zip code locations were statistically significant either pre- or post-Marshall Fire.

4.4.1 Normality Test

Since the study had a small sample size of just 14 samples (e.g., 14 months of pre-fire and 14 months of post-fire data in each sample), determining the distribution of the monthly ZHVI housing value variable was important for choosing an appropriate statistical method. The Shapiro-Wilk test was performed for each data sample since it is considered the best normality test for small sample sizes (e.g., less than 50 samples). Test results indicate that all sample data residuals follow a normal distribution as shown in Table 7.

Table 7. Shapiro-Wilk Normality Test Results

Test Statistics	Zip Code Location					
	Fire-affected		Fire-adjacent		Rest of Colorado	
	<i>Pre-fire</i>	<i>Post-fire</i>	<i>Pre-fire</i>	<i>Post-fire</i>	<i>Pre-fire</i>	<i>Post-fire</i>
Statistic (<i>W</i>)	0.88	0.94	0.90	0.95	0.94	0.93
<i>df</i>	13	13	13	13	13	13
Sig. (<i>p-value</i>) ^a	0.06	0.47	0.11	0.53	0.47	0.28

^aalpha = 0.05

4.4.2 Paired T-Tests

Since the sample size was small, the distribution of the data was important for choosing an appropriate statistical testing method. Based on the outcomes of the Shapiro Wilk normality tests, which did not show evidence of non-normality, parametric tests were used (Montgomery, 2019). Two-sample paired t-tests (two-tailed) for each of the three different groups of zip code locations

(fire-affected, fire-adjacent, and the rest of CO) were conducted for the 14 months pre- and post-fire. In other words, the t-tests were used to determine if the mean ZHVI housing values within each of the three zip code groups changed pre- and post-fire, and if those changes within each geographic location were statistically significant.

Three paired t-tests were conducted for each sample (fire-affected, fire-adjacent, and the rest of CO) pre and post-fire to analyze the differences in mean ZHVI housing values before and after the Marshall Fire. Results indicate statistically significant differences in mean ZHVI housing values pre- and post-fire in each of the zip code regions, as shown in Table 8 below. The differences in mean ZHVI housing values observed pre and post-fire within each of the study zip code regions (e.g., the fire-affected, fire-adjacent, and the rest of CO zip codes) were statistically significant. These results highlight how the residential housing market was changing across all of Colorado during the 28-month study timeframe. However, these statistically significant changes to mean ZHVI home values over time could be due to multiple socioeconomic factors and the effects of the Marshall Fire cannot be independently assessed.

Table 8. Paired Samples T-Test Results: Pre- and Post- Fire

Zip Code Location	Paired Differences (Pre- & Post-Fire)			
	Difference in Mean ZHVI Housing Values (\$USD)	<i>t</i>	<i>df</i>	Significance (2-tailed) ^a
<i>Pair 1</i> Fire-affected	\$ 99,254	11.886	13	< 0.0001
<i>Pair 2</i> Fire-adjacent	\$ 102,972	11.044	13	< 0.0001
<i>Pair 3</i> Rest of CO	\$ 68,050	11.426	13	< 0.0001

^aalpha = 0.05

A paired-samples t-test was conducted to compare the monthly typical housing values of fire-affected zip codes 14 months pre- and post-fire. The analysis revealed a significant difference in the housing value data pre-fire and post-fire; $t(13) = 2.160, p < 0.0001$. These findings suggest that the difference is statistically significant, indicating that the fire indeed has an effect on housing values. The same analysis was repeated for the other two zip code location groups, and they also exhibited statistically significant differences pre- and post-fire.

For the fire-affected zip codes, in 14 months, the average median home value increased by \$99,254. They didn't lose value just because they had the fire, they still increased on average. For the fire-adjacent zip codes, the housing value increased by \$102,972. However, in the rest of CO, it went up by \$68,050, significantly less compared to the other two groups. This suggests that fire-affected and surrounding areas are more expensive zip codes and clearly experienced a fire effect, while the rest of CO consists of more rural areas with negligible fire effects. It is important to note that these differences cannot necessarily be attributed solely to the Marshall Fire, but changes occurred in all regions pre- and post-fire.

4.4.3 ANOVA Test Results

Lastly, a repeated measures ANOVA test was conducted to determine if the differences in pre and post-fire mean ZHVI housing values were statistically significant. The repeated measures ANOVA was used to analyze the data because this study assesses changes in the same location over different time periods and because the sample data did not exhibit non-normality in the Shapiro Wilk test (Montgomery, 2019). In other words, a repeated measures ANOVA was performed to compare the effect of geographic proximity to the Marshall Fire (e.g., fire-affected, fire-adjacent, and the rest of CO zip code locations) on mean ZHVI housing values.

Utilizing the zip code location as the independent variable and the mean ZHVI housing values as the dependent variable, results indicate that the zip code location affected the whole dataset without taking into account the repetitions (e.g., pre and post-fire differences). Table 9 below shows how the ‘group’, representing the three zip code locations from the study, had a statistically significant (p -value < 0.0001) on housing values.

Table 9. Repeated Measures ANOVA Results: Between Subject Effects

Source	df	Sum of Squares	Mean Squares	<i>F</i>	<i>p</i> -value
Group	2	205,917,0631,691	1,029,585,315,845	1139.02	< 0.0001
Error	39	35,252,934,191	903,921,389	-	-

Additionally, the effect of housing location over time was examined. The results of this analysis of variance are provided in Table 10 below. During the 14-month period before the Marshall Fire, zip code location had a statistically significant effect on mean ZHVI housing values within all three study locations (e.g., fire-affected, fire-adjacent, and the rest of CO), $F(2,39) = 480.25$, p -value < 0.0001 . These results align with the Zillow ZHVI housing values data previously reported, with residential home values in the wealthy suburbs of Boulder and Denver – including the fire-affected and fire-adjacent zip code areas – being approximately 170% higher than in the rest of Colorado. Interestingly, the effects of geographic location were exacerbated after the Marshall Fire.

Table 10. Repeated Measures ANOVA Results: Pre-Fire Analysis of Variance

Source	df	Sum of Squares	Mean Squares	<i>F</i>	<i>p</i> -value
Group	2	929,542,905,044	464,771,452,522	480.25	< 0.0001
Error	39	37,743,150,521	967,773,090	-	-
Corrected Total	41	967,286,055,565	-	-	-

During the 14-month period after the Marshall Fire, zip code location had an even more statistically significant effect on mean ZHVI housing values within all three study locations, $F(2,39) = 1,475.72$, $p\text{-value} < 0.0001$. The results of this analysis of variance are provided in Table 11 below. Although the mean ZHVI home values remained about 170% higher in the fire-affect and fire-adjacent zip codes than in the rest of CO zip codes, the post-fire ANOVA F -statistic increased over three-fold compared to the pre-fire F -statistic. This indicates that geographic proximity to the Marshall Fire had a much more significant effect on mean ZHVI housing values post-fire in comparison to pre-fire. To summarize, differences in mean ZHVI home values between the three zip code groups were exacerbated by the effects of the Marshall Fire.

Table 11. Repeated Measures ANOVA Results: Post-Fire Analysis of Variance

Source	df	Sum of Squares	Mean Squares	<i>F</i>	<i>p</i>-value
Group	2	1,134,777,531,362	567,388,765,681	1,475.72	< 0.0001
Error	39	14,994,830,274	384,482,827	-	-
Corrected Total	41	1,149,772,361,636	-	-	-

4.4 Limitations and Future Work

This study, centered on the Marshall Fire, examines the impacts of a suburban brushfire, serving as a unique case study in disaster research. It is crucial to note that our findings may not be universally applicable to all fire-related disasters due to the specific context of the Marshall Fire. Existing literature predominantly focuses on Wildland-Urban Interface (WUI) wildfires in rural areas, highlighting the distinctiveness of our study. To better understand the impacts of brushfires in suburban landscapes, there is a need for more research in this area.

To gather data on housing values in the affected area, this research exclusively relied on Zillow. Zillow is the only publicly available dataset providing monthly typical home values at the

zip code level. While Zillow asserts the accuracy of its assessments (Olsen, 2023), it is important to approach these figures with caution, recognizing that no dataset is without its flaws. The reliance on a single source for housing value data presents a limitation in our methodology, potentially introducing biases based on Zillow's assessment algorithms and market coverage.

The limited research on brushfires in the United States, especially those similar to the Marshall Fire, highlights a significant gap in the literature. This study pioneers an exploration into suburban brushfires, emphasizing the need for more empirical research. Future studies should build on this foundation by investigating a broader range of brushfire incidents in different denser communities to validate our findings. Additionally, comprehensive analyses of the post-disaster housing market across various types of disasters in denser communities could offer invaluable insights into the unique and possibly universal trends that emerge in the aftermath of such events.

CHAPTER 5: CONCLUSION

The Marshall Fire occurred in the suburban sprawl and had a different impact on the housing market compared to typical rural wildfires or those in WUI (Wildland Urban Interface) zones where the housing prices would typically drop after the fire event. A consistent trend was observed over the 14 months leading up to the fire where the average percentage increase in housing values for zip codes in the rest of Colorado group was found to be the highest, followed by Fire-adjacent zip codes, and finally, fire-affected zip codes. However, starting the second month following the fire (February), this pattern was reversed with the percentage change increasing significantly in the fire-affected zip codes (2.06%), surpassing the other two groups. 2-6 months after the fire this trend continued with Fire-affected zip codes experiencing the highest percentage increase, while the rest of Colorado with the lowest increase. Six months after the Marshall Fire (June 2022), the market began to stabilize following the pre-fire trend. The findings show that a significant shift in the percentage change in housing value occurred in the second month (February) following the Marshall fire, with the percentage change peaking in the fire zip codes, marking the beginning of their recovery after June 2022; six months after the fire event. The statistical test results also indicate that geographic proximity to the Marshall Fire had a much more significant effect on the mean ZHVI housing values post-fire in comparison to pre-fire.

5.1 Discussion

This initial spike in housing values in the fire-affected area after the fire can be attributed to the supply and demand dynamics within the housing market in the affected area. The Marshall Fire burned more than 1,000 homes at a time when there were already too few homes on the market in Colorado, causing a sudden drop in housing supply after the fire. The pre-existing housing

shortage in Colorado intensified the competition for the limited available houses in these areas post-fire. The surge reflects the scarcity of housing options and the increased demand for shelter, creating a short-term imbalance in the market. This surge could be the result of various factors such as a low perceived risk of wildfire in the urban setting and a lack of rental options.

5.1.1 Risk Perception

The study suggests that the unique nature of urban brushfires, like the Marshall Fire, does not have much impact on residents' wildfire risk perception. Unlike in rural communities where the fear of repeated fire incidents might drive people away, the lower likelihood of such occurrences in urban settings influences residents to stay in those areas, likely due to the amenities value associated with denser areas. Since the perceived risk of wildfire occurrence would be higher in rural fire risk zones, it would be reflected in a decline in housing values. However, in this case, the perceived risk was lower, and people were not willing to leave the area despite the risk of repeated wildfires. This increased demand in that area, leading to a rise in housing values. The decision of residents to remain in the fire-affected area, despite the fire, underscores the significance of amenities, commute distance, and school quality. The increased demand for these areas amid the housing crisis further influenced residents to stay, contributing to the observed surge in housing values. The distinctive characteristics and behaviors associated with urban living had a significant impact on the trends observed in the housing market after the fire.

5.1.2 Rental Market Influence

After the fire incident, the displaced population is likely to seek rental spaces rather than hastily purchasing houses. However, rental price gouging and the limited availability of rental options in fire-affected areas compelled displaced residents to make quick decisions—either buying in the same area or moving further away. Relocating to other areas was less appealing due

to elevated raw housing and rental prices and low rental availability in locations like Denver, Boulder, and Longmont compared to the fire-affected zip codes. Additionally, people were unwilling to move further away due to the valued amenities in the affected area, such as proximity to work, school quality, and neighborhood appeal. Consequently, the displaced population might have chosen to stay in the area, increasing the demand for available spaces, potentially resulting in increased housing values shortly after the fire. The scarcity of rental alternatives played a crucial role in contributing to the surge in housing values as residents sought immediate housing solutions.

5.1.3 Practical and Theoretical Contributions

This study represents one of the first examinations of urban brushfires in the United States. It contributes to the existing literature by highlighting the distinct behavior of wildfires in urban and suburban regions compared to Wildland-Urban Interface (WUI) wildfires or those in rural areas, where there is typically a significant decrease in housing values post-disaster. In a suburban sprawl, like our study area, because of housing demand, the wildfire event might not have the same impact on risk perception. Conversely, because of increased demand from the displaced population, housing prices may rise. An initial decrease in housing values percent change pre-fire was followed by a post-fire surge, likely a result of supply and demand dynamics, reflecting the immediate challenges residents faced in securing shelter. Prospective homeowners in Colorado should be aware that housing prices spike 2-6 months after a similar wildfire event, and the availability of rental housing has an impact on this trend.

The study highlights a notable difference in how fires behave in densely populated areas compared to rural regions, particularly evident in the aftermath of the Marshall Fire, which had a unique impact on Colorado's housing market. The decisions of residents to remain in densely populated areas, the nuanced recovery trends, and the interplay in the rental market emphasize the

multifaceted impact of the fire. Understanding this narrative is crucial for policymakers, urban planners, and residents as they navigate the complexities of recovery and prepare for similar incidents in the future.

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