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Assessing the financial impacts of significant wildfires on US capital markets: sectoral analysis

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Abstract
This study investigates the impact of significant wildfires from 2019 to 2022 on nine sectors within the US capital markets, utilizing a dataset encompassing 161 wildfires. Employing a combination of parametric and nonparametric tests, alongside regression analysis, the research scrutinizes how capital markets in distinct sectors respond to wildfire events, revealing nuanced effects. In sectors directly impacted, the insurance industry displays sensitivity to fire costs, with explicit country or event mentions correlating with sustained returns. Conversely, the real estate sector experiences diminished returns during prolonged wildfires, while the forestry and timber industry exhibits heightened sensitivity to fire costs, especially when ignited by lightning. Within indirect impact sectors, the health industry shows vulnerability to fire-related fatalities, with subsequent negative correlations with country mentions. In the food industry, fire costs contribute positively to returns, while duration and size yield negative effects. The transportation industry witnesses a gradual decline in returns, escalating with the number of fire days or associated costs. In resilience and mitigation sectors, utilities demonstrate recovery post-wildfires, contrasting with consistent declines in the energy sector. Among interconnected sectors, the travel and tourism industry sees increased returns tied to the number of victims, with events caused by human actions having a more pronounced impact. This research underscores the significance of tailored risk assessment and mitigation strategies, offering valuable insights for investors and policymakers navigating the intricate relationship between environmental events and financial markets.

Keywords Wildfires · Capital markets · Sectoral analysis · Financial impacts · Risk assessment

JEL Classification C58 · G14 · Q54

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1 Introduction

Wildfires in the USA are a complex and evolving phenomenon, significantly impacting diverse ecosystems, from forests to grasslands. Extensively documented in prior research, these wildfires vary in frequency, intensity, and distribution (Sherriff et al. 2014). Beyond immediate devastation, wildfires draw attention due to their economic, environmental, and human life implications, with recent trends exacerbated by climate change and human actions (Marlon et al. 2012). This study comprehensively examines the intricate interplay between wildfires, the US economy, and capital markets. It departs from conventional views, recognizing wildfires as complex events with profound consequences for economic activities and financial systems. Motivated by the increasing wildfire threat in recent years, linked to climate change and amplified by temperature shifts, droughts, and precipitation changes (Abatzoglou and Williams 2016; Dennison et al. 2014), this research employs a robust methodological approach. It encompasses parametric and nonparametric tests, regression analysis, and a diverse set of economic and trend variables.

This study contributes significantly to the existing literature in several ways. Firstly, it employs an extensive array of statistical tests, including four parametric and nonparametric tests, as well as robustness tests, enhancing the reliability and robustness of the findings compared to conventional event research within the wildfires domain. Secondly, the study assesses the impact of wildfires on nine distinct sectors in the USA. Thirdly, it introduces eight macroeconomic and trend variables into the wildfires research landscape, providing a comprehensive understanding of the impact of wildfires across diverse economic contexts. Lastly, the study enhances its credibility by examining large wildfire events sourced from the National Interagency Coordination Center. The findings reveal a nuanced relationship between wildfires and US stock market sectors. "Direct impact" sectors like insurance and real estate experience negative cumulative abnormal returns (CAR) due to immediate financial implications and property damage. In contrast, "indirect impact" sectors like food and transportation exhibit positive CAR driven by increased demand and supply chain adjustments. "Resilience and mitigation" sectors, including utilities and energy, display mixed responses, while the "tourism" sector shows an initial decline followed by a sharp rebound. The regression analysis underscores the importance of wildfire characteristics, indicating that larger wildfires lead to more significant financial losses and differential effects on sectors.

2 Literature review

2.1 Economic and financial impacts of natural disasters

Natural disasters, encompassing events such as earthquakes, floods, hurricanes, and wildfires, are recurrent global challenges that exert profound influences on economies and financial systems. Numerous scholars have undertaken investigations into this multifaceted phenomenon, shedding light on its profound implications for both macroeconomic indicators and financial markets.

2.1.1 Economic consequences of natural disasters

Natural disasters wield a profound influence on the economies of afflicted nations, a consensus corroborated by several studies conducted by scholars such as Bergholt and Lujala (2012), Cavallo et al. (2013), Crespo Cuaresma et al. (2008), Kim (2010), and Skidmore and Toya (2002). These researchers collectively affirm the existence of a significant negative effect on the real gross domestic product (GDP) in countries affected by natural disasters. The distinctive characteristics of the natural disaster itself wield substantial influence over its economic ramifications. Specifically, climate-related disasters have been observed to stimulate the accumulation of human capital and foster technological development, thus acting as catalysts for economic growth. In stark contrast, geologic disasters tend to precipitate the destruction of human capital, thereby introducing distinctive complexities and challenges to post-disaster economic recovery.

In an additional study conducted by Noy (2009), an inquiry was undertaken to discern the factors that bolster a nation's capacity to withstand the economic shocks emanating from natural disasters. Noy's research underscores a set of determinants, including higher per capita income, heightened engagement in international trade, elevated government expenditure, increased foreign currency reserves, and a more robust domestic credit environment. These elements collectively contribute to heightened financial resilience when confronted with the disruptive forces of natural calamities.

2.1.2 Financial impacts of natural disasters

Natural disasters have significant financial impacts across various sectors, including stock markets, corporate valuations, sustainability indices, energy prices, government finances, and banking systems. While some studies initially suggested that natural disasters could lead to stock market volatility, subsequent research has offered more nuanced perspectives. For instance, Worthington and Valadkhani (2004) found that Australian stock markets experienced notable fluctuations in response to natural disasters, with the most significant effects occurring on the day of the event and subsequent adjustments in the following days. However, Worthington (2008) later argued that natural disasters do not significantly contribute to overall stock market volatility.

In addition to stock markets, natural disasters impact corporate valuations. Kowalewski and Śpiewanowski (2020) discovered an average 1.15% drop in market value for affected potash mining firms within two days of a disaster, affecting both current and future competitors. Hendricks et al. (2020) examined supply chain disruptions resulting from the 2011 Great East Japan Earthquake and found significant losses for affected firms, underscoring the broader consequences for supply chains. Sustainability indices have also felt the influence of natural disasters. El Ouadghiri et al. (2021) noted positive impacts on US sustainability stock indices due to increased public attention to climate change and pollution, reflecting investor preferences for sustainable investments.

Furthermore, natural disasters affect energy markets, as highlighted by Wen et al. (2021), who found increased oil price risk associated with both natural and human-induced extreme events. Government finances are not immune to these impacts. Chen

(2020) emphasized the importance of disaster reserves for local governments in mitigating financial strains resulting from natural disasters. The banking sector faces risks as well. Klomp (2014) identified geophysical and meteorological events as posing significant threats to commercial banks, emphasizing the need for effective risk management. Lastly, Keerthiratne and Tol (2017) found that natural disasters can increase private credit, particularly in lower-income countries, revealing a complex relationship between disasters and financial development.

2.2 Wildfires in the USA

2.2.1 Causal factors of wildfires

Climate change stands out as a primary driver behind the surge in wildfires across the USA. Escalating temperatures, prolonged droughts, and shifting precipitation patterns collectively create an environment increasingly prone to ignition and the rapid spread of fires, as convincingly documented by Abatzoglou and Williams (2016). The heightened vulnerability due to climate change finds further support in the research conducted by Barnard et al. (2023), which delves into the impact of climate change on wildfires in the western USA. Their findings reveal a concerning trend of rising wildfire frequency and intensity, with significant adverse effects on mountain source water systems and agricultural water supply.

The period from 2019 to 2022 witnessed extraordinary fire seasons across the USA, marked by prolonged fire durations, habitat destruction, and even the emergence of nocturnal wildfires. California, in particular, faced substantial challenges due to its Mediterranean climate, extended droughts, and the prevalence of dry Santa Ana winds—conditions highly conducive to wildfires, as highlighted by Keeley and Syphard (2021). The Pacific Northwest has also experienced substantial wildfires, partly attributed to evolving climate conditions. An example is the Bootleg Fire in Oregon, which emphasized the heightened risk of large-scale fires in the region due to climate change and forest management practices.

A notable shift in recent years has been the expansion of human communities into wildfire-prone areas, known as the wildland-urban interface (WUI). Population growth, urban sprawl, and housing developments in these regions have significantly increased the interface between human activities and fire-prone landscapes, creating a multifaceted challenge for wildfire management. Consequently, fires now pose threats to both human lives and property, as noted by Burke et al(2021). Human activities, whether accidental or intentional, have also significantly contributed to recent wildfires. Ignition sources such as unattended campfires, discarded cigarettes, power line issues, and equipment malfunctions can act as potential sparks, particularly in dry and windy conditions. Additionally, arson has intentionally ignited wildfires, underscoring the importance of public awareness, fire safety education, and responsible behavior in fire-prone regions Balch et al. (2017).

2.2.2 Economic and financial impact of wildfires

The economic and financial consequences of wildfires have become more pronounced over the last few years, affecting a wide spectrum of sectors, including agriculture, real estate, insurance, tourism, and public health. Wildfires can have catastrophic consequences for the agricultural sector. Regions susceptible to wildfires often experience the destruction of crops, grazing lands, and agricultural infrastructure, resulting in substantial losses for farmers and ranchers. As a result, this can lead to reduced agricultural production, increased operational costs, and potential long-term effects on food prices, as noted by Kabeshita et al. (2023).

Furthermore, the real estate sector faces immediate economic repercussions following wildfires. The destruction of residential and commercial properties, along with the displacement of entire communities, results in substantial property damage and insurance claims amounting to billions of dollars. While necessary, the processes of rebuilding and recovery impose additional financial burdens on local governments and insurers, potentially straining their financial resources, as observed by Thompson et al. (2023). Additionally, Mueller et al. (2009) found that wildfires in California led to a 10% decrease in house prices after the first fire and a 23% decrease after the second fire. The insurance industry plays a crucial role in managing the financial aftermath of wildfires. With the increasing frequency and severity of wildfires, insurance companies face rising claims and liabilities. This can result in higher insurance premiums for policyholders and, in some cases, the withdrawal of insurance coverage from high-risk areas, exacerbating the economic impact on homeowners and businesses, as discussed by Benali and Feki (2017).

Tourism, a significant source of revenue for many US regions, can suffer when wildfires, especially when accompanied by poor air quality, discourage tourists and disrupt travel plans. The subsequent decline in tourism-related activities, including accommodation, dining, and outdoor recreation, can result in revenue losses for local businesses and municipalities, as highlighted by Thapa et al. (2013). Wildfires extend their impact beyond the aforementioned sectors, affecting timber and forest management (Galizia et al. 2021), transportation and logistics (Niggli et al. 2022), and infrastructure maintenance (Wang et al. 2021). The scale and complexity of these economic repercussions underscore the urgent need for a comprehensive analysis of wildfires' influence on the US economy and its capital markets.

2.3 Event study and natural disasters

The event study methodology, originating in the 1960s, provides a systematic framework for assessing the influence of events on financial markets. Early pioneers like Ball and Brown (1968) and Fama et al. (1969) investigated earnings announcements and stock splits, respectively, shaping its initial development. Methodological enhancements by scholars such as Patell (1976) and Cowan (1992) improved its precision and robustness. This methodology has transcended its original scope in capital market analysis, finding application across disciplines. In environmental studies, Palatnik et al. (2019) and Tavor (2023) evaluated the impact of gas discoveries on foreign exchange markets. In marketing research, Delattre (2007) reviewed marketing articles using the event study methodology. Duso et al. (2010) examined merger profitability in accounting. Even the tourism sector has benefited, with Teitler-Regev and Tavor (2023) applying it to understand Airbnb's effects on hotel companies.

The academic discourse on natural disasters' impact on financial markets is multifaceted. It covers various aspects of this topic, revealing how financial markets respond to unexpected natural events (Koerniadi et al. 2016). Becerra et al. (2014) explore Official Development Assistance (ODA) post-disasters, finding it often inadequate and influenced by event severity and recipient characteristics. Another focus is on financial firms' responses to natural disasters. Chen et al. (2023) discovered diverse reactions, with security companies experiencing significant negative returns, banks reacting mainly to earthquakes, and insurance companies showing less impact. Sovereign credit risk is another intriguing dimension explored by Di Tommaso et al. (2023), highlighting varying responses across European sovereigns to natural disasters. Corporate social responsibility (CSR) emerges as an influential factor shaping stock performance during disasters. Malik et al. (2023) found that CSR-focused firms outperformed during disasters, especially those emphasizing environmental CSR practices.

Equity markets also come into focus. Li (2012) examines the Australian market's response to natural catastrophes, revealing varied effects across industries. Additionally, Robinson and Bangwayo-Skeete (2016) emphasize significant losses in stock markets in small island developing states post-disasters. Similar findings were reported by Bourdeau-Brien and Kryzanowski (2017), who delved into the impact of natural disasters on US firms' stock returns and volatilities, with notable effects on firms in affected regions. In contrast, Akkuş and Kişlalioğlu (2023) find no significant difference in Turkish sectoral stock indices after earthquakes. Furthermore, Luo's analysis (2012) of the global impact of the 2011 Japanese earthquake on stock markets reveals a mixed set of effects, illustrating the global interconnectedness of financial markets. Intriguingly, Teitler-Regev and Tavor (2019) explore profit opportunities for investors during natural disasters, advocating for short-selling strategies and risk management practices, recognizing that certain financial opportunities can emerge even in the face of disasters.

2.4 Hypotheses and theoretical framework

Building upon the empirical evidence presented above, the following hypotheses are formulated:

Hypothesis 1 (H1) The cumulative abnormal return differs significantly among sectors in the pre- and post-wildfire events.

Rationale for Hypothesis 1:

H1 is rooted in the extensive body of research demonstrating that natural disasters affect economic sectors differently. Extensive research, such as Becerra et al. (2014) and Robinson and Bangwayo-Skeete (2016), underscores the sector-specific responses to natural events in financial markets. For instance, sectors like insurance and real estate may experience negative cumulative abnormal returns (CAR) due to immediate financial implications and property damage, as observed in Mueller et al. (2009). In contrast, sectors like food and transportation may exhibit positive CAR, driven by increased demand and supply chain adjustments, as suggested by Kowalewski and Śpiewanowski (2020) and Hendricks et al. (2020). The distinct impacts across sectors underscore the necessity of exploring the stock market response to wildfires within each sector individually. Moreover, the event study methodology, as effectively applied in contexts such as profit opportunities during natural disasters by Teitler-Regev and Tavor (2019), further supports this hypothesis. Therefore, H1 posits that the effect of wildfires on stock indices is not uniform and significantly varies among sectors.

Hypothesis 2 (H2) There is a significant relationship between the size and economic cost of wildfires and the cumulative abnormal return in specific sectors within the US stock market.

Rationale for Hypothesis 2:

H2 is based on the recognition that the magnitude and financial consequences of wildfires have distinctive effects on the stock returns of specific sectors, in accordance with prior research. The discourse on natural disasters underscores that the scale and implications of these events play a pivotal role in shaping financial outcomes. Akkuş and Kişlalioğlu (2023) emphasize the significance of event severity in influencing sectoral stock indices. Similarly, the economic and financial consequences of wildfires, as elucidated by Kabeshita et al. (2023) and Thompson et al. (2023), illustrate how the extent of destruction and associated costs can impact various sectors, including agriculture, real estate, and insurance. This rationale aligns with the event study methodology's capability to measure and quantify the effects of event characteristics on stock market responses, as demonstrated by Teitler-Regev and Tavor (2019). Thus, H2 posits that the size and cost of wildfires play a significant role in shaping sector-specific stock returns within the US stock market.

3 Data and empirical methodology

3.1 Data

In this section, the data collection process and methodological framework designed to assess the ramifications of wildfires that unfolded in the USA on the financial markets of nine sectors are explored. These sectors, namely insurance, real estate, forestry and timber, health, food, transportation, utilities, energy, and tourism, have been categorized into four distinctive groups: direct impact sectors, indirect impact sectors, resilience and mitigation sectors, and interconnected sectors. The primary focus of this research centers on substantial wildfires that occurred over a four-year period, spanning from 2019 to 2022. The crucial data for this analysis were gathered from the National Interagency Coordination Center (NICC), serving as the fundamental dataset for the investigation.

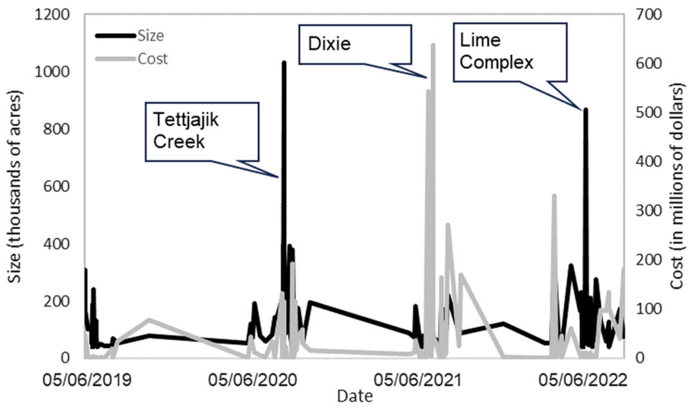

Fig. 1 Temporal distribution of significant wildfires in the USA. *Note* This figure presents the distribution of notable wildfires in the USA spanning the years 2019 through 2022. The primary y-axis denotes wildfire size, measured in thousands of acres and represented by a black line, while the secondary y-axis signifies the cost of wildfires, quantified in millions of dollars and indicated by a gray line

The dataset encompasses a total of 161 significant wildfires, distributed across the four years under scrutiny. Specifically, the count stands at 27 wildfires in 2019, 51 in 2020, 38 in 2021, and 45 in 2022, as visually depicted in Fig. 1. These wildfires serve as the basis for the study as the research seeks to evaluate their influence on financial markets.

To conduct a comprehensive assessment of the influence of US wildfires on financial markets, a diverse array of stock and sectoral indices, coupled with a market index, have been employed. This diversified spectrum of indices encompasses a broad swath of sectors and market segments, allowing for a multifaceted analysis. The roster of sectoral indices comprises the Dow Jones Insurance index (InsureX), Dow Jones Real Estate index (RealEstX), Dow Jones Health Care index (HealthX), Dow Jones Food Retail & Wholesale index (FoodX), Dow Jones Industrial Transportation index (TranspoX), Dow Jones Utilities index (UtiliX), S&P 500 Energy index (EnergyX), Dow Jones Travel & Tourism index (TourX), and the noteworthy Forestry and Timber Industry index (TimberX). The latter, TimberX, has been constructed from the amalgamation of data pertaining to the four largest companies in the industry: PotlatchDeltic (PCH), Rayonier (RYN), UFP Industries Inc (UFPI), and Weyerhaeuser Company (WY).

In addition to these sectoral indices, the inclusion of the S&P 500 index (S&PX) in the analytical framework serves the essential purpose of calculating abnormal returns within different sectors during wildfire events. To obtain the requisite data for the analysis, the daily returns for the designated indices over a defined temporal span encompassing 251 days for each wildfire event were sourced from Investing.com. This temporal framework is divided into 205 days leading up to the announcement of the wildfire and 45 days following the announcement. This data collection methodology has been devised to provide insights into both short-term and long-term impacts stemming from the occurrence of wildfire events.

The outcomes presented in Fig. 1 provide a comprehensive depiction of the temporal and geographical distribution of wildfires. Notably, the data reveal that wildfires are a year-round phenomenon, with a pronounced surge in occurrences during the summer months, primarily from June to August. Within this timeframe, Fig. 1 highlights three noteworthy wildfires that stand out due to their size and economic impact.

The first of these significant wildfires, named Tettjajik Creek, ignited in the Northern California Area on August 17, 2020. This formidable wildfire engulfed an extensive area, spanning 1,032,648 acres and incurring substantial economic losses amounting to 116 million dollars. The second major wildfire, known as Dixie, erupted in the Northern California Area on July 13, 2021. It left a significant mark, covering a vast territory of 963,309 acres and causing extensive economic damage totaling 637 million dollars. Lastly, the third major wildfire, Lime Complex, originated in the Alaska Area on June 15, 2022. Although it covered a substantial land area of 865,625 acres, its economic impact was relatively lower, resulting in damages amounting to 13 million dollars.

3.2 Empirical strategy

3.2.1 Event study methodology

This study employs the event study methodology as described by MacKinlay (1997) to investigate the impact of wildfires in the USA on financial markets.

In employing the event study methodology, day zero ($t = 0$) was defined as the wildfire's outbreak date, with adjustments for non-trading days. Two key time frames were established: the estimation window (L_1), covering days $t \in [-205, -6]$, for statistical data collection, and the event window (L_2), spanning days $t \in [-5, +45]$, to assess immediate and longer-term effects on financial markets.

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it} \tag{1}$$

where R_{it} represents the daily returns related to the event i, while R_{mt} signifies the daily returns of the overall market portfolio, represented by the S&P 500 index, and ε_{it} is the error term. Abnormal returns (AR) for each event are then computed by comparing actual returns (R_{it}) with expected returns and can be calculated as:

$$AR_{it} = R_{it} - \widehat{\alpha}_i - \widehat{\beta}_i R_{mt} \tag{2}$$

The cumulative abnormal returns (CAR) were calculated as follows:

$$CAR_{i,t_1,t_2} = \sum_{t=t_1}^{t_2} AR_{it} \tag{3}$$

In this study, an array of parametric and nonparametric tests were utilized to assess the significance of abnormal returns and cumulative abnormal returns. The first parametric test, Patell's standardized residual test (1976), was employed to gauge the resilience of abnormal returns while considering cross-sectional correlation. A second parametric test, the standardized cross-sectional approach (BMP) introduced by Boehmer et al. (1991), addressed limitations associated with the standard t-test when applied to event-induced variance.

Nonparametric tests, which do not make assumptions about data distribution, were also incorporated. The Sign Test (SIGN) developed by Cowan (1992) was applied to handle skewed return distributions, while the Generalized Sign Test (G-SIGN), also proposed by Cowan (1992), compared the rate of positive abnormal returns during an event period to an unaffected period.

3.2.2 Regression methodology

In alignment with event research methodology, this study integrates an extensive analytical approach, employing weighted least squares (WLS) regression analysis. The utilization of WLS aims to extend the investigation into the intricate relationship between abnormal returns and various indicators of fire severity, trend variables reflecting exposure to events, and the impact of spatial influence score (SIS) across different sectors. This section elucidates the intricacies of the regression model employed, elucidating its pivotal role in broadening the analytical framework of this study. As depicted in the ensuing equation:

$$\mathrm{WSS}(\beta, \gamma, \delta, \mathrm{W}_{reg}) = \sum_{i=1}^{N} \mathrm{W}_{reg} \Bigg[\mathrm{CAR}[\mathrm{t}_1, \mathrm{t}_2]_{k,i} - \beta_{k,0,i}\mathrm{CAR}[-5, -1]_{k,i} - \beta_{k,1,i}\mathrm{Cause}_{k,i} - \sum_{j=1}^{6} \beta_{k,j,i} \ln(\mathrm{WildfireFactor})_{k,j,i} - \sum_{l=1}^{2} \gamma_{k,l,i} \ln(\mathrm{GTW})_{k,l,i} - \sum_{s=1, s\neq k}^{9} \delta_{k,s,i}\mathrm{SectorEffect}_{k,\mathrm{s},\mathrm{i}} \Bigg]^2 \quad (4)$$

Within the scope of this regression analysis, the study engages with several key indices and variables. The index “i” designates the event number, spanning from 1 to N, while the categorical index “k” distinguishes among the nine sector indices under scrutiny. Additionally, “j” denotes the variable associated with wildfire characteristics, “l” signifies the index for Google Trend Worldwide (GTW) variables, and “s” represents the sector index accounting for the effect of other sectors.

The regression coefficients, symbolized as “β,” elucidate the relationship between the dependent variable—abnormal returns—and the indicators of wildfire severity variables. Concurrently, the coefficients “γ” unveil the association between abnormal returns and trend variables, while “δ” reflects the spatial influence score. The explanatory variables encompass an assorted array of indicators related to wildfire severity, trend variables, and spatial influence score variables.

Specifically, indicators of wildfire severity encompass components such as “Cause,” categorizing wildfire responsibility into 1 for ‘lightning,’ 2 for ‘under investigation,’ and 3 for ‘human.’ The “WildfireFactor” indicator differentiates among five other severity indicators: “Size,” quantifying the wildfire area’s extent in acres; “Cost,” gauging monetary expenses in US dollars; “Fatalities” and “Casualties,” denoting the number of lives lost and individuals injured during the wildfire incident; and “Datedif,” representing the temporal duration of the wildfire event in days.

Beyond severity indicators, the analysis incorporates trend variables (GTW), consisting of two variables, labeled "GTW-E" and "GTW-S," publicly available through Google Trends. These variables serve as quantitative measures of public discourse and prevalence related to wildfires, offering distinct perspectives by segmenting references according to event nomenclature and geographical state classifications. Values range from 0 to 100, where 100 denotes the highest frequency of mentions and 0 indicates the absence of mentions, with intermediate values allocated proportionally.

Furthermore, the analysis introduces the "SectorEffect" variable, examining the spatial influence score between different sectors, defined by the equation:

$$\mathrm{SectorEffect}_{k,s,i} = W_{sec,k,s} \bullet \mathrm{CAR}[t_1, t_2]_{k,s,i} \tag{5}$$

In this context, $W_{sec,k,s}$ denotes the weight signifying the influence of sector "s" on sector "k," computed through the utilization of Input–Output (I–O) accounts data retrieved from the US Bureau of Economic Analysis (BEA) government website, as detailed in Appendix A. $\mathrm{CAR}[t_1, t_2]_{k,s,i}$ represents the cumulative abnormal return of sector "s" during a specific period.

4 Empirical results

This section presents a comprehensive overview of the research findings, emphasizing the primary research objective: evaluating the repercussions of wildfires in the USA on the financial markets within nine distinct sectors. Furthermore, the study explores the effectiveness of investor strategies in capitalizing on this event to achieve excess profits. Additionally, an examination is conducted to identify any potential additional variables that may influence the abnormal returns observed in these sectors in the immediate aftermath of the wildfires.

4.1 Descriptive statistics

Table 1 in this study provides essential descriptive statistics to offer insights into various aspects related to stock indices, wildfire severity variables, and trend variables. These statistics are presented in two panels. Panel A details nine sector indices grouped into categories: direct impact sectors (InsureX, RealEstX, TimberX), indirect impact sectors (HealthX, FoodX, TranspoX), resilience and mitigation sectors (UtiliX, EnergyX), and interconnected sectors (TourX). The S&PX market index is also included. This grouping helps organize the analysis of these indices in response to wildfire events. Panel B provides a comprehensive description of regression variables, including event severity variables (Size, Cause, Cost, Fatalities, Casualties, Datedif) and trend variables (GTW-E, GTW-S). These variables are essential for quantifying wildfire event severity and understanding evolving trends.

Analysis of the findings presented in Panel A reveals discernible variations in both the mean returns and standard deviations among various sectors. Notably, the food

Table 1 An overview of descriptive statistics for stock indices and regression variables

Variables	N	Mean	Std. Dev	Min	Median	Max
Panel A: market model indices						
Stock indices						
Direct impact sectors						
InsureX	1678	0.046	1.318	− 11.930	0.090	11.250
RealEstX	1678	0.014	1.393	− 17.430	0.060	8.530
TimberX	1678	0.037	2.103	− 20.890	0.126	22.995
Indirect impact sectors						
HealthX	1678	0.046	1.127	− 10.260	0.070	7.610
FoodX	1678	0.065	1.269	− 10.620	0.110	8.090
TranspoX	1678	0.051	1.474	− 12.010	0.070	11.060
Resilience and mitigation sectors						
UtiliX	1678	0.022	1.292	− 11.530	0.070	13.000
EnergyX	1678	0.035	2.074	− 20.080	0.040	16.310
Interconnected sectors						
TourX	1678	0.047	2.156	− 12.540	0.090	14.880
Market index						
S&PX	1678	0.049	1.234	− 11.980	0.070	9.380
Panel B: regression variables						
Size	161	129.321	140.172	40	85.073	1,032.648
Cause	161	1.594	0.712	1	1	3
Cost	141	41.702	84.398	0	11.656	637.428
Fatalities	20	2.900	3.567	0	2	16
Casualties	26	10.192	19.250	1	5	100
Datedif	161	45.621	37.352	0	35	196
GTW-E	161	44.206	34.407	5	18	100
GTW-S	161	48.857	35.890	0	67	100

This table encompasses an extensive array of statistical metrics. In Panel A, nine sector indices and market index are presented and expressed as percentages. Shifting to Panel B, it includes variables such as “Size,” quantifying the wildfire area in thousands of acres; “Cause,” categorizes wildfire responsibility as follows: 1 for ‘lightning,’ 2 for ‘under investigation,’ and 3 for ‘human; “Cost,” measuring monetary expenses in millions of US dollars related to wildfire incidents; “Fatalities” and “Casualties,” representing the number of lives lost and individuals injured during wildfire events; and “Datedif,” denoting the temporal duration of wildfire events in days. Additionally, two trend variables, “GTW-E” and “GTW-S,” function as quantitative indicators of the extent and frequency of public discourse concerning wildfires, based on event nomenclature and geographic state classifications. These variables are measured on a continuous scale ranging from 0 to 100

sector exhibits the highest return, yielding 0.065%, while the real estate sector displays the lowest return at 0.014%. In terms of volatility, the forestry and timber, and tourism sectors exhibit the highest degrees of variability, with values of 2.103% and 2.156%, respectively. Conversely, the health sector demonstrates a comparatively lower standard deviation, indicating greater stability with a value of 1.127%.

Panel B of the analysis sheds light on various aspects of forest wildfires. Notably, the average size of these wildfires stands at 129,321 acres, and the largest wildfire, Tettjajik Creek, covers an extensive 1,032,648 acres. Lightning is the predominant cause of these fire incidents, and the average cost associated with these wildfires is approximately 41.702 million dollars. The Dixie fire stands out as the costliest, reaching a 637 million dollars. These wildfires also resulted in casualties, with 16 deaths and 100 injuries recorded. The duration of these wildfires varies, with the average event lasting around 45.621 days, and the longest wildfire lasted 196 days. Shifting to trend variables, the mention of these fire events and the countries where they occur demonstrates a moderate presence, scoring an average of 44.206 and 48.857, respectively, on a scale ranging from 0 to 100.

4.2 Analyzing the impact of wildfires on financial market indices

Figure 2 illustrates the cumulative average abnormal returns (CAAR-5, + 45) associated with nine distinct sectors during a 51-day event window surrounding the occurrence of a wildfire event. This window extends from 5 days prior to the wildfire announcement to 45 days following it. These sectors have been categorized into four

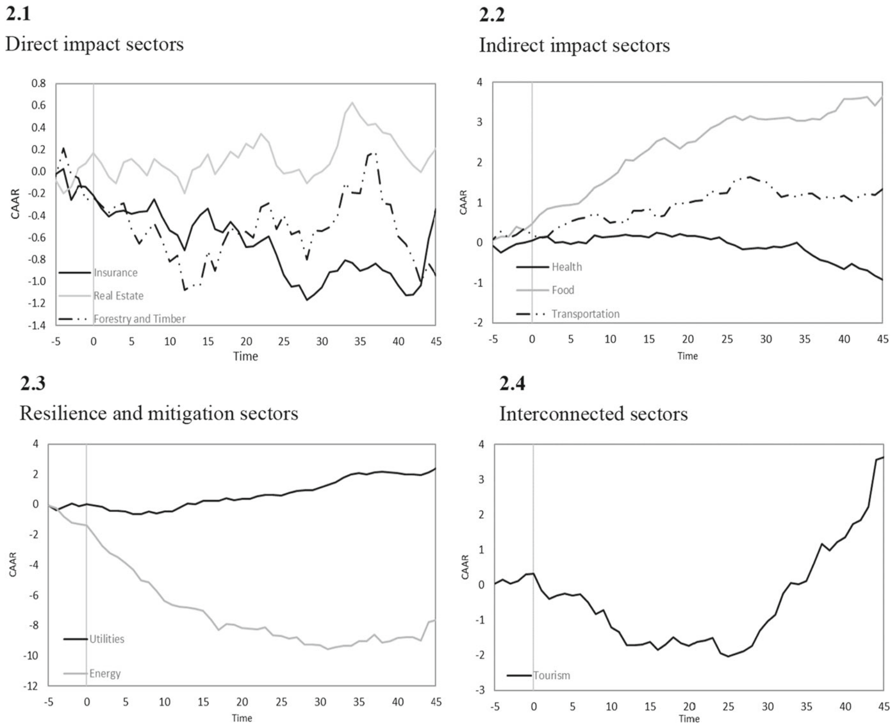

Fig. 2 CAAR patterns across diverse sectors. *Note* The figure shows the behavior of the $CAAR_{-5,+45}$ during the event window surrounding the day of the event for the nine sectors

groups: direct impact sectors (Fig. 2.1), indirect impact sectors (Fig. 2.2), resilience and mitigation sectors (Fig. 2.3), and interconnected sectors (Fig. 2.4). Concurrently, Table 2 provides a comprehensive overview of cumulative abnormal returns and presents the results of both parametric and nonparametric tests conducted for a total of 161 wildfires that transpired within the USA. These analyses were performed over two types of windows: the time-limited event window and the extended event window. Within Table 2, the second column furnishes insights into cumulative abnormal returns (CAR_{t_1,t_2}). Columns 3 and 4 proffer the outcomes derived from two parametric tests, specifically PATELL and BMP, while columns 5 and 6 convey the results obtained through two nonparametric tests, SIGN and G-SIGN.

In Panel A, encompassing direct impact sectors, insurance experiences a decrease in Cumulative Abnormal Returns (CAR) for up to 28 days after a wildfire. This decline can be attributed to the increased costs associated with claims and payouts due to fire-related damages, leading to a negative financial impact on insurance companies. The real estate sector likewise witnesses a post-wildfire CAR decrease, albeit of shorter duration (typically up to three days). This may be linked to concerns about property damage and reduced real estate values in affected areas. Notably, the forestry and timber industry's erratic CAR behavior reflects the industry's intricate relationship with wildfires, encompassing both declines (linked to immediate destruction) and increases (connected to reforestation efforts). Shifting the focus to Panel B, encompassing the indirect impact sectors, distinct patterns emerge. In the health sector, CAR initially rises post-wildfire, suggesting increased demand for healthcare services due to injuries or smoke-related health issues. However, this upward trend is not sustainable, and CAR decreases until approximately 45 days post-event as concerns about the long-term impact of wildfires set in. The food industry exhibits a substantial and continuous CAR increase throughout the entire 45-day post-wildfire period. This surge is likely associated with increased demand for food supplies and safety concerns, translating into higher stock performance. Conversely, the transportation sector experiences an initial CAR decrease lasting two days, driven by disruptions in supply chains and logistics during wildfires. This trend reverses after the initial disruption, resulting in a consistent CAR increase up to 45 days post-wildfire as transportation services recover.

In Panel C, comprising resilience and mitigation sectors, utilities demonstrate a CAR decrease in the days following a wildfire, likely due to damages and service disruptions. However, as these utilities recover and make necessary repairs, CAR subsequently increases up to 45 days post-wildfire. On the other hand, the energy sector experiences a consistent CAR decrease throughout the entire post-wildfire period, which can be attributed to supply disruptions, safety concerns, and the environmental implications of wildfires affecting the sector. Finally, in Panel D, within the analysis of the Tourism industry, an initial gradual CAR decrease extending up to 25 days post-wildfire can be linked to concerns about the impact on tourist destinations, including closures due to the fires. However, a sharp CAR increase over the subsequent 20 days indicates a recovery as these areas reopen, signifying a more positive outlook for the sector.

The findings validate Hypothesis 1, affirming that wildfires have varying impacts on stock indices, which aligns with prior research (Becerra et al. 2014; Robinson and Bangwayo-Skeete 2016). As this study reveals, direct impact sectors such as insurance

Table 2 Wildfire incidents' impact on capital markets: a CAR analysis

	Panel A: direct impact sectors									
	Insurance					Real estate				
		Parametric tests		Nonparametric tests			Parametric tests		Nonparametric tests	
Daily time	CAR(%)	PATELL	BMP	SIGN	G-SIGN	CAR(%)	PATELL	BMP	SIGN	G-SIGN
Time-limited event window										
CAR[− 5, − 1]	− 0.138	− 1.445	− 1.472	− 0.552	− 0.472	0.075	0.464	0.533	− 1.970*	− 2.213**
CAR[0, + 1]	− 0.190	− 2.167**	− 2.343**	− 1.340	− 1.260	0.002	− 0.470	− 0.515	1.340	1.098
CAR[0, + 2]	− 0.271	− 2.791***	− 3.011***	− 2.128**	− 2.048**	− 0.122	− 1.378	− 1.267	− 1.970*	− 2.213**
CAR[0, + 3]	− 0.231	− 2.081**	− 2.097**	− 0.867	− 0.787	− 0.184	− 1.918*	− 1.722*	− 0.867	− 1.109
CAR[+ 1, + 3]	− 0.154	− 1.626	− 1.690*	0.079	0.158	− 0.277	− 2.407**	− 2.269**	− 2.286**	− 2.528***
CAR[0, + 7]	− 0.224	− 1.517	− 1.399	− 0.867	− 0.787	− 0.110	− 0.993	− 1.071	− 1.340	− 1.582
Extended event window										
CAR[0, + 28]	− 1.032	− 3.783***	− 4.576***	− 1.655*	− 1.575	− 0.180	− 1.053	− 1.631	0.079	− 0.163
CAR[+ 8, + 38]	− 0.535	− 2.320**	− 3.049***	− 1.025	− 0.945	0.390	0.279	0.372	1.182	0.940
CAR[+ 25, + 45]	0.417	0.802	0.920	− 0.394	− 0.314	0.157	0.123	0.158	2.443**	2.202**

Table 2 (continued)

	Panel A: direct impact sectors									
	Insurance					Real estate				
		Parametric tests		Nonparametric tests			Parametric tests		Nonparametric tests	
Daily time	CAR(%)	PATELL	BMP	SIGN	G-SIGN	CAR(%)	PATELL	BMP	SIGN	G-SIGN
CAR[+ 1, + 45]	− 0.203	− 1.462	− 1.654*	− 0.867	− 0.787	0.135	− 0.457	− 0.719	4.177***	3.936***

	Panel A: direct impact sectors					Panel B: indirect impact sectors				
	Forestry and timber					Health				
		Parametric tests		Nonparametric tests		Parametric tests			Nonparametric tests	
Daily time	CAR(%)	PATELL	BMP	SIGN	G-SIGN	CAR(%)	PATELL	BMP	SIGN	G-SIGN
Time-limited event window										
CAR[− 5, − 1]	− 0.261	− 1.148	− 1.536	− 1.655*	− 1.685*	0.007	0.524	0.556	− 0.552	− 0.593
CAR[0, + 1]	− 0.043	− 0.787	− 1.081	− 0.236	− 0.266	0.127	1.881*	1.831*	2.758***	2.717***
CAR[0, + 2]	− 0.114	− 1.282	− 1.563	− 1.970*	− 2.000**	0.150	1.716*	1.451	0.394	0.352
CAR[0, + 3]	− 0.051	− 0.904	− 1.111	0.394	0.364	0.001	0.009	0.009	− 2.443***	− 2.485**
CAR[+ 1, + 3]	− 0.078	− 0.782	− 0.946	− 0.552	− 0.582	− 0.049	− 0.507	− 0.521	− 1.497	− 1.539
CAR[0, + 7]	− 0.295	− 1.333	− 1.495	0.079	0.049	− 0.028	− 0.097	− 0.084	− 0.709	− 0.751
Extended event window										
CAR[0, + 28]	− 0.537	− 1.218	− 1.855*	− 1.340	− 1.370	− 0.160	− 0.655	− 0.825	− 0.079	− 0.121
CAR[+ 8, + 38]	0.266	0.073	0.111	1.025	0.995	− 0.450	− 1.714*	− 2.719***	− 1.970**	− 2.012**

Table 2 (continued)

	Panel A: direct impact sectors					Panel B: indirect impact sectors				
	Forestry and timber					Health				
		Parametric tests		Nonparametric tests		Parametric tests			Nonparametric tests	
Daily time	CAR(%)	PATELL	BMP	SIGN	G-SIGN	CAR(%)	PATELL	BMP	SIGN	G-SIGN
CAR[+ 25, + 45]	− 0.421	− 0.932	− 1.218	− 0.552	− 0.582	− 1.047	− 4.689***	− 5.851***	− 3.231***	− 3.273***
CAR[+ 1, + 45]	− 0.684	− 1.159	− 1.465	− 0.236	− 0.266	− 0.928	− 2.931***	− 4.097***	− 1.813*	− 1.854*

	Panel B: indirect impact sectors									
	Food					Transportation				
		Parametric tests		Nonparametric tests			Parametric tests		Nonparametric tests	
Daily time	CAR(%)	PATELL	BMP	SIGN	G-SIGN	CAR(%)	PATELL	BMP	SIGN	G-SIGN
Time-limited event window										
CAR[− 5, − 1]	0.309	1.824*	2.935***	1.813*	2.202**	0.341	1.643	1.478	1.497	1.423
CAR[0, + 1]	0.385	3.703***	4.494***	4.177***	4.568***	− 0.219	− 2.542**	− 2.667***	− 2.286**	− 2.360**
CAR[0, + 2]	0.531	3.951***	4.822***	4.807***	5.198***	− 0.198	− 1.910*	− 1.925*	− 2.601***	− 2.675***
CAR[0, + 3]	0.591	3.802***	4.242***	4.807***	5.198***	0.008	− 0.222	− 0.214	− 2.916***	− 2.990***
CAR[+ 1, + 3]	0.440	3.258***	3.468***	3.546***	3.937***	0.151	1.097	1.043	− 0.236	− 0.311
CAR[0, + 7]	0.835	3.982***	4.340***	3.704***	4.095***	0.283	1.182	1.166*	0.236	0.162
Extended event window										
CAR[0, + 28]	2.842	7.100***	6.355***	8.433***	8.825***	1.299	3.193***	3.629***	4.177***	4.103***
CAR[+ 8, + 38]	2.083	5.349***	5.714***	6.857***	7.248***	0.514	1.142	1.164	2.443**	2.369**
CAR[+ 25, + 45]	0.690	2.747***	2.529***	1.182	1.571	0.100	0.091	0.094	− 1.182	− 1.256

Table 2 (continued)

	Panel B: indirect impact sectors									
	Food					Transportation				
		Parametric tests		Nonparametric tests			Parametric tests		Nonparametric tests	
Daily time	CAR(%)	PATELL	BMP	SIGN	G-SIGN	CAR(%)	PATELL	BMP	SIGN	G-SIGN
CAR[+ 1, + 45]	3.334	7.091***	7.406***	9.221***	9.614***	0.990	1.774*	1.804*	3.231***	3.157***

	Panel C: resilience and mitigation sectors									
	Utilities					Energy				
		Parametric tests		Nonparametric tests			Parametric tests		Nonparametric tests	
Daily time	CAR(%)	PATELL	BMP	SIGN	G-SIGN	CAR(%)	PATELL	BMP	SIGN	G-SIGN
Time − limited event window										
CAR[− 5, − 1]	− 0.100	− 0.574	− 0.466	1.970*	1.389	− 1.273	− 2.988***	− 2.427**	− 1.340	− 0.886
CAR[0, + 1]	0.025	0.016	0.016	0.709	0.126	− 0.753	− 3.378***	− 3.837***	− 4.650***	− 4.198***
CAR[0, + 2]	− 0.072	− 0.836	− 0.737	0.552	− 0.032	− 1.453	− 5.000***	− 5.259***	− 4.177***	− 3.725***
CAR[0, + 3]	− 0.323	− 2.526**	− 1.806*	− 0.394	− 0.978	− 1.957	− 5.922***	− 6.953***	− 5.753***	− 5.302***
CAR[+ 1, + 3]	− 0.457	− 3.537***	− 2.657***	− 1.340	− 1.925*	− 1.834	− 6.381***	− 6.562***	− 4.177***	− 3.725***
CAR[0, + 7]	− 0.551	− 2.509**	− 1.711*	0.709	0.126	− 3.727	− 8.702***	− 8.351***	− 6.226***	− 5.775***
Extended event window										
CAR[0, + 28]	1.037	1.601	1.694*	2.443**	1.862*	− 8.001	− 9.502***	− 9.421***	− 8.748***	− 8.299***
CAR[+ 8, + 38]	2.801	5.144***	5.901***	3.231***	2.651***	− 4.145	− 5.289***	− 6.436***	− 7.487***	− 7.037***
CAR[+ 25, + 45]	1.752	4.036***	4.596***	5.280***	4.702***	1.029	0.368	0.388	− 0.394	0.061
CAR[+ 1, + 45]	2.474	3.602***	4.449***	3.231***	2.651***	− 6.352	− 6.832***	− 6.728***	− 4.807***	− 4.356***

Table 2 (continued)

	Panel D: resilience and mitigation sectors				
	Tourism				
		Parametric tests		Nonparametric tests	
Daily time	CAR(%)	PATELL	BMP	SIGN	G-SIGN
Time-limited event window					
CAR[− 5, − 1]	0.293	1.287	1.745*	1.497	1.555
CAR[0, + 1]	− 0.443	− 2.032**	− 2.730***	− 3.862***	− 3.804***
CAR[0, + 2]	− 0.697	− 2.642***	− 3.263***	− 4.335***	− 4.277***
CAR[0, + 3]	− 0.594	− 1.897*	− 2.478**	− 2.758***	− 2.701***
CAR[+ 1, + 3]	− 0.615	− 2.264**	− 2.597***	− 1.655*	− 1.598
CAR[0, + 7]	− 0.781	− 1.610	− 1.997**	− 1.340	− 1.282
Extended event window					
CAR[0, + 28]	− 2.022	− 2.341**	− 2.802***	− 1.970**	− 1.913*
CAR[+ 8, + 38]	1.476	2.061**	2.731***	1.340	1.397
CAR[+ 25, + 45]	5.583	8.524***	8.945***	5.596***	5.653***
CAR[+ 1, + 45]	3.348	3.765***	5.144***	4.492***	4.550***

The table presents the cumulative abnormal returns (CAR) for the nine sectors in column 2, followed by two parametric tests in columns 3 and 4 and nonparametric tests in columns 5 and 6. Significance levels are denoted by *p*-values (* for 10%, ** for 5%, and *** for 1%)

and real estate exhibit CAR declines, consistent with expectations. This trend corresponds with the sector-specific responses to natural events observed in previous studies, underscoring the validity of Hypothesis 1. The empirical outcomes in sectors like food and transportation further reinforce the hypothesis. These sectors experience notable CAR increases, reflecting heightened demand and supply chain adjustments, echoing the findings of Kowalewski and Śpiewanowski (2020) and Hendricks et al. (2020). These results accentuate the necessity of investigating stock market responses within each sector individually, aligning with Hypothesis 1's focus on the non-uniform impact of wildfires across sectors. Overall, these results, coupled with the relevant literature (Becerra et al. 2014; Robinson and Bangwayo-Skeete 2016), stress the importance of adopting a sector-specific approach in understanding the financial repercussions of wildfires. The sector-based variations underscore the distinct characteristics of each sector and further support the relevance of this study.

4.3 Robustness check

The robustness check section rigorously examined the data using the ordinary t-test (ORDIN) across the nine sectors, as summarized in Table 3. These supplementary analyses reinforce and complement the initial test results. Within sectors directly affected by the events in question, the insurance industry experienced a significant decline in abnormal returns. Conversely, in sectors indirectly impacted, abnormal returns decreased in the health sector, while the food and transportation sectors demonstrated an increase in abnormal returns. Furthermore, the resilience and mitigation sectors demonstrated distinct patterns. The utilities sector demonstrated an increase in abnormal returns in contrast with the energy sector, which showed a decline in abnormal returns. In the case of the interconnected sectors, as exemplified by the tourism industry, the analysis revealed an initial decline in abnormal returns in the days immediately following the events. However, this trend subsequently shifted, leading to an increase in abnormal returns.

4.4 Regression results

This section undertakes a regression analysis to investigate the influence of wildfire characteristics, trend indicators, and the spatial influence score on the capital markets of nine selected sectors within the USA. The resultant findings are presented in Table 4 and methodically organized across four distinct panels, each expressly dedicated to specific sectoral categories: direct impact (Panel A), indirect impact (Panel B), resilience and mitigation (Panel C), and interconnected (Panel D). The regression models encompass a varied set of strategically chosen explanatory variables, aiming to elucidate the nuanced relationship between wildfire-related announcements and the performance of capital markets within these sectoral domains. For each sector, the impact of these variables is evaluated across two discrete time frames. The initial analysis focuses on the short term, scrutinizing effects within the event window [0, + 2], while the subsequent examination extends to the longer term, encompassing the event window [+ 1, + 45].

The examination of the impact of wildfires on different sectors of the US stock market provides a multi-faceted view of how these natural disasters resonate throughout the economy. In the domain of direct damage, the insurance industry emerges as particularly sensitive to the cost of fire. Larger damages translate into more substantial financial losses due to increased insurance claims. Furthermore, the number of fatalities adversely affects the industry, particularly in the short term. Interestingly, mentioning the country or the event correlates with an increase in returns over the

Table 3 Capital markets' resilience to wildfire incidents: a robustness analysis

	Panel A: direct impact sectors					
	Insurance		Real estate		Forestry and timber	
Daily time	CAR(%)	ORDIN	CAR(%)	ORDIN	CAR(%)	ORDIN
Time-limited event window						
CAR[− 5, − 1]	− 0.138	− 0.606	0.075	0.242	− 0.261	− 0.483
CAR[0, + 1]	− 0.190	− 1.316	0.002	0.009	− 0.043	− 0.127
CAR[0, + 2]	− 0.271	− 1.535	− 0.122	− 0.507	− 0.114	− 0.273
CAR[0, + 3]	− 0.231	− 1.132	− 0.184	− 0.662	− 0.051	− 0.106
CAR[+ 1, + 3]	− 0.154	− 0.871	− 0.277	− 1.149	− 0.078	− 0.187
CAR[0, + 7]	− 0.224	− 0.775	− 0.110	− 0.280	− 0.295	− 0.432
Extended event window						
CAR[0, + 28]	− 1.032	− 1.877*	− 0.180	− 0.241	− 0.537	− 0.413
CAR[+ 8, + 38]	− 0.535	− 0.942	0.390	0.504	0.266	0.198
CAR[+ 25, + 45]	0.417	0.891	0.157	0.246	− 0.421	− 0.381
CAR[+ 1, + 45]	− 0.203	− 0.296	0.135	0.144	− 0.684	− 0.423

	Panel B: indirect impact sectors					
	Health		Food		Transportation	
Daily time	CAR(%)	ORDIN	CAR(%)	ORDIN	CAR(%)	ORDIN
Time-limited event window						
CAR[− 5, − 1]	0.007	0.036	0.309	0.971	0.341	1.214
CAR[0, + 1]	0.127	1.054	0.385	1.916*	− 0.219	− 1.233
CAR[0, + 2]	0.150	1.013	0.531	2.157**	− 0.198	− 0.912
CAR[0, + 3]	0.001	0.007	0.591	2.077**	0.008	0.031
CAR[+ 1, + 3]	− 0.049	− 0.331	0.440	1.785*	0.151	0.695
CAR[0, + 7]	− 0.028	− 0.115	0.835	2.076**	0.283	0.797
Extended event window						
CAR[0, + 28]	− 0.160	− 0.349	2.842	3.711***	1.299	1.922*
CAR[+ 8, + 38]	− 0.450	− 0.947	2.083	2.631***	0.514	0.735
CAR[+ 25, + 45]	− 1.047	− 2.680***	0.690	1.059	0.100	0.174

Table 3 (continued)

	Panel B: indirect impact sectors					
	Health		Food		Transportation	
Daily time	CAR(%)	ORDIN	CAR(%)	ORDIN	CAR(%)	ORDIN
CAR[+ 1, + 45]	− 0.928	− 1.622	3.334	3.495***	0.990	1.177

	Panel C: resilience and mitigation sectors				Panel D: interconnected sectors	
	Utilities		Energy		Tourism	
Daily time	CAR(%)	ORDIN	CAR(%)	ORDIN	CAR(%)	ORDIN
Time-limited event window						
CAR[− 5, − 1]	− 0.100	− 0.275	− 1.273	− 2.045**	0.293	0.534
CAR[0, + 1]	0.025	0.108	− 0.753	− 1.912*	− 0.443	− 1.275
CAR[0, + 2]	− 0.072	− 0.253	− 1.453	− 3.013***	− 0.697	− 1.640*
CAR[0, + 3]	− 0.323	− 0.987	− 1.957	− 3.514***	− 0.594	− 1.209
CAR[+ 1, + 3]	− 0.457	− 1.615	− 1.834	− 3.802***	− 0.615	− 1.446
CAR[0, + 7]	− 0.551	− 1.192	− 3.727	− 4.732***	− 0.781	− 1.124
Extended event window						
CAR[0, + 28]	1.037	1.178	− 8.001	− 5.335***	− 2.022	− 1.528
CAR[+ 8, + 38]	2.801	3.078***	− 4.145	− 2.673***	1.476	1.079
CAR[+ 25, + 45]	1.752	2.339**	1.029	0.806	5.583	4.960***
CAR[+ 1, + 45]	2.474	2.256**	− 6.352	− 3.400***	3.348	2.032**

The table displays cumulative abnormal returns (CAR) and the ORDIN test results for nine sectors. Significance levels are denoted by *p*-values (* for 10%, ** for 5%, and *** for 1%)

long term, potentially indicating support or sympathy. The interplay with other sectors reveals a negative influence from the food industry, while the utilities industry has a positive impact on the insurance sector. Shifting the focus to the real estate sector, as the duration of fires extends, a reduction in returns is observed, reflecting broader economic disruptions and property damage resulting from prolonged fires. Additionally, the number of fatalities exerts a negative impact on the sector, especially in the short term. The mention of the country correlates with an increase in long-term returns, suggesting support or sympathy. The interaction with other sectors reveals a positive effect from the health, food, and services sectors on the real estate sector.

In the forestry and wood industry, sensitivity to the cost of fire is evident, with greater damages causing more significant financial losses. Fires ignited by lightning, with their unpredictability and potentially wide-reaching damage, have a more pronounced negative effect on industry yield compared to those caused by human activity. Trend analysis shows a short-term negative effect when mentioning the fire event, followed by a long-term change indicating adaptation and recovery strategies. Notably, the

Table 4 An examination of event characteristics, trend indicators, and the spatial influence score through regression analysis

	Panel A: direct impact sectors											
	Insurance				Real estate				Forestry and timber			
	Time-limited impact		Extended impact		Time-limited impact		Extended impact		Time-limited impact		Extended impact	
	R Square = 0.340	$F < 0.001$	R Square = 0.791	$F < 0.001$	R Square = 0.846	$F < 0.001$	R Square = 0.802	$F < 0.001$	R Square = 0.647	$F < 0.001$	R Square = 0.180	$F < 0.001$
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	0.639	0.449	− 6.938	− 2.399**	1.405	1.069	− 3.746	− 1.748*	− 5.912	− 2.342**	8.120	0.869
CAR[− 5, − 1]	0.062	1.106	0.602	5.201***	− 0.056	− 1.086	− 0.219	− 2.958***	0.009	0.155	0.820	3.573***
Cause	0.122	0.854	− 0.192	− 0.524	0.142	1.209	0.329	1.566	0.499	2.323**	− 1.517	− 1.589
Size	− 0.099	− 0.781	0.189	0.742	− 0.178	− 1.531	0.236	1.234	0.149	0.615	− 0.366	− 0.453
Cost	− 0.008	− 0.509	− 0.046	− 2.095**	0.002	0.130	− 0.019	− 0.671	0.073	2.745***	0.033	0.337
Fatalities	− 0.611	− 2.791***	0.221	0.223	− 0.427	− 3.360***	− 0.106	− 0.393	0.450	1.536	2.344	1.466
Casualties	0.127	0.964	0.175	0.658	0.102	1.462	0.056	0.387	− 0.135	− 0.765	− 0.468	− 0.481
Datedif	− 0.029	− 0.332	0.036	0.559	− 0.022	− 0.312	− 0.231	− 1.769*	0.017	0.135	0.572	1.045
TrendEvent	0.079	0.585	0.700	1.806*	0.027	0.235	0.385	1.605	0.439	2.691***	− 1.756	− 1.969**
TrendState	0.016	0.256	0.787	5.723***	0.094	1.601	− 0.49	− 5.073***	0.138	1.656*	1.091	2.718***
SIS insurance												
SIS real estate	− 77.346	− 1.351	− 121.263	− 1.475								
SIS forestry and timber												
SIS health					418.785	2.703***	10.108	0.118				

Table 4 (continued)

	Panel A: direct impact sectors											
	Insurance				Real estate				Forestry and timber			
	Time-limited impact		Extended impact		Time-limited impact		Extended impact		Time-limited impact		Extended impact	
	R Square = 0.340	$F < 0.001$	R Square = 0.791	$F < 0.001$	R Square = 0.846	$F < 0.001$	R Square = 0.802	$F < 0.001$	R Square = 0.647	$F < 0.001$	R Square = 0.180	$F < 0.001$
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
SIS food	− 1,294.257	− 3.219***	− 802.977	− 1.811*	− 1,238.780	− 0.351	8,716.323	4.932***				
SIS transportation												
SIS utilities	2,307.351	4.687***	2,353.778	5.593***	2,280.587	8.658***	1,557.176	13.031***				
SIS energy												
SIS tourism					8.591	1.331	− 2.404	− 1.025				
	Panel B: indirect impact sectors											
	Health				Food				Transportation			
	Time-limited impact		Extended impact		Time-limited impact		Extended impact		Time-limited impact		Extended impact	
	R Square = 0.712	$F < 0.001$	R Square = 0.736	$F < 0.001$	R Square = 0.360	$F < 0.001$	R Square = 0.648	$F < 0.001$	R Square = 0.112	$F < 0.001$	R Square = 0.413	$F < 0.001$
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	1.872	2.383**	− 0.228	− 0.117	2.061	1.681*	2.072	0.575	− 2.073	− 1.139	5.125	0.889
CAR[− 5, − 1]	− 0.183	− 4.504***	− 0.642	− 7.672***	− 0.130	− 1.765*	− 0.897	− 5.206***	− 0.104	− 2.061**	0.694	4.605***
Cause	0.108	1.207	0.26	0.889	− 0.080	− 0.77	− 0.985	− 3.262***	0.328	1.807*	− 0.431	− 0.671
Size	− 0.104	− 1.632	− 0.057	− 0.324	− 0.241	− 2.228**	− 0.429	− 1.379	0.045	0.267	0.533	1.028

Table 4 (continued)

	Panel B: indirect impact sectors											
	Health				Food				Transportation			
	Time-limited impact		Extended impact		Time-limited impact		Extended impact		Time-limited impact		Extended impact	
	R Square = 0.712	$F < 0.001$	R Square = 0.736	$F < 0.001$	R Square = 0.360	$F < 0.001$	R Square = 0.648	$F < 0.001$	R Square = 0.112	$F < 0.001$	R Square = 0.413	$F < 0.001$
	Coefficient	t-Statistic	Coefficient	*t*-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Cost	0.003	0.463	0.014	0.955	− 0.014	− 0.768	0.093	1.848*	− 0.003	− 0.098	− 0.174	− 3.354***
Fatalities	0.127	0.893	− 1.567	− 3.453***	0.112	0.871	− 0.046	− 0.263	− 0.149	− 0.588	− 0.941	− 0.8
Casualties	0.033	0.364	0.387	1.036	0.009	0.147	− 0.076	− 0.411	0.110	0.678	1.156	2.939***
Datedif	0.018	0.439	− 0.084	− 0.796	− 0.162	− 2.075**	− 0.009	− 0.035	− 0.154	− 1.364	− 1.202	− 4.439***
TrendEvent	− 0.106	− 1.234	0.094	0.332	0.540	4.834***	1.926	4.885***	0.340	2.177**	− 1.172	− 2.481**
TrendState	− 0.143	− 3.548***	− 0.077	− 0.662	− 0.111	− 1.523	− 0.268	− 1.588	0.002	0.020	0.601	3.018***
SIS insurance												
SIS real estate					− 0.711	− 2.018**	1.976	3.248***				
SIS forestry and timber												
SIS health					79.573	3.179***	− 85.348	− 4.041***				
SIS food												
SIS transportation												
SIS utilities	1,623.278	11.802***	166.643	1.416								
SIS energy												
SIS tourism	− 35.831	− 6.642***	− 37.872	− 7.778***	− 1.962	− 4.037***	− 2.257	− 6.776***	14.733	1.080	− 2.149	− 0.202

Table 4 (continued)

	Panel C: resilience and mitigation sectors								Panel D: interconnected sectors			
	Utilities				Energy				Tourism			
	Time-limited impact		Extended impact		Time-limited impact		Extended impact		Time-limited impact		Extended impact	
	R Square = 0.381	$F < 0.001$	R Square = 0.756	$F < 0.001$	R Square = 0.299	$F < 0.001$	R Square = 0.319	$F < 0.001$	R Square = 0.203	$F < 0.001$	R Square = 0.855	$F < 0.001$
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	− 2.104	− 1.387	− 10.389	− 2.481**	8.293	2.510**	− 23.747	− 1.457	− 0.451	− 0.236	− 9.369	− 1.321
CAR[− 5, − 1]	0.028	0.722	− 0.572	− 4.152***	0.081	1.482	− 0.088	− 0.483	0.075	1.516	− 0.434	− 3.499***
Cause	0.173	1.321	0.897	1.762*	0.130	0.399	1.622	1.177	0.072	0.344	1.175	2.242**
Size	0.068	0.520	− 0.194	− 0.495	− 0.621	− 2.116**	1.295	0.877	0.011	0.060	0.878	1.356
Cost	− 0.006	− 0.248	− 0.024	− 0.371	0.042	1.311	0.067	0.433	0.012	0.355	0.004	0.086
Fatalities	− 0.551	− 5.189***	− 0.446	− 0.830	− 0.161	− 0.494	4.117	1.210	− 0.136	− 0.638	2.644	1.167
Casualties	0.200	1.807*	0.177	0.578	0.087	0.437	0.292	0.224	0.228	1.763*	− 0.872	− 1.181
Datedif	0.042	0.425	− 0.627	− 1.980**	− 0.009	− 0.048	0.579	0.764	− 0.127	− 1.020	− 0.14	− 0.727
TrendEvent	0.080	0.654	3.845	9.439***	− 0.694	− 2.458**	− 2.043	− 1.336	− 0.052	− 0.300	− 0.074	− 0.095
TrendState	0.145	1.931*	− 0.409	− 2.457**	− 0.001	− 0.008	2.146	3.297***	0.139	1.481	0.242	0.967

Table 4 (continued)

	Panel C: resilience and mitigation sectors								Panel D: interconnected sectors			
	Utilities				Energy				Tourism			
	Time-limited impact		Extended impact		Time-limited impact		Extended impact		Time-limited impact		Extended impact	
	R Square = 0.381	$F < 0.001$	R Square = 0.756	$F < 0.001$	R Square = 0.299	$F < 0.001$	R Square = 0.319	$F < 0.001$	R Square = 0.203	$F < 0.001$	R Square = 0.855	$F < 0.001$
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
SIS insurance												
SIS real estate									1.041	1.076	− 5.616	− 3.043***
SIS forestry and timber												
SIS health												
SIS food	17,772.975	1.548	22,910.376	1.996**	− 11,338.798	− 2.790***	− 12,704.464	− 3.334***	− 294.470	− 3.472***	211.349	2.405**
SIS transportation	2.738	0.537	− 3.146	− 0.650					0.301	0.190	1.404	0.92
SIS utilities					118.592	2.112**	178.169	1.874*	− 4.181	− 1.955*	0.634	0.328
SIS energy												
SIS tourism	− 202.127	− 5.180***	72.743	2.459**								

The table displays results from a multivariate regression analysis that includes a set of event characteristics, trend indicators, and the spatial influence score. Statistical significance levels are denoted by p-values (* for 10%, ** for 5%, and *** for 1%)

recall of the country consistently positively affects industry returns. Transitioning to the indirect impact sectors, the health industry's vulnerability to the number of people killed in fires becomes apparent. Additionally, mentioning the country is negatively correlated with an increase in returns. The interplay with other sectors reveals a positive influence from the services sector, while the tourism sector exerts a negative influence on the health sector.

In the food industry, several factors contribute to the impact on returns over time. The fire cost component contributes to a positive effect, while the fire's duration and size contribute to a negative effect. Fires caused by lightning lead to a more pronounced increase in yields than those caused by human activity. Trend analysis highlights a positive effect when the country is mentioned. Interaction with other sectors reveals a negative impact from the real estate sector in the short term, changing the trend in the long term. The health sector has a positive impact in the short term, while the tourism sector negatively influences the food sector. The response of the transportation industry to fires is characterized by a gradual decrease in returns as the number of fire days or the cost of the fire increases. Fires caused by people intensify this decline. Trend variables show positive correlation with returns when country references are made, indicating government support or investment in infrastructure during wildfire events. Simultaneously, the trend analysis reveals a short-term positive effect when the fire event is mentioned, followed by a long-term change.

Within the resilience and mitigation sectors, the service industry exhibits vulnerability to wildfires, with a high number of fatalities or increased fire days adversely affecting returns. The imperative to repair and maintain infrastructure following fires serves as a key driver of this trend. Conversely, mentioning the country exhibits a strong positive effect on industry returns in the short term and brings about changes in the long term, indicative of government support for utility companies facing fire-related challenges. The event mention also causes a positive effect in the long term. Interaction with other sectors reveals a positive impact from the food sector, while the tourism sector has a negative impact in the short term, changing the trend in the long term. The response of the energy sector to fires is negatively affected by the size of the fire, with state mentions moderating declines in the industry. The negative impact of event mentions underscores the regulatory and market challenges this sector faces during wildfire events. Interaction with other sectors reveals a negative influence from the food sector, while the utilities sector has a positive influence. Finally, in the interconnected sectors, the behavior of the travel and tourism industry stands out. The number of victims causes an increase in industry returns, and events caused by people have a higher impact, reflecting the phenomenon of disaster tourism and increased interest in visiting affected areas. Interaction with other sectors reveals a negative impact from the real estate and utilities industries, while the food industry negatively influences in the short term but changes the trend in the long term.

The results align with Hypothesis 2, underscoring the significance of the size, cost, and duration of wildfires in exerting a substantial impact on cumulative abnormal returns within specific sectors of the US financial markets. This underscores the critical importance of incorporating considerations of fire characteristics and their economic ramifications when analyzing sector-specific returns in the context of natural disasters. The observed patterns resonate with prior research, as exemplified by Akkus and Kişlalioğlu (2023), which accentuated the influence of event severity on sectoral stock indices. Similarly, Kabeshita et al. (2023) and Thompson et al. (2023) elucidated the ways in which the extent of destruction and associated costs can variably affect different sectors. These insights support the hypothesis's claim that wildfire characteristics play a pivotal role in shaping sector-specific stock returns, emphasizing the need for investors to consider these factors during natural disasters.

5 Discussion

This research undertook a thorough examination to evaluate the repercussions of wildfires in the USA on the capital markets across nine distinct sectors. Utilizing a methodology involving parametric and nonparametric tests, robustness checks, and regression analysis, the study presents a nuanced depiction of the broader economic implications of these natural disasters. Significantly, the results illuminate the unique reactions exhibited by each sector concerning variables such as wildfire size, duration, and causative factors. These insights, derived from both the event study and subsequent regression analyses, collectively contribute to an understanding of the intricate dynamics shaping sector-specific responses to wildfires.

The results from the event study illuminate distinctive sectoral behaviors. In the direct impact sectors, the insurance industry experiences a decline in Cumulative Abnormal Returns (CAR) linked to increased costs from claims and payouts. The real estate sector witnesses a shorter-duration CAR decrease, likely tied to concerns about property damage and reduced values. The forestry and timber industry exhibits erratic CAR behavior, reflecting the sector's intricate relationship with wildfires. In the indirect impact sectors, the health sector initially sees a rise in CAR, followed by a decrease due to concerns about long-term impacts. The food industry, conversely, experiences a substantial and continuous CAR increase, indicative of heightened demand for food supplies. The transportation sector undergoes an initial CAR decrease followed by a consistent increase post-wildfire as transportation services recover. Within the resilience and mitigation sectors, utilities witness a CAR decrease post-wildfire, likely attributed to damages and service disruptions. The energy sector consistently experiences a CAR decrease throughout the post-wildfire period, indicating supply disruptions, safety concerns, and environmental implications. In the tourism sector, an initial gradual CAR decrease is succeeded by a sharp increase, signifying recovery as tourist destinations reopen.

Turning to the regression results, a nuanced understanding of the impact of wildfires on different sectors emerges. In the insurance industry, sensitivity to the cost of fire is evident, with larger damages resulting in substantial financial losses. Notably, mentioning the country or the event correlates with a long-term increase in returns. The real estate sector experiences a reduction in returns as the duration of fires extends, reflecting broader economic disruptions and property damage. The forestry and wood industry exhibits sensitivity to the cost of fire, with a more pronounced negative effect from fires ignited by lightning. Notably, the recall of the country consistently positively affects industry returns. Transitioning to the indirect impact sectors, the health industry is vulnerable to the number of people killed in fires, with a subsequent negative correlation with country mentions. In the food industry, the fire cost contributes to a positive effect, while the fire's duration and size contribute to a negative effect. The transportation industry undergoes a gradual decrease in returns, intensifying with the number of fire days or the cost of the fire. Utility companies within the resilience and mitigation sectors face vulnerability, with a high number of fatalities or increased fire days adversely affecting returns. Mentioning the country exhibits a strong positive effect on industry returns in the short term and brings about changes in the long term. The energy sector's response to fires is negatively affected by the size of the fire, with state mentions moderating declines. Regulatory and market challenges become evident in the negative impact of event mentions. Within the interconnected sectors, the travel and tourism industry sees an increase in returns linked to the number of victims, with events caused by people having a higher impact. Interaction with other sectors reveals nuanced influences, with negative impacts from the real estate and utilities industries in the short term, changing trends in the long term.

6 Conclusion

In conclusion, the comprehensive analysis of wildfires' impact on US capital markets across nine sectors has illuminated the nuanced responses of these sectors to varying wildfire characteristics. As discussed in the preceding section, these findings emphasize the complex interplay between environmental shocks and financial market behavior, providing insights into the specific vulnerabilities and resilience strategies exhibited by different sectors. Reflecting on these findings reveals that no single sector responds uniformly to wildfires, with each demonstrating a unique set of sensitivities and adaptive strategies. This diversity of responses underscores the necessity for tailored risk assessment and mitigation approaches when confronting natural disasters.

This research contributes to the growing body of knowledge concerning the intersection of environmental events and financial markets, offering implications for both investors and policymakers. By understanding how specific sectors are affected by wildfires, investors can make more informed decisions, and policymakers can formulate targeted strategies to support sectors vulnerable to such events. While this study has significantly advanced the understanding of wildfires' impact on capital markets, it also provides opportunities for future research. Subsequent studies may delve deeper into the intricacies of sector-specific responses and explore the potential role of policy interventions in mitigating financial losses. In summary, the analysis reveals that wildfires have distinctive repercussions for various sectors, underscoring the importance of sector-specific risk assessment and preparedness. Understanding these nuances provides valuable insights for navigating the intricate interplay between environmental events and financial markets.

7 Policy implications

The research offers vital insights for policymakers dealing with the financial implications of wildfires on various sectors. It underscores the need for tailored approaches and sector-specific risk assessment. Policymakers should prioritize informed decision-making, targeted support, environmental policies, healthcare readiness, and climate change mitigation.

7.1 Concrete guidance for policymakers

Sector-specific risk assessment: Policymakers should conduct thorough assessments of each sector's vulnerabilities to wildfires. Tailored guidelines and preparedness measures can help sectors mitigate financial losses and enhance resilience.

Targeted support: Policymakers can offer targeted financial support, regulatory frameworks, and infrastructure investments to sectors at risk. This support should align with the specific needs of each sector and foster rapid recovery.

Environmental and land use policies: Strengthening environmental and land use policies is essential to reduce wildfire risks. Policymakers can enforce regulations that promote responsible land management and controlled burn practices.

Emergency response and healthcare: Policymakers must ensure robust emergency response and healthcare systems capable of handling increased demand during wildfires. Contingency plans should address health-related challenges that may arise from these events.

Climate change mitigation: Policymakers should prioritize measures to combat climate change. Efforts to reduce greenhouse gas emissions and limit climate change effects are crucial for long-term wildfire risk reduction.

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Data Availability The data that support the findings of this study are available in figshare at https://figshare.com/s/0037d26d01e43ebbb45e.

Declarations

Conflict of interest I have carefully reviewed the journal's policies and affirm that neither the manuscript nor the study violates any of these guidelines. This research does not involve human participants or animals. It is entirely self-funded, and I hereby declare that there are no conflicts of interest to disclose.

Appendix

See Table 5.

Table 5 I–O account data weights

	Influencing sectors (indexed as s)								
	Insurance	Real estate	Forestry and timber	Health	Food	Transportation	Utilities	Energy	Tourism
Impacted sectors (indexed as k)									
Insurance		0.00128			0.00015		0.00013		
Real estate				0.00060	0.00002		0.00024		0.00691
Forestry and timber									
Health							0.00022		0.00452
Food		0.16574		0.00351					0.08078
Transportation								0.00391	
Utilities					0.00001	0.01083			0.00109
Energy					0.00004		0.00231		
Tourism		0.12087			0.00139	0.05486	0.05400		

The table presents weights representing the influence of sectors denoted as 'influencing sectors' (indexed as s) on sectors referred to as 'impacted sectors' (indexed as k). These weights are calculated using input–output (I–O) accounts data obtained from the US Bureau of Economic Analysis (BEA) government website

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