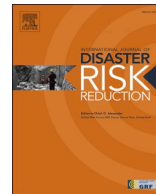




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Natural hazards compound COVID-19 impacts on small businesses disproportionately for historically underrepresented group operators

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ABSTRACT

In the wake of the COVID-19 pandemic small businesses made headlines as hard hit by customer losses, revenue declines, and business closures. Yet, the impacts have been felt disproportionately by small businesses that suffered interruption due to pre-existing socioeconomic stressors and/or concurrent natural hazards experienced during the pandemic. To illuminate those compound impacts, we conducted a survey of over 1350 U.S.-based small businesses. Our findings indicate that those businesses that experienced concurrent natural hazards during the pandemic were associated with relatively greater negative impacts. But importantly, enterprises that are historically underrepresented group operated (HUGO)—minority, women, and veteran-operated businesses—saw largely amplified negative impacts from COVID-19. In terms of the magnitude of COVID-19 impacts, the effect size of belonging to HUGO was more than twice as large as the effect size of experiencing a concurrent natural hazard during the pandemic. These results provide evidence for the disproportionate impacts that HUGOs face due to the pandemic, which are exacerbated when compounded by natural hazards. Given these results, there is evidence that the opportunity gap between HUGO and non-HUGO businesses is significant ahead of additional stressors or shocks. This opportunity gap is further accelerated when compounded with other events, here the compounding of natural hazards and COVID-19. Additional interventions need to be offered to HUGO businesses in areas with high likelihood of overlapping incidents. Further work is required to address social inequity and economic fragility of HUGO businesses, especially those that face the complexity of additional shocks, such as natural hazards.

1. Introduction

Vulnerability arises from physical, social, economic, or environmental factors, which increase susceptibility of community

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members and their assets to the impacts of public health and natural hazard events [1]. Likewise, vulnerability is recognized as a potential contributor to small business failures or a barrier to their recovery from disasters [2,3]. Such vulnerabilities may result from the socioeconomic characteristics of small business operators and/or from the community-level characteristics associated with where they operate and their access to resources. Importantly, however, the extent to which such stressors amplify business disruptions remains unclear, especially when combined with multiple disruptions, such as natural or human-made disasters. The concurrence of these interrupting acute shocks and chronic stressors creates complexity and may nonlinearly magnify the impacts on small- and medium-sized businesses (SMBs), creating what is referred to as a complex event [4] and encompass systemic risks, the impacts of which are interdependent and transboundary, opposed to conventional risks [5,6].

Pre-pandemic, there were 30.7 million small businesses in the U.S., which accounted for 99.9% of all U.S. business [7]; of these, approximately 18.3% were minority-owned and about 19.9% were owned by women for reference year 2018 [8]. From the start of the COVID-19 pandemic, the number of active SMBs plummeted, with minority and female-owned businesses disproportionately impacted [9]. Despite their significance to the U.S. economy, there is little information on how SMB operators and their firms plan for, respond to, or learn from pandemics with few exceptions [10,11]. Yet, research focused upon resilience of SMBs does not frequently account for compounding impacts, such as the confluence of acute, chronic, and structural socioeconomic challenges. In 2020 alone, there were 22 natural hazards on top of COVID-19, each with losses exceeding \$1 billion in the U.S [5]. Notably, there has been little attention paid to the ways that socioeconomic stressors and natural hazards compound, especially for small businesses. And there has been much less that looks at the confluence of these compound risks and the additional impacts of pandemic conditions. It is critical that these types of complex event impacts be considered in understanding the context for risk management challenges to small businesses and more broadly to the systemic risks [5,6].

To understand these complex event impacts on small businesses we conducted a national survey in the summer 2020 to address the intersection of socioeconomic vulnerabilities, natural hazards, and pandemic impacts on SMBs. In our study, SMBs include those with fewer than 500 employees at a single location. The following groups are included in the historically underrepresented group operator (HUGO) category for our survey: women, racial/ethnic minorities, and veterans. Our operator classification captures business owners and managers of SMBs.

Our study and analysis are framed to determine the differential impacts of belonging to the HUGO SMB category in the context of complex events involving human and environmental hazards, and explicitly through analysis of COVID-19 impacts in the face of natural hazards.

2. Background and context

Pre-COVID-19, SMBs¹ made up 44% of U.S. economic activities. SMBs are often recognized as the lifeline for local economies throughout the U.S., having employed 59 million people in 2018 [7]. In the wake of the COVID-19 pandemic, SMBs have been greatly impacted through supply- and demand-side difficulties, such as limiting customer interactions, employee availability, as well as larger supply chain issues [12].

SMBs benefit their local communities by providing local jobs, increasing the tax base, fostering community involvement, and providing diverse, locally sourced/made products and services. They are invested in their communities and improve local median household income, reduce poverty, and decrease income inequality [13,14]. However, the COVID-19 pandemic has shone a spotlight on the social and economic importance of SMBs and their impact on communities across the U.S. [15], from large cities to more remote areas. It has also highlighted the precariousness of operating an SMB [16]. There was a documented U.S. economy-wide excess establishment exit of about 200,000 firms during the first year of the pandemic, implying an exit rate about one-quarter to one-third above normal [17]. In particular, minority and women-owned small businesses continue to struggle even as the U.S. economy shows signs of recovery [18].

2.1. Complex events

Researchers and practitioners have long advocated for multi-hazard planning solutions and the value of anticipatory adaptation [19–22]. Studying SMBs in areas prone to natural hazards offers a chance to understand whether planning for one type of hazard may influence preparedness for a significantly different hazard: in this case, COVID-19. It also provides an opportunity to understand how impacts of one event compound with those of additional events and pre-existing structural challenges (e.g., socioeconomic vulnerabilities) to create different challenges and potential opportunities for resilience and recovery.

Chronic events are recurring and often can be expected; they may include events such as seasonal flooding and the influenza season, as well as persistent socioeconomic challenges such as social inequality and economic fragilities experienced by disadvantaged communities. Such chronic challenges are also referred to as stressors. Acute events, however, are associated with less predictable hazard events that occur less frequently. In some literature acute events are referred to as shocks [23,24]. COVID-19 is a unique covariate event due to its impact on the entire U.S. and the global business landscape; however, impacts and the experience of the pandemic vary significantly across regions and individual SMBs, e.g., due to inherent adaptive capacities, socioeconomic vulnerabilities, localized infection rates, and the local experience with other stressors or shocks. These characteristics account for “systemic

¹ Here we take an SMB to be a business with fewer than 500 employees at a given location. A full table matching a size standard with each NAICS Industry or U.S. Industry code is also published annually by SBA in the Federal Register., [65 FR 30840, May 15, 2000, as amended at 67 FR 52602, Aug. 13, 2002; 74 FR 46313, Sept. 9, 2009].

risks" [5] to SMBs that have received proportionately little attention in public discourse ahead of the COVID-19 pandemic.

Even though research focused upon SMB resilience to natural disasters tends to be established in the literature and offers relevant insights as to the SMB operators' response to and recovery from such events [3,25], there is a considerable gap in understanding the ways socioeconomic stressors, natural hazards, and the pandemic compound and how improvements to governance and supporting capacity building may best be designed. The concurrence of these interrupting acute shocks and chronic stressors creates a complex event [3] and may amplify the impacts on SMBs and their employees, customers, and wider communities in ways that warrant additional investigation.

2.2. Disproportionate structural challenges to HUGO SMBs

Structural challenges face HUGOs in the marketplace, even at times of relative calm. There are significant funding and opportunity gaps that explicitly impacts businesses owned by women and racial or cultural minorities in the U.S. HUGO businesses do not raise as much capital as their counterparts even when controlling for firm characteristics, such as number of employees [26,27]. There are at least three major access challenges to HUGO businesses: (1) access to capital, (2) access to skill development, and (3) access to formal business networks [28].

HUGO businesses tend to have lower employee numbers; however, their average revenue lags significantly and is particularly lower for African American-owned businesses [26], as an example of HUGO businesses. Marshall et al. [29] found that female, non-white owned firms, excluding Asian-owned firms, tended to lag behind male, Caucasian-owned firms in terms of employment growth and survival. Additionally, Jarmin et al. [30] found that the Great Recession, as a major economic disruption to small businesses, disadvantaged minority business owners disproportionately; to the extent that minority business owners depended on home asset values as collateral for business loans, the crisis put those businesses at risk. Aligned with previous disaster experiences, minority and female business owners were clearly disproportionately impacted due to small financial buffers and limited access to various financial sources [31,32].

There are several covariate factors that make isolating effects of belonging to the HUGO group on SMB impact, response, and recovery difficult to assess directly. HUGOs have long faced socioeconomic and cultural barriers to business formation, which remain difficult to fully quantify [33] outside of times of additional stress (e.g., a pandemic). For example, there tends to be greater prevalence of sole ownership, non-employee firms, and higher rates of home-based operations for black-owned businesses compared to white-owned businesses [34]. The sources of funding for minority-owned entrepreneurial businesses tend to be largely on personal and family savings compared to white-owned businesses and additionally profits of minority-owned businesses are disproportionately impacted by access and cost of capital [35]. The 2020 National Survey of Military-Affiliated Entrepreneurs [36] found that in addition to denial to credit, key challenges to veteran-operated businesses relate to social capital barriers, such as difficulty with the transition from military to civilian life via loss of connection with the military community and loss of sense of purpose/camaraderie combined with trouble finding local business support/advice. Additionally, interruptions that are unique to certain operator types are relevant. There is also spatial and temporal diversity and geographical variation of the impact on SMBs, which is partially due to the differences in underlying vulnerabilities, mitigation policies, and mandates [37]. Furthermore, serving as employers and local stakeholders, SMB operators are critical to household and community resilience in the face of complex events [38–40]. Understanding impacts to small business operators may provide insights into overall community resilience to complex disasters.

2.3. SMB natural hazard interruption and recovery

Previous research on business interruption arising from natural hazards provides insight as to the importance of focusing on certain measures of interruptions and recovery when considering complex event experiences.

2.3.1. Measuring interruption and recovery

Research on business recovery after a natural hazard disturbance in the U.S. and at the individual firm level tends to focus on long-term recovery [29]. A few studies focus on short-term business outcomes [41–43], identifying the need for longitudinal, comprehensive studies of business recovery, which are becoming more typical [38].

In many studies that assess SMB impact, response, and recovery, objective indicators of organizational success are used, including gross revenue, growth in sales, profitability, and employee retention [12]. Yet, Danes et al. [44] find evidence that SMB success is not unidimensional, but rather composed of objective and subjective indicators. SMBs must meet operator expectations in addition to economic criteria and provide insights as to the operator's commitment to the firm, which is particularly important to smaller firms [44,45]. Considering such dynamics in cases of complex events that may not have quantifiable objective risk, but clearly expose existing social and physical vulnerabilities is important [46]. Thus, the use of self-reported perceived impact data as a subjective indicator of COVID-19 impact is reasonable, especially in the early stages of the pandemic.

2.3.2. Control variables in SMBs hazard recovery

SMB financial interruptions and recovery from natural hazards varies widely based on sector and physical location; however, results are not consistent across the literature [47]. Alesch et al. [48] find that the level of criticality of the main product offered by a firm is a factor in recovery; thus, supplies for immediate consumption, such as food and medications, are purchases that cannot be delayed by those in need. The designation of "essential businesses" during the COVID-19 pandemic is a conspicuous example of such effect.

In addition, preparation actions against business interruptions define a wide space of inquiry and option sets are difficult to bound when considering different business characteristics (e.g., sector, size, ownership structure) and potential interruption mechanisms.

Some studies have found short-term disaster preparation to not be a significant predictor of business survival and recovery trajectories [29,49]. Not surprisingly, the type and extent of disaster preparation tends to be a function of business size; larger firms frequently have dedicated disaster and continuity planning staff [50]. It should also be noted that there is wide variation across natural hazard types and associated intensity experienced.

Of all the potential covariates explored related to SMB resilience in past research, the liability of smallness and newness are often highlighted as consistently associated with limited disaster preparedness and business resilience. Smaller businesses (i.e., employee number) are less likely to survive and recover than their larger counterparts due to limited human and financial capital [51,52], less diversified products and services, and a high potential that their customers are the victims of the same disaster [53]. Dahlhamer and Tierney [41] found there to be a “liability of newness” in their analysis of businesses after the Northridge earthquake. Newer firms tend to react with greater sensitivity to changes in the economic environment [54]. Furthermore, firm survival has been linked to operators’ human capital via educational level, managerial skills/experience, and identifying as male [55].

In addition, experience with previous disasters/business interruptions have been shown to be a benefit to business recovery for some business types [29,50]. Yet, previous work on multi-hazard planning, generally, and for SMBs focused on the existence of a plan, opposed to the result of planning when a disruptive event occurs. This focus has led to limited understanding of how hazard planning and experience may influence a new hazard experience, either of the same or a different hazard type. Thus, there is an opportunity to study complex hazard impacts of natural hazards during a pandemic, which interacts with existing socioeconomic vulnerabilities.

3. Materials and methods

The design of our study and accompanying analyses were focused upon disentangling components of the complex impacts observed from the confluence of pre-existing social vulnerabilities, past natural hazard experience, and current COVID-19-related impacts.

3.1. Survey design

This study is based on a national U.S. data collection targeting SMB operators; we conducted this survey online from June to August, 2020.² The study protocol was approved by the National Institute of Standards and Technology (NIST) Institutional Review Board. Informed consent was obtained from all participants. This survey asked SMB operators about how COVID-19 impacted their SMB, and how the SMB adapted to these impacts; about the operator’s business experience with natural disasters prior to and during COVID-19; and the level of preparation (i.e., mitigation planning) the operators had taken against interruption before March 2020. In addition, the survey collected demographic information about the SMB operator and background information about the SMB (e.g., year founded and sector). Respondents were asked to indicate if they would like to be contacted in the future and if they would like to be sent a report on survey findings. Invitations to complete the online survey reached SMB operators through direct emails, at the invitation of partner networks, and through social media posts. Both English and Spanish-language versions of the survey were available. The survey collected both quantitative and qualitative data from respondents across five sections:

- (1) Introduction,
- (2) COVID-19 Impact and Adaptation Practices,
- (3) Natural Hazard Experience,
- (4) Attitudes, including future plans in the context of COVID-19 response, as well as short-, medium-, and longer-term concerns that may combine with COVID-19 impacts to create a complex event, and
- (5) Business information and demographics.

For additional details on survey development and to view the full instrument, please refer to Helgeson et al. [4].

3.2. Sampling

Our sample of SMBs was selected based on the following criteria: (1) 500 employees or fewer at a single site; (2) Located in counties with natural disaster experience since 1960. Counties prone to natural hazards were identified using the SHELDDUS™ database, which lists counties for each state that suffered losses due to thunderstorms, hurricanes, floods, wildfires, and tornados from 1960 to the present. All counties that experienced a natural disaster at least once since 1960 were selected. As is the case with covariate disasters, though a county is prone to a natural disaster, the relative impact at a given SMB location may differ from business to business. Within each county, SMBs were sampled at random to ensure heterogeneity in potential disaster experience. The survey was also disseminated through partner networks. At the federal level, NOAA’s Weather Ready Nation, Sea Grant, and the Regional Integrated Science and Assessment (RISA) Network, as well as the Minority Business Development Agency (MBDA), each distributed the survey to their stakeholders across the country. In addition, the National Chamber of Commerce Foundation, the NYC Department of Small Business Services, and various local Chambers of Commerce publicized the survey to their stakeholders online.

The main purpose of the current study is to use the survey data to describe the relationship between COVID-19 impacts (i.e., dependent variable) and social and environmental vulnerabilities, such as belonging to the HUGO group and experiencing natural hazards during the pandemic (i.e., independent variables). Our work does not aim to use predictive inference methods to describe the specific finite population of this study. We, therefore, do not focus on minimizing coverage error (e.g., by sample weighting) to ensure representation and accuracy. Instead, we intentionally focus on measuring the covariates that can potentially play a significant role in

² The timing of the survey may have caused an undercount in those impacted. By June 2020 many of the most vulnerable firms may have already failed [56].

explaining the relationships of interest, rather than making statements about the specific finite population (e.g., the entire SMB population). (See Ref. [57] for an extensive discussion about the difference between estimation procedures with nonprobability samples). We are not interested in precise measurement of impacts from COVID-19 in the population of interest. Consequently, we do not use pseudo design-based methods to treat our non-probability sample as a probability one and substitute a weight in place of a known probability of being in the sample [57]. Instead, we use model-based estimation, which relies on a statistical model that describes the variable being estimated in the survey and treats the outcomes rather than the sampling process as being the random variables while controlling for a set of covariates.

3.3. Statistical analyses

Our analysis was conducted using IBM SPSS Statistics 27. The dependent variable in our statistical models is COVID-19 overall impact on SMBs. To measure COVID-19 overall impact on SMBs, we adapted the items developed and used by the U.S. Census Bureau Small Business Pulse Survey (SBPS) [12], which measure the effect of changing business conditions during the COVID-19 pandemic on nation's small businesses by focusing on changes in revenues, business closings, employment and hours worked, and disruptions to supply chains. Accordingly, we used six survey items to gauge COVID-19 associated impacts:

1. Closure due to external mandates
2. Closure due to financial hardships
3. Decrease in business expected revenue
4. Declines in number of costumers and consumer demands
5. Problems with supply chain such as receiving essential supplies and inventories
6. Issues with delivery of products or services to customers

For each of these survey items, respondents were asked to self-report the magnitude of impact using an ordinal scale corresponding to the duration of time businesses experienced the impact: 0 = No effect, 1 = Minor effect (corresponding to one week or less), 2 = Moderate effect (corresponding to one to four weeks), and 3 = Large effect (corresponding to more than four weeks). Principal Component Analysis (PCA) was used to test the dimensionality of these six items. We explored whether all items could statistically significantly load on a single component; thus, the measure could be assumed to be unidimensional. We also tested the scale reliability using Cronbach's alpha, which is a coefficient of internal consistency, showing how closely related this set of six items are as a group. For fairly high correlations between items, alpha can reach values around 0.7 [58]. The result of the PCA confirmed our assumption about the unidimensionality of six items that concerned COVID-19 associated impacts on SMBs (see Results). We therefore measured the overall COVID-19 impact on SMBs by aggregating the responses to these six self-reported items as follows:

$$\omega_m = \frac{1}{6} \sum_{i=1}^6 \frac{W_i}{3} \quad (1)$$

where ω_m is a number between 0 and 1 representing the overall COVID-19 impact on SMB, and W_i is the operator's self-reported impact for item i , which can take a value between 0 and 3 as described above.

We then explored the changes in the overall impact given two fixed factors: (1) whether the business experienced a natural hazard during COVID-19 (i.e., factor z); and (2) whether the business belongs to the class of HUGO businesses (factor x); as well as the interaction of these two factors (i.e., $x \times z$). These two factors allowed us to define four groups (2×2) and compare the means of COVID-19 impacts across these groups. To do so, we built a general linear model (GLM) that used an ordinary least squares (OLS) regression to estimate the adjusted means of COVID-19 overall impact on businesses given factors x and z , while controlling for the effect of covariates:

$$\omega = \beta_0 + \beta_1 x + \beta_2 z + \beta_3 (x \times z) + \beta_4 V + \varepsilon \quad (2)$$

where ω is the adjusted overall impact, factor x is the operator's characteristic dummy variable ($x = 1$ if the SMB belongs to HUGO category, and $x = 0$ otherwise); factor z is another dummy variable that indicates natural hazard concurrence with COVID-19 ($z = 1$ if the SMB experienced at least one natural hazard during the pandemic, and $z = 0$ otherwise), and V is the vector of covariates including business sector, location, and frequency of natural hazards experienced in the past ten years.

Participants self-identified their business sector, selecting one of 16 categories (see Fig. S1 in Supplementary Information for the list of business sectors). These categories represent codes within the North American Industry Classification System (NAICS). Additionally, participants were able to select the "other" option and provide a description. We re-coded these open-ended responses for sector to either "other" or one of the relevant NAICS categories. Business locations were sorted by Federal Emergency Management Agency (FEMA) classification, which consists of ten regions in the continental United States and territories [59]. Finally, past experiences with natural hazards were measured by the number of natural hazard events that affected the organization in the past ten years (affected = caused at least a one-day closure).

There are three null hypotheses to be tested in our analysis:

1. H_0 : The COVID-19 impact on HUGO and non-HUGO businesses are not different.
2. H_0 : The COVID-19 impact on businesses that experienced and did not experience natural hazards during the pandemic are not different.

3. H_0 : The COVID-19 impact on HUGO businesses that experienced natural hazards during the pandemic and HUGO businesses that did not experience natural hazards during the pandemic are not different.

We used F-tests to reject the above null hypotheses and compare the means of COVID-19 impact across groups defined by factors x and z . These tests are based on the pairwise comparisons of adjusted means of COVID-19 impact (ω) that are estimated using Eq. (2), while controlling for the effects of covariates. This method is called two-way factorial analysis of covariance (ANCOVA). We also used Šidák adjustment for multiple comparisons [60] to control the familywise error rate of $\alpha = 0.05$, and therefore each null hypothesis is rejected that has a p -value lower than α_{SID} :

$$\alpha_{SID} = 1 - (1 - \alpha)^{\frac{1}{m}} \quad (3)$$

Where α_{SID} is Šidák-adjusted level and m is the number of different null hypotheses.

To further illuminate the socioeconomic vulnerabilities of HUGO businesses, we used our dataset to compare HUGO and non-HUGO businesses in terms of business size (i.e., self-reported number of employees) and age (i.e., self-reported years in business). As highlighted by past research, the liabilities of both smallness and newness can be critical drivers of disaster associated impacts on businesses [61]. We also compared HUGO and non-HUGO SMBs regarding their designation as *essential*, which is based on an ordinal scale (i.e., 1 = non-essential, 2 = some segments essential, and 3 = essential). Respondents self-reported as providing essential services in their jurisdiction during the pandemic, which might influence the effect of local guidance on businesses during COVID-19 (e.g., government mandated closures).

Additionally, we compared HUGO and non-HUGO SMBs in terms of their mitigation planning and disaster preparedness ahead of COVID-19. We asked about mitigation planning³ ahead of COVID-19 across 22 items. We conducted a factor analysis on these 22 items using a Principal Component Analysis (PCA) method with orthogonal rotation (varimax). The Kaiser–Meyer–Olkin measure verified the sampling adequacy for the analysis [62]. Three components had eigenvalues over Kaiser’s criterion and in combination explained about 40% of the variance. (See Supplementary Information, Table S1 for the factor loadings after rotation). Subsequently, disaster mitigation items were collapsed into three dummy variables (i.e., generated latent variables using the arithmetic mean of values of grouped items) representing: emergency management planning (*EM.Plan.Mitigation*), domain general mitigation activities that are applicable across hazard types (*Domain.G.Mitigation*), and specific physical mitigation actions most relevant to natural hazards (*Physical.Mitigation*). The scale reliability of items that clustered on the same components were measured using Cronbach’s alpha [58].

Finally, we repeated our ANCOVA analyses with an extended vector of covariates (i.e., business size, business age, essential designation, and levels of preparedness regarding the three types of mitigation planning) in addition to the prior vector of covariates (i.e., business sector, location, and frequency of natural hazards experienced in the past ten years). These new tests are based on pairwise comparisons of adjusted means of COVID-19 impact (ω) on businesses that are estimated using the following model:

$$\omega = \beta_0 + \beta_1 x + \beta_2 z + \beta_3 (x \times z) + \beta_4 V + \beta_5 V^* + \varepsilon \quad (4)$$

where V^* is the vector of additional covariates that includes a set of variables that are commonly used to determine the socioeconomic vulnerabilities of small businesses, as noted in Section 2.3.

Apart from the items concerning the impacts, we asked participants about their perceptions and expectations of current and future risks associated with COVID-19 pandemic across three items:

1. COVID-19 impacted my business in a significant manner.
2. COVID-19 posed the greatest risk yet to my organization’s survival.
3. The impacts of COVID-19 will leave my organization unable to cope with a natural disaster, should one occur, in the next year.

Responses to each of these items were collected using a 5-point Likert scale in which responders specified their level of agreement to the statement: (1) Strongly disagree; (2) Disagree; (3) Neither agree nor disagree; (4) Agree; and (5) Strongly agree. We then performed chi-square tests to determine whether there was a statistically significant difference between HUGOs and non-HUGOs in responding to these items by selecting a scale of agreement between 1 and 5. In addition, we gauged participants’ expectations of recovery times for their business defined as the time that needs to pass before the business could return to its pre-COVID conditions. Participants responded to this question were compared across HUGOs and non-HUGOs using independent samples t -test.

4. Results

4.1. Unidimensionality of COVID-19 impact on SMBs

The result of the PCA confirmed our assumption about the unidimensionality of six items that concerned COVID-19 associated impacts on SMBs. The Kaiser–Meyer–Olkin measure of sampling adequacy was 0.65, above the commonly recommended value of 0.6. Three components had eigenvalues over one. Solutions for one, two, and three factors were each examined using varimax rotation of the factor loading matrix. Even though three components had eigenvalues >1 , the one factor solution (i.e., unidimensionality assumption), which explained close to 40% of the variance, was preferred because of (a) its previous application and practical support

³ SMB operators were asked about mitigation behaviors in a general manner with special focus on natural hazard-relevant actions; some answer options were highly relevant to mitigation of COVID-19 associated impacts.

(e.g., the SBPS survey [12] used a unidimensional overall impact indicator); (b) the leveling off of eigenvalues on the scree-plot after first factor; (c) the observation that values of the standardized loading on the first factor were greater than the generally acceptable value of 0.3 [62] for all items, confirming that all the items could strongly be relevant for one factor; and (d) finally the ease of interpreting the use of only one factor, compared to three factors, representing the overall COVID-19 impact on SMBs.

4.2. Subgroup descriptions

As shown in Fig. 1 A, of 1374 total respondents, businesses that experienced a natural hazard during COVID-19 comprised 22% of the entire sample, while 52% reported no experience with natural hazards during COVID-19, and 26% did not respond to this question. In each of these subgroups, about one-third of respondents self-identified their business as HUGO (Fig. 1 B). A Chi-square test of independence showed that there was no significant association between belonging to HUGO (i.e., factor x) and experiencing natural hazards during COVID-19 (i.e., factor z), $X^2(1, N = 798) = 1.368, p = 0.242$. This confirms our assumption that factors z and x are independent.

4.3. Impact of covariates: sector, location, and past natural hazard experiences

A Chi-Square test of independence was used to determine if there is a significant relationship between business sector and belonging to HUGO. The result of this chi-square test revealed that these two variables are dependent: $X^2(18, N = 848) = 30.57, p = 0.032$. This means that, in our sample, respondents from at least one sector have significantly higher or lower proportion of HUGO businesses. See Fig. S1 in Supplementary Information for the frequency of respondents in each sector grouped by operator characteristic (HUGO? Yes/No).

A second Chi-Square test of independence was used to determine if there is a significant relationship between business location (as determined by FEMA regions) and belonging to HUGO. The result of this test of independence, too, revealed that these two variables are dependent: $X^2(9, N = 843) = 34.31, p < 0.001$. This means that, in our sample, respondents from at least one region have significantly higher or lower proportion of HUGO businesses. See Fig. S2 in Supplementary Information for the frequency of respondents in each region grouped by operator characteristic (HUGO? Yes/No).

Additionally, our results demonstrated no significant difference in the businesses' past experiences with natural hazards across HUGO and non-HUGO businesses; however, those businesses that experienced a natural hazard concurrent with COVID-19 also had significantly higher frequency of natural hazard events that affected the organization in the past ten years ($M = 32.84, SD = 29.12$), as compared to businesses that did not experienced a natural hazard concurrent with COVID-19 ($M = 22.17, SD = 22.76$): $t = 5.67, p < 0.001$.

Also, it is not unlikely to see business sector, location, and the experience with natural hazards in the past are related to our dependent variable, which is the overall impacts on businesses. Variations in operators' prior disaster management experiences, levels of preparation in place and planning ahead of time, geographic variations in disaster severity, prior damages to infrastructure due to past events, and heterogeneity in supply-chain vulnerabilities across different sectors are examples of how business sector, location, and the prior experience with natural hazards can lead to heterogeneous impacts on SMBs. Therefore, when estimating the impacts on businesses from COVID-19 conditional on HUGO status (i.e., factor x) and the concurrence of natural hazards with the pandemic (i.e., factor z), we controlled for these variables as potential confounders.

4.4. Two-way factorial comparisons of COVID-19 impact

Fig. 2A shows the adjusted means of COVID-19 impact on SMBs (ω). These adjusted means (i.e., means that are adjusted to control for covariates) were estimated using Eq. (2) and were tabulated via a 2×2 factorial format. Comparing ω across HUGO and non-HUGO

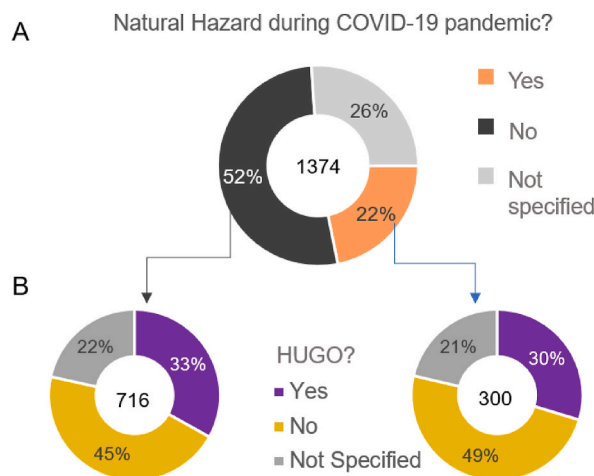


Fig. 1. Distribution of business operators participated in the study grouped primarily by the concurrence of a natural hazard with COVID-19 (A), and secondarily by the operator's belonging to HUGOs (B).

businesses revealed a statistically significant difference between the two groups (i.e., $\tau_x > 0$). This indicates that belonging to the HUGO business category, on average, is associated with significantly higher COVID-19 impact. Similarly, comparing ω across businesses that experienced natural hazards during the pandemic and those that did not revealed a statistically significant difference between the two groups (i.e., $\tau_z > 0$). This indicates that experiencing a natural hazard during COVID-19, on average, is associated with significantly higher impact on businesses.

Importantly, however, the effect size of factor x is more than twice as large as that of factor z (see Table 1). This result indicates that, in our sample, belonging to HUGO business category is associated with greater COVID-19 impacts on SMBs, as compared to experiencing a concurrent natural hazard during the pandemic. Also, the interaction chart shown in Fig. 2B demonstrates a positive interaction effect, which suggests that experiencing natural hazards during COVID-19 disproportionately amplified the impact magnitude for HUGO businesses, compared to those experienced by non-HUGO businesses. However, this synergistic interaction effect is not statistically significant at the 0.05 level.

4.5. Adjusting for socioeconomic vulnerabilities

Some of our results may explain why HUGO SMBs experience higher socioeconomic vulnerabilities and have been disproportionately impacted by COVID-19. As shown in Fig. 3, HUGO businesses in our sample are statistically significantly smaller (i.e., lower self-reported employee numbers) and newer than their non-HUGO counterparts. Also, it is less likely for sampled HUGO SMBs to be designated as a business providing essential services during the pandemic, which may amplify impacts of local guidance during COVID-19, such as government mandated closures. In addition, reports of mitigation planning preceding COVID-19, which were determined through factor analysis and classified into (i) general mitigation activities (ii) emergency management planning, and (iii) specific physical mitigation actions, indicated statistically significantly lower levels of disaster preparedness for HUGO businesses compared to non-HUGO businesses. Correlation analyses revealed that almost all COVID-19 impact items are negatively associated with business size; business age; essentiality of services the business provided during the pandemic; and mitigation planning and actions the business implemented ahead of COVID-19. See Table S2 in Supplementary Information for results of correlation analyses. Therefore, smallness, newness, non-essentiality of services, and low levels of disaster preparedness may explain why belonging to HUGO is associated with higher COVID-19 impacts on SMBs.

However, comparing the adjusted means of COVID-19 impact on SMBs (ω) using Eq. (4) revealed that belonging to the HUGO business category is still associated with a significant increase in the overall COVID-19 impact even when HUGO businesses' smallness, newness, non-essentiality of services, and low levels of disaster preparedness (i.e., lack of mitigation planning) are accounted for as additional covariates in the model (Table 2). These variables are thought to be relevant proxies for socioeconomic vulnerabilities of HUGO SMBs, as noted in Section 2. Yet, our results indicate that these proxies are not comprehensive enough to capture key unobservable hurdles and undiscovered socioeconomic impediments associated with HUGOs that amplify COVID-19 impacts on their businesses, such as structural and financial obstacles to planning pre-pandemic.

4.6. Risk perceptions and recovery expectations

As shown in Fig. 4, comparing participants' perceptions and expectations of current and future risks associated with the COVID-19 pandemic revealed that, for all three items asked, the proportion of HUGOs who indicated *Strong Agreement* with the statement were statistically significantly larger than the proportion of non-HUGOs who did so. Also, for all three items, the proportion of HUGOs who indicated *Disagreement* with the statement were statistically significantly smaller than the proportion of non-HUGO business who did so. Importantly, for the third statement "The impacts of COVID-19 will leave my organization unable to cope with a natural disaster, should one occur, in the next year," the proportion of non-HUGOs who indicated strong disagreement with the statement were statistically significantly larger than the proportion of HUGOs who did so (Fig. 4).

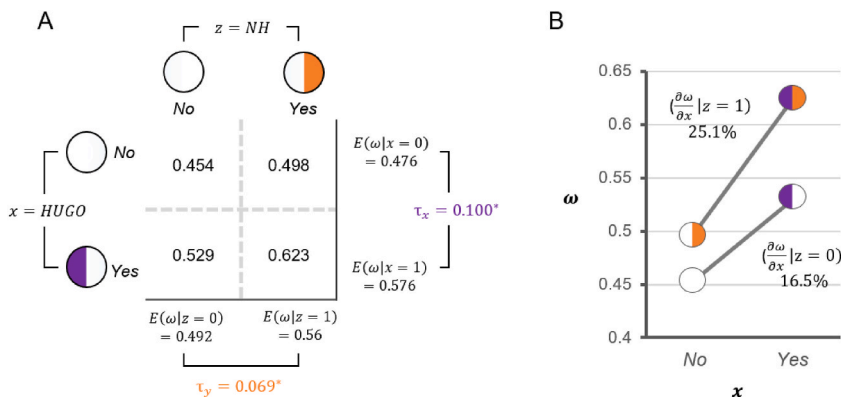


Fig. 2. Estimated adjusted means of COVID-19 impact (ω), while business location, sector, and frequency of natural hazard events experienced in the past ten years are controlled for in the models. (A) 2×2 factorial table of ω , where each factor takes two levels depending on whether the business experienced natural hazard concurrent with COVID-19 (z), and whether the operator belonged to HUGO category (x). (B) The interaction effect of two factors on impact magnitude. * denotes difference is significant at the 0.05 level with Šidák adjustment for multiple comparisons. N of Valid Cases = 798.

Table 1

Results of univariate F tests using a two-way factorial ANCOVA with covariates being business sector, location, and natural hazard experience in the past 10-yrs.

Univariate Tests							
Dependent Variable: Overall COVID-19 Impact (ω)							
	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
Factor (X)	1.266	1	1.266	21.618	0.000	0.034	0.996
Factor (Z)	0.587	1	0.587	10.031	0.002	0.016	0.885
Interaction (X × Z)	0.076	1	0.076	1.305	0.254	0.002	0.207

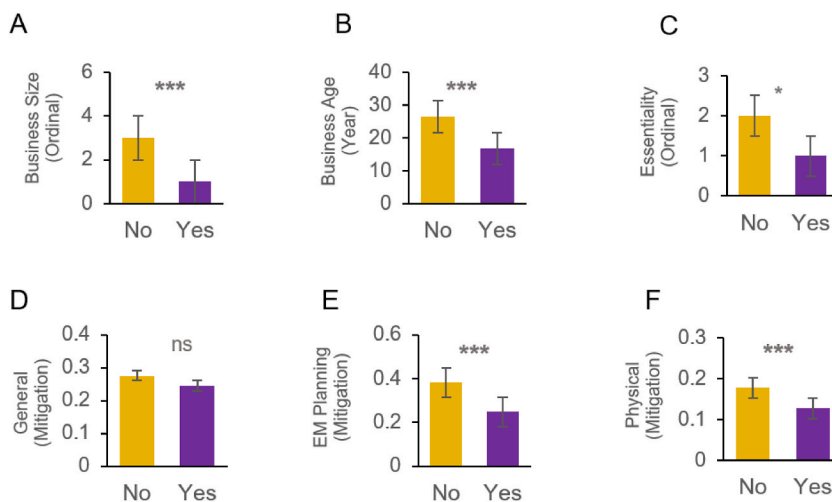


Fig. 3. Comparisons of businesses' characteristics across HUGO and non-HUGO businesses. (A) Business size (i.e., employee number reported as ranges on an ordinal scale), (B) business age (i.e., years in business), and (C) essential designation (i.e., ordinal scale including essential, some segments essential, and non-essential). (D-F) Types of hazard mitigation employed pre-COVID-19. In A and C, bar charts indicate the median values and Independent-Samples Median Tests and Mann-Whitney U Tests were used to determine the significance of differences. In B and D-F, bar charts indicate the mean values and Independent-Samples t Tests were used to determine the significance of differences. * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; and ns denotes the mean difference is not significant. See Supplementary Information, Table S3 for test results. N of Valid Cases = 853.

Table 2

Results of univariate F tests using a two-way factorial ANCOVA with covariates being business sector, location, and natural hazard experience in the past 10-yrs, as well as business size, age, essentiality of service and disaster preparedness (i.e., mitigation planning).

Univariate Tests							
Dependent Variable: Overall COVID-19 Impact (ω)							
	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
Factor (X)	0.388	1	0.388	7.541	0.006	0.014	0.783
Factor (Z)	0.365	1	0.365	7.096	0.008	0.013	0.758
Interaction (X × Z)	0.032	1	0.032	.626	0.429	0.001	0.124

Finally, the independent samples t -test revealed that HUGO businesses' expectations of the recovery time needed to pass before their business returns to its pre-COVID conditions, was statistically significantly longer than that of non-HUGO businesses, $t(737) = 2.267, p = 0.024$.

5. Discussion

Our results agree with previous reports that HUGO SMBs are affected disproportionately by COVID-19; for example, there are indications that HUGOs are more concerned about permanent business closure and also have relatively less access to resources, such as loans [61]. In addition, prior research suggests higher vulnerability of HUGOs to natural hazards [29]. However, such reports are often based on few observations and localized assessments; furthermore, they do not consider the concurrence of interruptions that may have compounded the total impacts on businesses from such complex events. Our work is the first to empirically address the complexity of impacts from natural hazards during a pandemic that are further amplified by the socioeconomic vulnerability of HUGO SMBs. Importantly, this work provides evidence that HUGOs are associated with greater impacts during COVID-19 than counterpart businesses, notably when experiencing a natural hazard during COVID-19. Several respondents alluded to vulnerabilities in this manner. For example, an open-ended response from our survey indicates that "I am already a minority because I am a female who owns

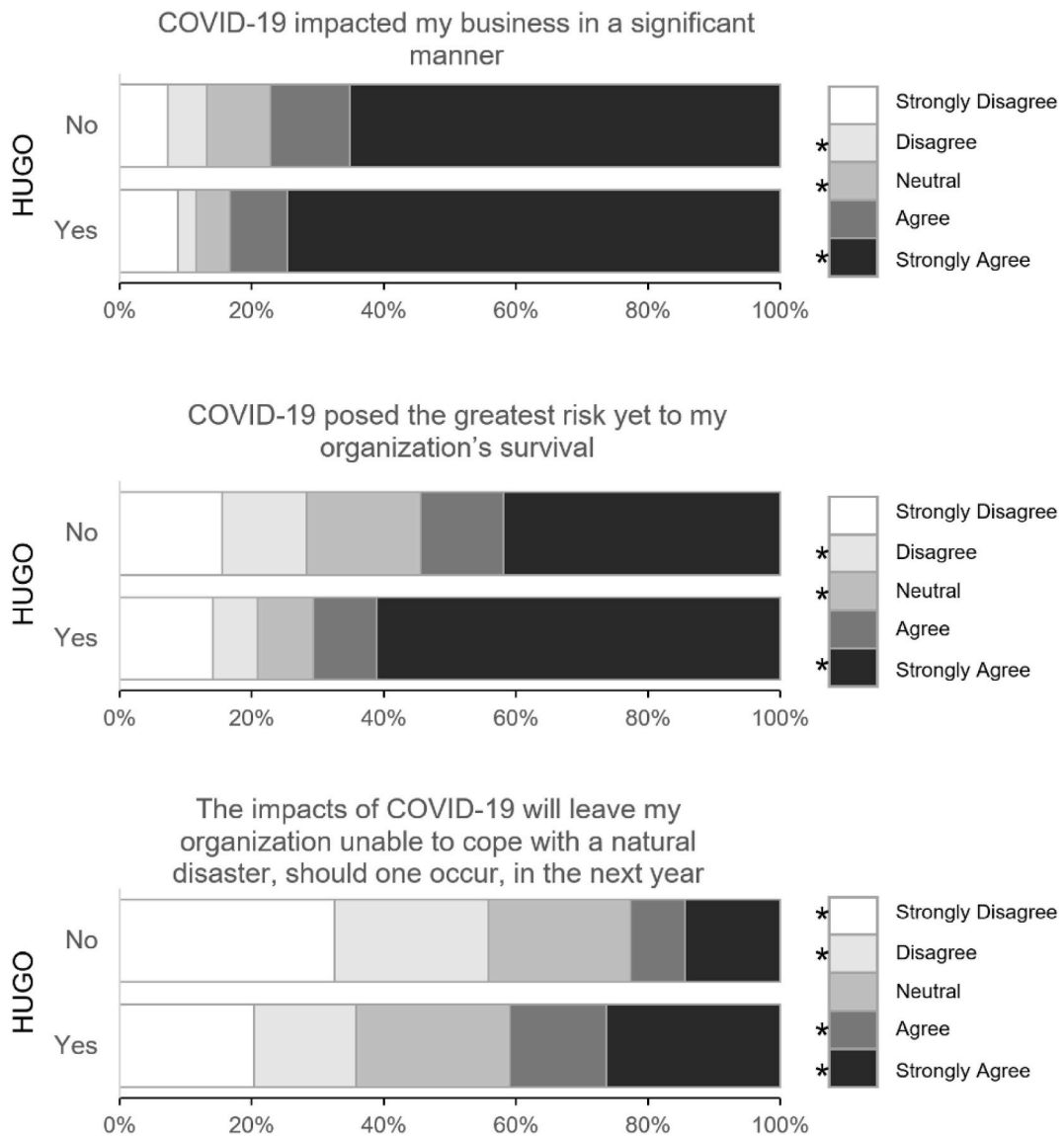


Fig. 4. Operators' perception of COVID-10 impacts on their businesses and expectations of future risks. The Chi-square tests of independence indicate that there is a significant difference in responding to these items across HUGO and non-HUGO businesses: Top panel $\chi^2(4, N = 846) = 14.714, p = 0.005$; middle panel $\chi^2(4, N = 836) = 35.509, p < 0.001$; and bottom panel $\chi^2(4, N = 806) = 38.255, p < 0.001$. Post hoc tests further revealed the differences. Asterisks denote statistically significantly different proportions across HUGO and non-HUGO business in selecting a particular response (i.e., strongly disagree, disagree, neutral, agree, and strongly agree).

a [male dominated sector business] and I have struggled to get ahead; now it is [even more] difficult to do [because of COVID-19].”

Importantly, our work highlights the need to understand the compounding nature of socioeconomic business vulnerability, especially in the context of pandemic and natural hazard readiness in a world confronting the multidimensions of climate change and economic equality. It is concerning, but not surprising, that we observe amplified impacts experienced by HUGO businesses during COVID-19, which can be traced back to ownership characteristics (i.e., minority, women, and veteran-owned businesses). Explicitly this is related to preexisting disproportionate vulnerability correlated with demographic data alone, before any acute events occurred. This becomes ever more alarming when considering that the average impacts on HUGO SMBs from COVID-19 alone are disproportionately greater than impacts on non-HUGOs from concurrent events of COVID-19 and natural hazards.

Notably, our results indicate that when estimating the COVID-19 impacts on SMBs, even if adjusting for HUGOs' socioeconomic vulnerabilities such as associated liability of smallness and newness and their lack of disaster preparedness (i.e., mitigation planning), belonging to the HUGO category is still significantly associated with amplified impacts. These results highlight the need to address gaps in risk governance and social understanding of unobservable (hidden) hardships, and unmeasured distresses that are disproportionately experienced by HUGO SMBs, as well as the mechanisms that alleviate/exacerbate the conditions. For example, minority- and

women-owned small business owners are more likely to be denied private loans through the Paycheck Protection Program (PPP) because “financial institutions are favoring pre-existing customers when distributing the funds, therefore ignoring many minority and women entrepreneurs who may not have a bank loan” [63]. In addition, Gallup [64] found that even when controlling for political affiliation, business size, and business location (urban/rural area), “female owners report experiencing higher levels of daily stress than do men (62% vs. 51%, respectively), as well as higher levels of daily worry (60% vs. 47%)” [64].

The COVID-19 pandemic has demonstrated the value of SMB operators having planned for business interruption across hazard types and the imperative for general mitigation actions. Additionally, our findings highlight the importance of having systems in place and socioeconomic structure that support HUGOs long before acute interruptions, such as access to capital and greater government programs tailored to their needs. The need to understand the limitations faced because of existing socioeconomic vulnerabilities that amplify business impacts from singular and complex event types is critical. Especially, the importance of mitigation actions that are general in nature (i.e., are applicable across business interruption types) is demonstrated in our analysis of the full dataset (See Table S2 in Supplementary Information) as well as in individual respondents’ open-ended explanations; this is especially pertinent when considering the potential occurrence of highly uncertain and novel events, such as a pandemic. Business operators that prepared for and experienced natural hazards (both before and during the pandemic) while maintaining minimal interruption noted that they “[take] general risk mitigation steps not specific to natural hazards” and “[use] general emergency preparedness, emergency funds [are] set aside, [and] contacts with local and state officials [are maintained].”

There are inherent limitations in conducting SMB research at the enterprise-level; nearly all such survey work, including the current study, tends to use convenience or non-probability sampling methods, as opposed to a randomized sampling strategy [47,65]. Given the constraints posed by the COVID-19 transmission period, our survey was conducted entirely online. Internet-based surveys are one of the most predominant survey types due to ease of use, cost, and rapid response times. At the same time, not all potential respondents always have access to the Internet and their recruitment is characterized by self-selection; there can be “under-coverage bias” [66]. Given that 93% of American adults use the internet today [67], and this might have increased during the pandemic, the issue of “under-coverage” may not be problematic in the current study.

6. Conclusions and future directions

Our research emphasizes the significance of continued research and meaningful assessment at the intersection of socioeconomic vulnerabilities, natural hazards, and pandemic impacts on business operators. Understanding the way in which socioeconomic structures impact that socioeconomic success of various groups is critical. The case of SMBs offers a means for highlighting such inequities, which was clearly further amplified by impacts of COVID-19 and natural hazards. It is not just about securing resources and funding for recovery, but about the ability to be successful and resourceful, which have to do with other system complexities, such as social networks, education, experience, incentives, and changing precedents across these categories. As reflected in our sample, the effect size of belonging to the HUGO SMB group was more than twice as large as the effect size of experiencing a concurrent natural hazard during the pandemic. This requires careful attention in research going forward. In addition to socioeconomic vulnerabilities, market barriers and sociocultural barriers that are hard to measure and evaluate may preempt HUGO SMBs’ growth. Additionally, soft aspects of resilience capacity, such as learning, agency, and flexibility [68] may be less available to HUGO SMBs ahead of disruptions in ways that ultimately preempt future growth. Adjustment strategies available to HUGOs appear to be largely reactive, opposed to proactive.

Generally, businesses that did not take proactive mitigation actions ahead of an event (e.g., because they chose not to do so or did not have the resources available), may need to take reactive actions to cope with the effects of a natural hazard, for example through requesting monetary aid, which in the U.S. is formally provided through loans from the Small Business Administration (SBA). However, historically, there are limited paths for SMB operators to finance disaster recovery after the fact, especially for HUGO SMBs. Throughout the COVID-19 period, however, the SBA has been increasingly flexible with loan and grant programs (e.g., the Targeted Economic Injury Disaster Loan Advance and the Supplemental Targeted Advance grants to all eligible businesses). To make these advancements truly equitable across SMB types, there needs to be more analyses like our current study that disentangle the complexity of systemic risks and transboundary impacts they encounter. Furthermore, future research on the benefits of early investment to assist adaptive capacity and to reduce risk, especially for HUGOs is needed.

Our analysis provides rationale for a clear call to better understand how initial business interruption and resilience as a latent quality of SMBs is enhanced or constrained by framing processes, institutions, and policies that are human designed. HUGOs clearly faced structural challenges that underscored their economic fragility ahead of COVID-19. These underlying challenges in turn may directly affect the operational health of HUGO SMBs during COVID-19 and natural hazards—individually and when experienced as a highly complex event. It is important to better understand barriers to securing resources and funding (specific to hazard preparedness and more generally) for HUGOs and to evaluate methods to overcome those barriers. In addition, during the recovery period from COVID-19, SMB operators hardest hit during the pandemic will continue to employ a variety of coping strategies, from reducing current consumption to disposing of productive assets.

This has serious implications for HUGOs’ ability (e.g., available resources) to plan for resilience ahead of ever more frequent and intense natural hazards and extreme weather events. In the first six months of 2021 there were eight weather/climate disaster events with losses exceeding \$1 billion each affecting the U.S [69]. In addition, COVID-19 is the sixth global pandemic to occur since 2000; it is preceded by H1N1 in 2009, polio in 2014, Ebola in 2014, Zika in 2016, and Ebola 2019 [70]. Complex events, therefore, are increasingly likely to occur and adaptation strategies that include specific preparation for them is critical, especially domain general mitigation actions that can reduce impacts across hazard types, as indicated in our analysis. Normalizing data collections and analyses

that take into account the complex landscape of concurrent disruptive events and structural challenges for resilience of SMBs and other systemic risks more broadly is imperative.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ijdr.2022.102845>.

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