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Rumor has it: The role of social ties and misinformation in evacuation to nearby shelters after disaster

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ABSTRACT

When crisis strikes, why do some communities utilize evacuation shelters more than others? This mixed methods study draws on a new dataset of almost-daily tallies of evacuees at 660 local shelters following Japan's 2018 Eastern Iburi Earthquake in Hokkaido to create a large-N time-series cross sectional (TSCS) dataset of local, short-distance evacuation. We pair time-series cross-sectional data models with qualitative comparative analysis (QCA) of nine affected municipalities to examine why some shelters see higher evacuation rates than others. While past studies have used Facebook user data, post-hoc surveys, or ad-hoc roadside interviews to measure evacuation, this study uses meticulously recorded shelter attendance data to draw inferences about evacuation behavior. Controlling for types of shelters, damage levels, infrastructure quality, social vulnerability, governance capacity, and community resources, we find that in affected communities, stronger bridging social ties, especially when aided by linking ties, motivate greater evacuation to shelters. In unaffected communities, stronger bonding and bridging ties encourage potentially unnecessary evacuation, helping spread rumors during blackouts. These results highlight the necessity of clear, transparent communication with the public, and fostering trust in government during crises.

1. Introduction

When crisis strikes, why do some communities see higher use of evacuation shelters than others? Past scholars investigated evacuation using surveys at highway rest-stops during crisis (Collins et al., 2017, 2018), post-hoc surveys of disaster hit neighborhoods in weeks and months following crisis (Elliott et al., 2010), and, more recently, through geocoded internet user data (Martín et al., 2017; Metaxa-Kakavouli et al., 2018; Yabe et al., 2019; Fraser et al., 2020a, 2020b). However, while many of these focus on long-distance evacuation, scholars still struggle to accurately measure short-distance, local evacuation to shelters during hazard events. Further, recent scholarship suggests that community resources, particularly bridging and linking social capital (Fraser et al., 2020b; Fraser et al., 2020a; Metaxa-Kakavouli et al., 2018), motivate long-distance evacuation. Social capital refers to the social ties among residents

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in a community that enable trust, reciprocity, and collective action (Nakagawa & Shaw 2003), and come in three types: bonding, bridging, and linking (Aldrich & Meyer 2015). *Bonding social capital* describes in-group ties linking together members of the same race, religion, class, gender, age, and other social groups, typically built between family, friends, and neighbors (Coleman, 1988; Hawkins and Maurer, 2010). *Bridging social capital* describes inter-group ties linking together members of different races, religions, class, genders, or age groups, typically built through associations and civil society participation (Aldrich and Sawada, 2015; Putnam, 2000). *Linking social capital* describes vertical ties linking together residents and local officials, helping them access key public goods and building trust in government (Aldrich, 2019; Szreter and Woolcock, 2004). However, questions remain as to how these community resources affect short-distance evacuation to shelters. Do bonding, in-group ties help residents evacuate their neighbors to shelters, more so than diffuse bridging ties or linking ties to authorities?

This mixed methods study draws on a new, *sui generis* dataset of almost-daily tallies of evacuees at 660 local evacuation shelters following the Eastern Iburi Earthquake, a magnitude 6.6 quake which struck Japan's northernmost island of Hokkaido in 2018. The earthquake struck on September 6, 2018 near Abira town, southeast of Sapporo, and plunged most of Hokkaido into blackouts when it cut off power from the Atsuma Coal-Fired Power Plant. The quake led to 41 confirmed deaths, 691 injuries, and communications outages in 53 municipalities and water outages in 35 municipalities, leaving many residents throughout the prefecture wondering whether they would need to evacuate (Fire and Disaster Management Agency 2018). This new dataset offers an unprecedented level of detail on which communities evacuated more and *when*. We use large-N time series cross-sectional models paired with qualitative comparative analysis (QCA) of nine affected municipalities to examine why some shelters saw higher evacuation rates than others. These meticulously recorded shelter attendance tallies reveal that in affected communities in the first two days after crisis, communities with stronger bridging social ties, especially when aided by linking ties, tended to send more residents to shelters. Meanwhile, in unaffected communities, stronger bonding and bridging ties encouraged potentially unnecessary evacuation, helping spread rumors during blackouts. These results highlight the necessity of clear, transparent communication with the public, and fostering trust in government during crisis.

This paper makes several contributions to the literature. First, this study benefited from a complete record of all shelters open in the earthquake. Past scholarship relied on difficult-to-gather responses from evacuees (Collins et al., 2017) or populations of internet users of varying levels of representativeness (Metaxa-Kakavouli et al., 2018; Fraser et al., 2020a, 2020b). Using the complete population of shelters adds further support for findings about the role of social capital in evacuation.

Second, this study found strong evidence that horizontal, bridging social ties facilitated greater short-distance evacuation to shelters in communities in need. This matched findings from past studies of long-distance evacuation, which found that residents with stronger bonding social capital tended to evacuate less in the face of Hurricane Harvey and Irma, while those with stronger bridging ties evacuated more (Metaxa-Kakavouli et al., 2018). This idea, dubbed the Janus-faced nature of social capital, implies that in-group, bonding ties might circulate misinformation and reduce information (Aldrich et al., 2018), and this phenomenon was found in our study as well.

Third, this study found that unaffected communities with stronger linking social ties saw less evacuation to shelters in the first few days, and that this occurred even in affected communities in the months after the crisis. While past studies suggest linking social capital boosts community resilience outcomes (Aldrich, 2019; Szreter and Woolcock, 2004), our findings match previous work on the Hokkaido quake, which found that communities with strong linking social ties also saw less long-distance evacuation (Fraser et al., 2020a, 2020b). This suggests that these communities may have been in less need of evacuation shelters, and greater levels of trust in government may have helped officials reserve room for the most vulnerable. These findings carry important implications for public officials and scholars involved in disaster evacuation and shelter operations.

2. Literature review

Why do some communities see greater evacuation to shelters than others? Past literature on disaster evacuation has focused mostly on why residents decide to stay or leave (Elliott et al., 2010; Riad et al., 1999; Whitehead et al., 2001; Metaxa-Kakavouli et al., 2018). These have focused on evacuation planning and modeling (Trainor et al., 2012; Lindell, 2013; Murray-Tuite et al., 2018), effects of evacuation notifications (Cova et al., 2017), and the experiences of mobile home residents (Ash, 2017; Strader et al., 2019). Scholars have also examined evacuation away from cities under threat, such as during incoming hurricanes (Horney et al., 2010; Collins et al., 2017, 2018; Martín et al., 2017; Metaxa-Kakavouli et al., 2018) or after fires (Li et al., 2019; Fraser, 2020). Others investigated what kinds of communities people evacuate *from* and *to* (Yabe et al., 2019; Fraser, 2020).

However, only a handful of studies have investigated evacuation shelters, mostly identifying new community adaptations or sites that can serve as shelters (Okubo et al., 2011; Gotoh et al., 2015; Sasaki & Katsumata, 2015; Kotani, Yokomatsu, & Ito, 2020). However, there is a lacuna of literature on why some communities rely on shelters more than others. This is unfortunate, because evacuation shelters are a key resource local governments can prepare before disaster and use to respond to immediate needs of residents after crisis. Removing people from harm's way remains among the most effective ways to mitigate the effects of hazards. If some communities, after accounting for differing levels of damage, utilize shelters more or less than others, this highlights an important inequality in access to the public goods local governments distribute after crisis at these sites. Past scholarship suggests four main reasons why some communities might see greater levels of evacuation to shelters than others, including *damage levels* and public works outages, *social vulnerability* to hazards, municipalities' *governance* capacity, and *community resources*, which we review below.

2.1. Disaster damage

First, some communities might see greater usage of shelters when facing higher levels of need due to disaster damage, power outages, or disruption in infrastructure like water services or sewage treatment. Broken roads and bridges can limit evacuation pathways (Boin & McConnell 2007, Petit et al., 2013, Na & Banerjee 2015); past investigation of earthquake evacuation in Japan revealed that many residents may in fact evacuate by car despite warnings and common perceptions to avoid this (Sun et al., 2017). Other kinds of infrastructure matter too; communities that maintain electricity may see better evacuation than those which lose power, especially for vulnerable populations like nursing home residents, where evacuation is otherwise impossible for those with electricity-reliant medicine or medical devices (Nakai et al., 2016). Further, communities might be more likely to evacuate if they hear an evacuation order from a trusted information source like TV or radio, but electricity outages frequently disrupt these modes of information (Burger et al., 2013). However, a wealth of recent scholarship has shown that communities facing high levels of damage can still respond effectively to crisis (Hawkins & Maurer, 2010; Elliott et al., 2010; Aldrich, 2012, 2019), and communities facing the most damage might still see residents reluctant to evacuate. As a result, communities that spend more on public works might see less need for evacuation, while those facing TV and water outages, more deaths and disaster damage, and greater proximity to the epicenter of the quake might see more evacuation to local shelters.

2.2. Social vulnerability

Alternatively, communities with greater numbers of socially vulnerable residents might see lower usage of shelters due to fear of discrimination, lack of resources, or mobility difficulties. Mobility is particularly challenging for elderly residents (Salvati et al., 2018), persons with disabilities, and persons with pre-existing health conditions (Uscher-Pines et al., 2009), especially if access to lifesaving medication is interrupted (Nakai et al., 2016). Disaster also disproportionately levies costs on women, who frequently are forced to care for family members, take on additional unpaid household labor, and may leave the workforce for it, requiring strong interventions to counter these harmful effects of disaster on women (Enarson, 1998; Moreno & Shaw, 2018). Similarly, blue-collar workers, unemployed residents, and residents in poverty face higher financial barriers to evacuation and recovery, making them wary and sometimes unable to leave (Ward and Shively, 2017; Hamideh & Rongerude, 2018). Further, many vulnerable minority communities frequently face discrimination from neighbors, landlords, and public officials, making them hesitant to leave behind their homes and belongings and distrustful of evacuation orders, even in the most dire of situations (Whitehead et al., 2001; Cutter et al., 2006; Fussell et al., 2009; Elliott et al., 2010; Wilson and Tiefenbacher, 2012; Uekusa & Matthewman, 2017). In Japan, the kinds of social vulnerability most likely to impede access to evacuation shelters are the effects of gender and age along with immigration and socioeconomic status (Ye & Aldrich, 2019; Fraser, 2021).

2.3. Government policies and capacity

Alternatively, even heavily damaged and socially vulnerable communities might see better evacuation rates to shelters in communities where public officials adopt community-oriented policies with strong governance capacity. Communities with better balanced budgets and those which invest more in emergency services may be better prepared to respond to crisis, reducing the need for residents to evacuate. Alternatively, they may also have more expansive efforts to get the word out about evacuation orders, or even provide door-to-door efforts or direct transportation to evacuation shelters. Communities that emphasize these “soft” policy and preparedness strategies tend to see better response and recovery (Bakema et al., 2019; Aldrich, 2012).

2.4. Community resources

However, even communities facing heavy damage, social vulnerability, and weak government response might see different levels of evacuation due to the social resources of those residents. Scholars cite social capital - the social ties in a community that enable trust, reciprocity, and collective action (Putnam 2000) - as a key determinant of community resilience (Nakagawa & Shaw 2003), with three types: bonding, bridging, and linking social capital (Aldrich and Meyer, 2015; Hawkins and Maurer, 2010; Szreter and Woolcock, 2004).

Bonding social capital refers to strong social ties that link members of the same groups and tend to proliferate among family, friends, and members of the same gender, age group, ethnicity, or religious groups (Coleman, 1988; Mouw, 2006; Pretty, 2003). Bonding social capital has been linked to better recovery within neighborhoods after the 1925 Kanto Earthquake in Tokyo, where residents helped each other salvage materials to rebuild houses (Aldrich 2012), after Hurricane Maria, where residents shared tools to clear rubble (Delilah Roque et al., 2020), and during Hurricane Katrina, where close friends and neighbors in the Lower 9th Ward, a predominantly African American neighborhood in New Orleans, checked in on each other to make sure they evacuated (Hawkins & Maurer 2010).

In contrast, bridging social capital refers to ties linking members of different social groups. These ties are frequently built in the workplace (Granovetter 1973), in unions (Norris et al., 2008), parent-teacher associations, and other community organizations (Pekkanen et al., 2014), and convey information, feelings of shared stake in community, mutuality, and reciprocity (Putnam 2000). Studies in the US (Aldrich & Crook, 2008; Smiley et al., 2018), Japan (Aldrich and Sawada, 2015; Fraser, 2021; Lee and Fraser, 2019), and elsewhere have highlighted that communities with stronger bridging ties and the community organizations that foster them have seen better response and recovery to crisis (Aldrich & Meyer 2015). More recently, scholars have connected bridging ties to better evacuation outcomes after several US-based hurricanes (Collins et al., 2017, 2018; Metaxa-Kakavouli et al., 2018).

Finally, linking social capital describes ties linking residents to local public officials; residents whose public officials are more embedded in the community may find it easier to petition them for support and key public goods after disaster and chart their course to recovery (Aldrich, 2019; Aldrich and Crook, 2008; Szreter and Woolcock, 2004; Tsai, 2007). Past studies suggest that residents with stronger linking ties are also more likely to trust public safety advisories from government officials, including evacuation orders (Metaxa-Kakavouli et al., 2018; Vinck et al., 2019), but also can quell misinformation and reduce unnecessary evacuation (Fraser et al., 2020a, 2020b). Tallies of Facebook users suggest that communities with stronger linking social capital saw less long-distance evacuation after the Hokkaido earthquake (Fraser et al., 2020a, 2020b), but questions remain as to whether that trend was seen in local evacuation as well.

In summary, past scholarship suggests that communities may see greater evacuation due to levels of disaster damage, power and water outages, or less evacuation due to higher levels of social vulnerability or higher levels of government preparedness, but the level of bonding, bridging, and linking social ties might convey differing effects on evacuation. Recent studies have highlighted that bonding social ties might reduce necessary evacuation, due to insular information networks and self-reliance within groups (Metaxa-Kakavouli et al., 2018), while bridging and linking ties might encourage necessary evacuation by circulating quality information from trusted sources (Fraser et al., 2020a, 2020b). While past scholars have investigated evacuation following the Hokkaido earthquake, these studies (Fraser et al., 2020a, 2020b) and others like them (Metaxa-Kakavouli et al., 2018) focused on long-distance evacuation, while the effect of social ties might differ when the decision is to evacuate to a local shelter. We hypothesize that the same divergent effects of bonding and bridging can be seen in shelter evacuation, where bridging ties encourage evacuation, but bonding ties restrict it, consistent with the so-called Janus faced nature of social capital (Aldrich et al., 2018). Additionally, the past studies reviewed above include both studies of evacuation *before* an event in order to avoid bodily harm (such as hurricane evacuation; Collins et al., 2017, 2018; Metaxa-Kakavouli et al., 2018), while others, including this study, focus on evacuation *after* an event for safe & healthier conditions (such as earthquake evacuation; Sun et al., 2017; Yabe et al., 2019; Fraser et al., 2020a, 2020b). Although past literature suggests that social capital helps enable collective action throughout evacuation (Collins et al., 2017), response (Andrew et al., 2016), and recovery (Aldrich 2012), the *timing* during a disaster when these social ties are activated might also shape their effect on evacuation. We further hypothesize that bonding social capital potentially complicating evacuation efforts early after crisis when information is scarce. Below, we introduce a research design to test the effect of social ties on evacuation.

3. Methods

This study examines why some communities see greater evacuation to shelters than others when crisis strikes. We examine the case of local shelter evacuation after the Eastern Iburi earthquake, drawing from time-series cross sectional models of shelter evacuation rates, Qualitative Comparative Analysis (QCA) of conditions leading to high shelter evacuation, and qualitative case studies of two municipalities facing high evacuation. This 6.6 magnitude earthquake struck Abira town on September 6, 2018 at 3 AM and damaged the Atsuma Power Plant, the largest coal fired power plant in Japan. In doing so, it temporarily plunged Hokkaido into darkness. Damage to infrastructure was limited, and regular traffic and public transit resumed within days after the disaster, but many homes and businesses near and far from the epicenter suffered collapse or structural damage and damaged water and power lines. As many as 53 communities reported a loss of TV service (41%, n = 128), and 35 communities reported water outages (27%, n = 128), with far-flung towns like Haboro-cho reporting the highest at 460 peak water outages per 1000 residents. The impact of the disaster was highly focused around Abira, Atsuma, and Mukawa towns near the epicenter, but evacuation to local shelters occurred throughout the prefecture. However, some communities saw greater evacuation than others. We apply a mixed methods toolkit to test the effect of social ties on evacuation to local shelters, which we introduce below.

This study relies on a new dataset that tallied the number of evacuees at 660 evacuation shelters located in 128 municipalities in Hokkaido, at regular intervals over three months. Public officials shared tallies with the prefectural government, which published them for the public in frequent updates, sometimes multiple times a day, with decreasing frequency until the final report on December 7, 2018 at 5 PM. We collected these tallies into a time-series cross-sectional data, reporting every shelter-day observation over 117 timesteps. We apply Lieberman's (2005) strategy of nested analysis, pairing several large-N analyses with small-N analysis of causal pathways. Below, we introduce our modeling strategies and clarify our methods for QCA and case studies.

3.1. Modeling

This study tests the effect of social capital on evacuation rates, controlling for other factors, using models of different samples of time-series cross-sectional shelter data. To signify evacuation, we use the *number of evacuees at a shelter at a given time per 1,000 residents* in that municipality, to adjust for population, while to signify social capital, we used Fraser's (2021) new bonding, bridging, and linking social capital indices scaled from 0 to 1. We discuss these indices and all variables in these models in **Appendix A,** to conserve space.

We use linear mixed models with nested random effects in the lme4 package in R (Bates et al., 2015) to model variation in the logevacuation rate of each shelter over time. For each sample, we log-transformed our outcome variable, because evacuation rates are strongly right skewed[1] Then, we applied three linear models: The first model controlled for just bonding, bridging, and linking social capital, to identify whether social capital has uniform effects or divergent effects, like the "Janus-faced" effects found in past studies (Aldrich et al., 2018). The second model then added an interaction effect between bonding and bridging social capital, while the third model added two-way interaction effects between bonding, bridging, and linking social capital. This tests whether combinations of social capital promote greater evacuation than strong social capital of specific types alone.We applied this modeling strategy to six samples of data, outlined in Table 1 and described in detail in **Appendix B**. For each subset, we conducted time-series cross-sectional models to estimate the effect of bonding, bridging, and linking social capital on evacuation rates while controlling for other factors. For each model (no. 1–6 in Table 1), we compared three types of random effects to account for interdependence, because each shelter is nested in a municipality and recorded over multiple days. The first version used *random effects by time period*, accounting for variation over time. The second version used *crossed random effects by time period and municipality*. Finally, the third version used *nested random effects by shelter and municipality*. Results were largely consistent across models. Finally, we summarize the goodness of fit of our models in **Appendix B**.

3.2. Qualitative Comparative analysis

These six random effects models help us understand how the effects of social ties on evacuation to shelters differ depending on timing and the severity of the disasters' effects in each community. While our models depict the overall estimated effect of social capital, we might expect that social capital functioned differently in communities with different traits. For example, strong bridging ties could spread misinformation and panic in a community facing water or power outages, but little actual damage; this could lead to considerable evacuation to shelters, even while bridging social capital helps mobilize residents to evacuate in a more positive way in communities heavily damaged by the disaster. To test this, we applied Charles Ragin's (2014) Qualitative Comparative Analysis (QCA) using the QCA package in R (Dușa, 2019) to identify the smallest possible set of conditions under which the 24 cities facing any damage, deaths, or injuries with at least 1 evacuee saw high levels of evacuation. QCA is a set-theoretic method that takes a dichotomous outcome (high/low evacuation) from a medium-N sample of cases (cities), compares that outcome against a series of dichotomous causal conditions, and minimizes that set of causal conditions into the smallest, most parsimonious set (or sets) of conditions that lead to the outcome (high evacuation). It is helpful for exposing situations when two or more conditions are necessary to produce an outcome, as well as situations where *multiple* different pathways lead to the outcome. In this case, we might expect that multiple different combinations of levels of social capital, vulnerability, government capacity, or crisis intensity might lead to evacuation.

To perform QCA, we zoomed into just towns which hosted at least 1 evacuee in the first two days following the crisis, leaving 24 towns, and then tallied up the peak number of evacuees each shelter hosted during this time. The peak best captures the height of evacuation during this period. Then, we binned each key variable of interest into dichotomous categories of "high" or "low" using guiding principles discussed in **Appendix C**. The binary truth table describing evacuation is highlighted in Fig. 1. This figure lists the dichotomous outcomes and potential causal conditions which QCA then will minimize into the most parsimonious set(s) of casual conditions for high evacuation. We discuss which conditions were found most critical through QCA in the Results (section 4.3). For more information, see **Appendix C**.

We simplified this truth table using boolean minimization via the CCubes algorithm, using remainders (counterfactual cases that did not occur but hypothetically could have) and consolidating the observed cases into the smallest set of four causal configurations. These five causal configurations focus just on the observed data and provide the most meaningful set of causal pathways we could establish with QCA. We highlight these causal configurations in Fig. 4 and discuss them in the results.

3.3. Case studies

Finally, QCA helped us select case studies and build theory on *why* our models show divergent effects of social capital. In keeping with Lieberman's (2005) strategy of nested analysis, we used these large-N (TSCS) and medium-N (QCA) analyses to identify one town that embodies our model results and one town that diverges from our model results. To explore these towns, the authors conducted semi-structured interviews in the disaster region with 11 residents, local bureaucrats, and first responders to gather qualitative evidence about these causal pathways. Interviews were conducted in December 2019, and we summarize these interviewees by trait in Table 2. We describe the case of Atsuma, where high bonding and bridging social ties helped ensure strong evacuation rates, compared with Mukawa, where in spite of weak social capital, strong municipal preparedness and need motivated high levels of evacuation. Synthesizing these Large-N, Medium-N, and Small-N strategies clarify the conditions under which bonding, bridging, and linking social capital aid evacuation, and under what conditions they might stymy it.

[1] For cases reporting zero evacuees per capita, these values could not be log-transformed. Rather than lose this important data, we imputed these zero-cases with a small-but-realistic value equal to half the smallest observed non-zero rate of evacuees, to maintain the shape of the distribution. This is a much better alternative to omitting these cases.

Table 1
Summary of Analyses.

No.	Outcome	Time-steps	Shelters	Municipalities	Type	Results
1	Short Term Evacuation	7	660	128	TSCS	Table D1
2	Short Term Evacuation in Towns facing no Damage, Deaths, or Injuries	7	301	92	TSCS	Table D2
3	Short Term Evacuation in Towns facing any Damage, Deaths, or Injuries	7	359	36	TSCS	Table D3
4	Short Term Evacuation in Towns facing Damage, Deaths, or Injuries over Median Levels	7	208	9	TSCS	Table D4
5	Long Term Evacuation in Towns facing Damage, Deaths, or Injuries over Median Levels	117	208	9	TSCS	Table D5
6	Long Term Evacuation in Towns facing High Evacuation	117	165	9	TSCS	Table D6
7	Peak Short Term Evacuation in Towns facing any Damage, Deaths, or Injuries with at least 1 evacuee	1–8(Single Snapshot)	298	24	QCA	Fig. 1 Fig. 4Fig. C1

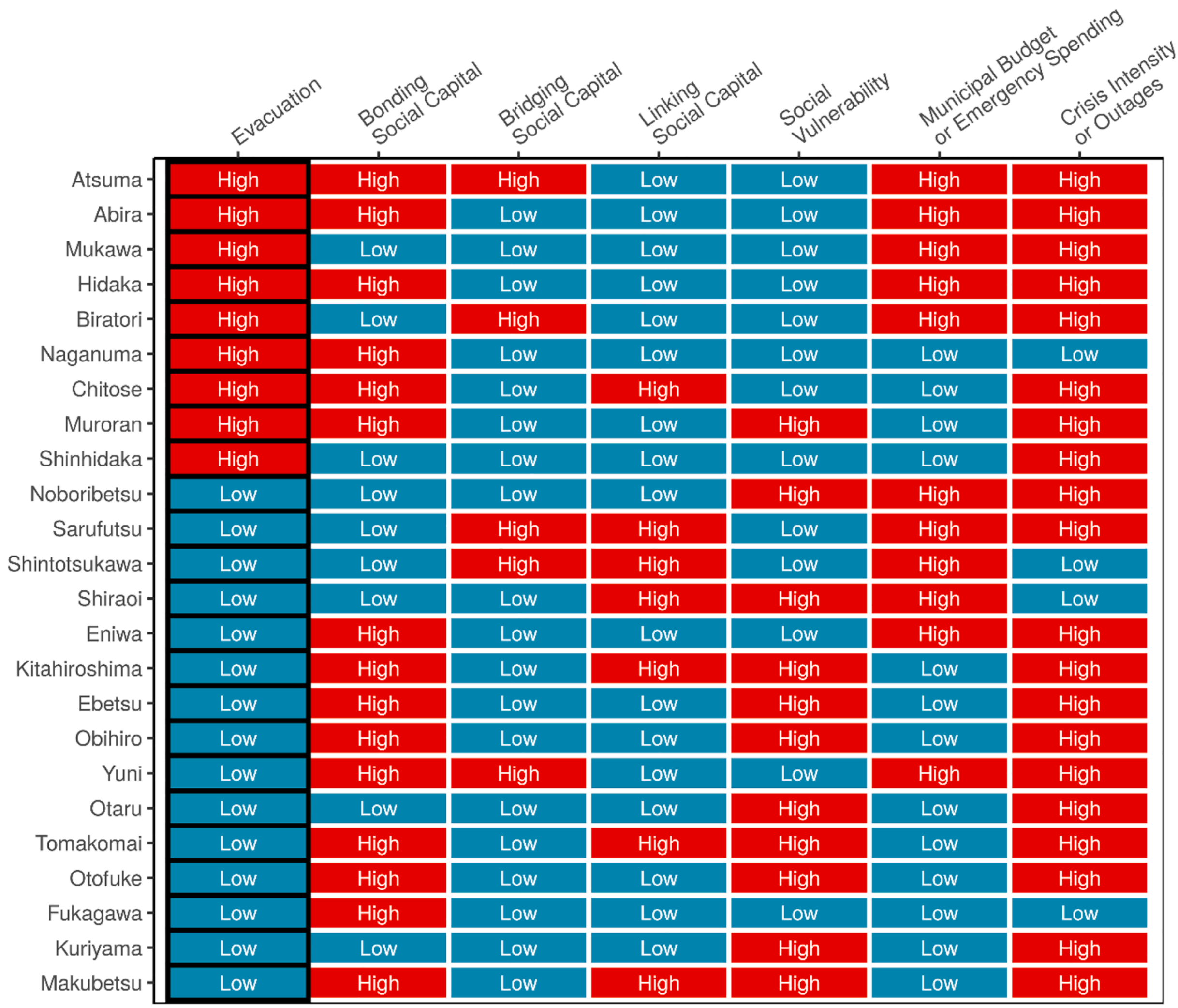

Fig. 1. QCA Truth Table.

4. Results

This study analyzed why some shelters saw higher evacuation rates over time than others after the Eastern Iburi Earthquake in Hokkaido, Japan, using several different subsets of shelters to distinguish differing effects of social ties. Below, we discuss our nested random effects model results, followed by QCA results.

Table 2
Interviewee Traits.

Community	Community Evacuation Level	Individual Moniker	Gender	Age	Role
Atsuma	High	Mr. M	M	50s	Firefighter
Atsuma	High	Mr. K	M	40s	Local Official - Town Development
Atsuma	High	Mr. A	M	50s	Local Official - Town Development
Atsuma	High	Mrs. Y	F	80s	Stationary Store Owner
Atsuma	High	Mr.s U	F	50s	Flower Shop Owner
Mukawa	High	Mr. I	M	50s	Firefighter/Paramedic
Tomakomai	Low	Mr. T	M	40s	Local Official - Crisis Management Unit
Tomakomai	Low	Mrs. S	F	40s	Fish Market/Restaurant Staff
Tomakomai	Low	Mr. O	M	50s	Coffee Shop Owner
Tomakomai	Low	Mr. N	M	60s	Construction Association Officer
Tomakomai	Low	Mr. W	M	40s	Construction Association Employee

4.1. *Modeling results*

First, our analysis of short term evacuation to shelters from September 6 at 6 PM to September 8 at 11 AM showed divergent effects of bonding, bridging, and linking social capital on evacuation rates (albeit with varying levels of statistical significance) association with evacuation rates. Curiously, we found that cities with more linking social capital (and trust in government) evacuated less, while those with stronger bonding or bridging ties evacuated more (**Appendix Table D1-D2**).

How could this be? A comparison of short term evacuation to shelters with and without damage helps explain this. In towns facing no reported deaths, injuries, or damage from the earthquake, bonding and bridging social capital fueled higher rates of evacuation, while communities with stronger linking or stronger bridging and linking ties saw less evacuation (**Appendix Table D3-D4**). Fig. 2 demonstrates this interaction using 1,000 statistical simulations generated by the Zelig package in R (Choirat et al., 2017; King et al., 2000). We simulated the number of expected evacuees per 1000 residents for an average shelter within multiple different confidence intervals (90, 95, 99, and 99.9%), by varying the level of bridging social capital by 2 standard deviations around the mean given linking social capital at low levels (1 standard deviation below the mean), medium levels (at the mean), or high levels (1 standard deviation above the mean). In each simulation, all other traits were held at their means (for continuous variables) or modes (for categorical variables). Fig. 2 depicts that cities facing no damage with stronger bridging social capital saw greater evacuation, but as the level of linking social capital increased from one standard deviation below the mean (low) to the mean (medium) to one standard deviation about the mean (high), then an increase in bridging social capital diluted and eventually led to *less evacuation.* (These effects persisted for nested, crossed, and simple random effects; for comparison plots, see Appendix **Figure D14**).

In contrast, towns that faced *actual deaths, injuries, or damage* saw very different patterns. Here, bridging social capital invigorated evacuation rates ($p < 0.05$), while bonding ties were associated with less evacuation. Meanwhile, communities with strong bonding, bridging, and linking ties saw higher evacuation rates ($p < 0.10$) (**Appendix Table D5-D6**). This dynamic is highlighted using 1,000 statistical simulations in Fig. 3**,** generated in the Zelig package in R (King et al., 2000; Choirat et al., 2017). Using the same methods in Fig. 2, we simulated the rate of evacuees per 1000 residents for an average shelter as bridging social capital varied by 2 standard deviations around the mean. The left panel assumes low bonding *and* linking social capital (1 standard deviation below the mean),

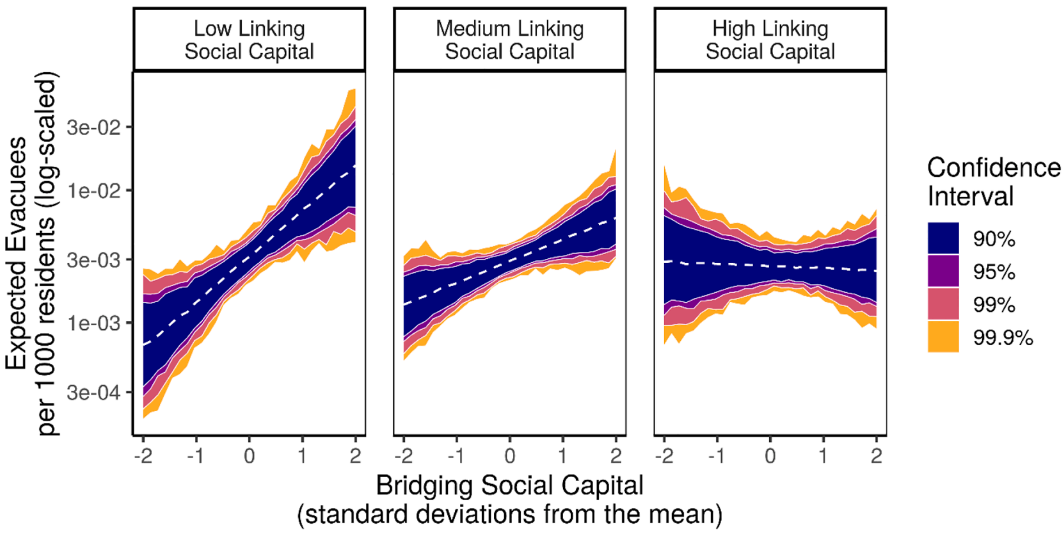

Fig. 2. Linking Ties alter effect of Bridging Ties on Unnecessary Evacuation.

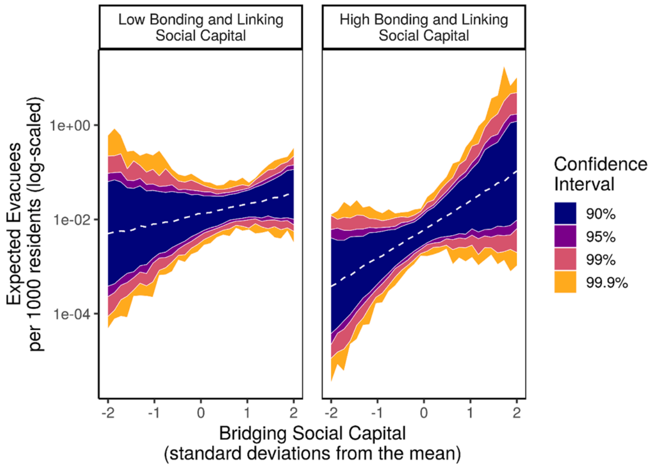

Fig. 3. Effects of Bridging Social Capital on Short Term Evacuation given any damage.

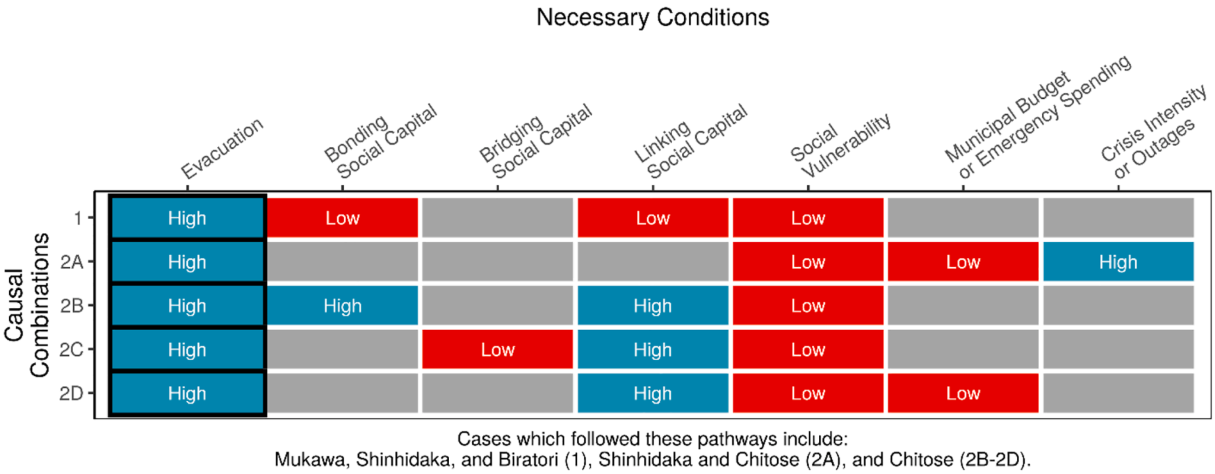

Fig. 4. QCA Causal Configurations.

while the right panel assumes high bonding *and* linking social capital (1 standard deviation above the mean). All other variables were held constant at their means or modes. Fig. 3 shows that in cities facing any damage, as bridging social capital increases, those with bonding and linking social capital one standard deviation below the mean are projected to see somewhat more evacuation, while those with bridging and linking social capital one standard deviation *above the mean* are projected to see considerably more evacuation given an increase in bridging social capital. (These trends persisted for nested, crossed, and simple random effects; for comparison plots, see Appendix **Figure D14**).

Similarly, when examining short-term evacuation in towns with damage, deaths, or injuries over median levels, we found here that bonding social ties were related to a decrease in evacuation rates ($p < 0.05$ in our simple random effects models), while linking social ties were related to increases in evacuation ($p < 0.10$) (**Appendix Table D7-D8**).

These results suggest social capital functions differently in affected and unaffected communities. In affected communities, bridging ties may link neighbors and people from different backgrounds, helping them hear that shelters have opened and that they should evacuate; linking capital augments this, because residents with strong linking ties tend to trust information from their local officials more. Meanwhile, bonding ties might insulate residents from this information and encourage them to shelter with friends and family instead. On the other hand, in unaffected communities, bonding and bridging social networks can feed panic, especially when trusted news sources like TV go offline, encouraging evacuation in areas that do not need it. In contrast, strong linking ties encourage these residents to trust their local officials, who did not issue evacuation orders in these areas. These results highlight the necessity of clear, transparent communication with the public, and fostering trusting in government during crisis.

Second, we compared these short term evacuation results with long-term evacuation rates. This applied to two smaller subsets of nine towns where shelters remained in use over time. These models highlight that in the weeks after disaster, evacuation rates become more a proxy for response and recovery. For example, in communities suffering deaths, injuries, or damage over median levels, social capital showed minimal effects on continued use of shelters. Instead, physical infrastructure spending was a much more consistent predictor ($p < 0.01$); in other words, communities that invested more in infrastructure in the past saw lower rates of long-term evacuation, even after controlling for the intensity of the crisis and social vulnerability of residents. This implies that residents were able to return home sooner in communities with better infrastructure, while those with worse infrastructure were stuck in shelters longer (See **Appendix Table D9-D10**). And when looking at long-term evacuation shelters where shelters hosted evacuees for 11 time-steps or more, linking social capital was a strong predictor of lower evacuation rates ($p < 0.05$). Communities where residents trusted officials' proclamations that the disaster was over were less likely to remain in shelters (See **Appendix Table D11-D12**).

Together, these results highlight that bridging social capital, combined with linking social capital, is most effective in encouraging evacuation in affected areas, but areas with higher linking social capital in general are more likely to act in accordance with local officials' recommendations to evacuate or not.

4.2. Qualitative Comparative analysis

These modeling results highlight that evacuation patterns are highly specific to different subsets of communities, and might be best portrayed as a series of different pathways that lead to high evacuation. We applied Qualitative Comparative analysis to examine under what conditions residents evacuate more to shelters, looking at peak evacuation rates above or below 1 evacuee per 1000 residents between September 6 and September 8 at 11:00 AM in cities facing any damage, deaths, or injuries where at least one resident evacuated to a shelter. This generated 5 reduced causal pathways leading to high evacuation, or at least 1 evacuee in a town per 1,000 residents. These pathways and their necessary conditions are displayed in Fig. 4. Pathway 1 explained 33% of cases with high evacuation, while Pathways 2A-2D each explained a different 11% of high evacuation. In other words, these models are descriptive, but by no means exhaustive, as any combination described a maximum of 44% of high evacuation.

First, cities saw high evacuation, even if they had weak social capital, when they involved communities with low social vulnerability. This described Mukawa, Shinhidaka, and Biratori, which have weak social capital (although Biratori does have strong bridging ties, which may have helped). Second, cities might have seen high evacuation due to four other competing explanations; high levels of damage motivate evacuation, even in spite of little emergency response funds, because these communities are not very socially vulnerable. Third, communities with strong bonding and linking like Chitose highlight a situation where, facing outages, social capital motivated evacuation in each of its competing explanations. These causal pathways are by no means exhaustive, but help clarify three possible pathways (1, 2A, and 2B-2D, which are mostly the same) by which communities end up seeing high evacuation. Some cities evacuate in spite of weak social capital, because they were unhindered by other barriers (Path 1), while others' evacuation tends to rely on strong linking social ties (Paths 2B-2D).

5. Case studies

Finally, we turn to case studies to investigate and validate our large-N and medium-N analyses. First, we examine Atsuma, a city whose strong bonding and bridging social ties were matched by strong evacuation, as predicted by our nested random effects models, as an on the line case. Second, we investigate Mukawa, which QCA showed achieved high evacuation to shelters in spite of weaker bonding, bridging, and linking social capital, deviating from the general trends of our models. Below, we draw from qualitative interviews to discuss what boosted evacuation in these two divergent cities.

5.1. The emblematic case of Atsuma town

The town of Atsuma is a coastal city, which hosts a coal-fired power plant, the largest source of electricity in the prefecture. As a result, the city lost power for many days when the quake hit. The center of Atsuma was approximately 7.3 miles from the epicenter, and the town suffered damage to 1,901 buildings, including 224 homes and 662 nonresidential buildings destroyed, and 36 deaths, and 61 people with minor injuries, all in a town of 4,838 people. Atsuma hosts 18 evacuation shelters, including sites at 12 community centers, 3 schools, and 3 other buildings. On paper, Atsuma demonstrated the main trend shown by our models, where strong bonding and bridging social ties were matched by strong evacuation; up to 613 individuals had evacuated to a single shelter in Atsuma within the first two days. On the ground, we found several examples of social ties between friends, neighbors, and family that motivated evacuation or helped residents and officials coordinate response.

One of the main concerns immediately after the earthquake seems to have been access to information. Mr. M, a firefighter from Atsuma, highlighting the lack of information initially, described in an interview how first responders were struggling to get a complete picture of what was going on. "We had no news about the seismic intensity felt in Atsuma [either], I remember worrying about Mukawa and Abira, thinking it must have been worse for them." However, as they struggled to mobilize teams to assess damages, and commence rescue missions, they started receiving reports and information from residents through phones and radio; these residents described the damages in their area, of collapsed buildings, and of people who were trapped. Soon enough, it was evident that Atsuma was hit the hardest.

In Atsuma, social ties affected the spread of information. Mr. K, like many others in the area, was woken up by a violent, vertical shake into pitch black darkness to a partially destroyed home, leaving them without water nor electricity. As a city official at the Atsuma Town Hall, he knew he needed to get to the city hall as soon as possible but had to make sure his family was safe first. "We didn't have water, we didn't have electricity, [so] we couldn't get a lot of information, which is why I told my family to evacuate." Mr. K and his family would spend the next 2 weeks in evacuation shelters and temporary housing. As he left home, just a few moments after the earthquake, Mr. K noticed that there were area representatives already making rounds, checking up on people and houses. These neighborhood ties helped spread word about evacuation shelters. This matches past accounts of disaster response, which argued that local neighborhood associations and neighborhood representatives were important resources following the 3/11 disaster (Pekkanen et al., 2014).

The community aided each other directly too. When the earthquake hit and the lights went out, it wasn't long before neighbors, family and friends were checking up on Mrs. M, a 80 + year old store owner. Soon after, an evacuation shelter was set up behind her home. This allowed Mrs. M to stay home while volunteers, neighbors, and evacuees would bring her food and materials from the shelter. During this time, damage to roads and debris limited evacuation, and the lack of information about which infrastructure was affected levied an additional barrier to evacuation, and delayed receiving outside help. Facing these challenges, these kinds of social support helped her and others like her at the evacuation center get food and resources in the first 72 h after the disaster.

5.2. The divergent case of Mukawa town

On the other hand, evacuation in Mukawa diverged from the trends posed by our models. Mukawa hosts 26 evacuation shelters, scattered across 15 community centers, 7 schools, and 2 other buildings, and up to 270 individuals evacuated to a single shelter in town within the first two days of the crisis. Mukawa suffered just 1 death but 24 serious injuries and 250 minor injuries. Further, the city saw 3,689 properties damaged, including 33 homes completely destroyed, 482 partially damaged, and 151 nonresidential properties destroyed, a considerable number in a town of 8,596. At the height of the crisis, the city reported a max of 1,031 water outages. Facing this stark level of damage, Mukawa saw high evacuation even despite weaker bonding, bridging, and linking social capital. This begs the question, *why?* How did Mukawa achieve high rates of evacuation despite low levels of social capital? The high evacuation rates in Mukawa may be explained by the higher risk for tsunami threats and the larger number of collapsed buildings.

These were some main points stated by Mr. I, a firefighter and paramedic in Mukawa, during our brief interview. "Once the shakes subsided, we turned on the dry cell radio and we were listening for news of tsunamis… after confirming that there was no tsunami threat we were able to calm down a little." Recounts Mr. I, a firefighter and paramedic from the town of Mukawa. "Over where I live in Mukawa-cho, there were a lot of [houses that collapsed from the shakes], so there were a lot of people, friends and colleagues that… had to evacuate." Though our QCA pathways did not include the role of damage, on-the-ground accounts suggest that the type of damage that households suffered motivated residents to evacuate. Additionally, our aggregate-data indicates that Mukawa was among the less socially vulnerable communities in Hokkaido at the compare, suggesting fewer challenges to evacuation in terms of age, poverty, or health.

This highlights the diversity of triggers in evacuation. For example, in less affected areas like Tomakomai, city hall officials we interviewed reported frequent accounts of rumors on social media, implying that the city was going to lose water completely for weeks, circulating incorrect tallies of damage, and highlighting that aftershocks were expected, when none of these were the case. These information concerns, mentioned by several of the 5 persons we interviewed there, motivated the strong surge of evacuation that our models identified in cities experiencing little-to-no-damage (Fraser et al., 2020a, 2020b).

6. Discussion

This study investigated why some shelters saw greater levels of evacuation than others following the Eastern Iburi Earthquake in September 2018 in Hokkaido, Japan. We used linear mixed models with nested random effects on six different subsets of evacuation shelters over time to estimate the effects of bonding, bridging, and linking social capital on evacuation rates. Further, we investigated the many different pathways to achieving high levels of evacuation using Qualitative Comparative Analysis (QCA), and explored the emblematic case of Atsuma, which matched our models, and the divergent case of Mukawa, which differed from our predictions but was identified by our QCA model.

Past studies have delivered conflicting findings over the role of social capital in evacuation. For example, studies of long-distance evacuation after the Hokkaido earthquake showed that strong linking ties reduced the need for individuals to evacuate (Fraser et al., 2020a, 2020b). However, following major US hurricanes, linking ties to government officials made many individuals *more* likely to evacuate (Metaxa-Kakavouli et al., 2018). This study adds clarity by focusing on short-distance evacuation to shelters (as opposed to long-distance evacuation away from one's home city), and by breaking up evacuation into short-term or long-term stays at these shelters. Our finding that individuals with stronger linking social capital saw less evacuation overall, both in short- and long-term evacuation, adds to a growing argument that trust in government is vital during crisis, given frequent lapses in information flow from television, radio, or reliable news sources (Fraser et al., 2020a, 2020b). Further, our finding that communities with greater bridging social ties evacuated more to shelters when facing damage highlights another case where bridging social ties proved to be a key community resource, matching past research as well (Metaxa-Kakavouli et al., 2018).

6.1. Implications

This study also has several implications for policymakers and disaster scholars. First, on-the-ground interviews underline the importance of information and transparency during disaster response, as rumors shaped many individuals' evacuation behavior in areas facing little or no damage. Governments which provide this information quickly can help residents forecast and adjust; the knowledge of whether aftershocks are expected helps residents gauge their own level of need and influenced evacuation decisions, according to our interviewees. This study also highlighted that unnecessary evacuation is curious challenge; disaster scholars almost always want to encourage evacuation, because individuals are frequently reticent to leave their homes and belongings even in the face of dire impending threats, but in the case of Hokkaido, rumors inflated anxiety outside the main affected area, even though water and electricity would soon resume.

This study also found that governance capacity consistently mattered; in almost all cases, communities with better balanced budgets saw higher rates of evacuation. Similarly, on-the-ground interviews with first responders from Atsuma indicated that outdated equipment for emergency service personnel was a great barrier to response capacity. Future studies should investigate what kinds of small interventions to governance capacity can make a meaningful difference in evacuation and response outcomes.

Further, this study found continued support for the theory of horizontal social capital in disasters. Our interviews showed that checking in on neighbors, especially the elderly, matters greatly to evacuation efforts. Most responses knew their neighbors well and felt a strong sense of community, reinforced and strengthened by the disaster. For many residents, these social ties are increasingly seen as a resource not to be wasted.

6.2. Limitations

Finally, this study came with several limitations. First, the snowball sample of interviewees in this study led to 5 interviews in Atsuma, which developed our emblematic case, and 5 interviews in Tomakomai, which deeply shaped our sampling strategy, encouraging us to look at towns *damaged* and *facing little to no damage* separately. However, we received less coverage in Mukawa, where we spoke primarily with first responders. We also primarily spoke with residents and city officials in town, while conditions varied for residents outside the main towns. Finding interviewees willing to speak with the authors was challenging, since in these small communities, most residents knew at least one to two people who died, making the subject quite recent and traumatic. Further, several residents reported that these communities faced a blitz of engagement and publicity from the media, followed by what residents perceived as a subsequent dearth of public interest in the continuing challenges of disaster recovery; this raised trust concerns and led to some residents being exhausted to have to tell their story again. Each of these challenges highlights the importance of proper human subjects training and research ethics when interviewing residents affected by crisis, and underscores the need to accurately reflect their stories in disaster scholarship.

Second, the quantitative analysis was limited by data availability. First, while this study benefited from meticulous documentation of the number of evacuees at each shelter every several hours following the crisis, we lacked data on conditions at the shelters. As a result, this study was unable to examine a potential intervening variable, the quality of aid provided at shelters, room available for additional evacuees, and staffing. Instead, we sorted shelters into types, such as schools versus office buildings versus city hall to roughly approximate common categories that might affect the number of evacuees that each site could host. Future studies should certainly investigate the intervening effect of shelter conditions on the relationship between social capital and evacuation.

This study also used qualitative comparative analysis, but found several equally plausible causal pathways (dubbed 2A through 2D in Fig. 4). Rather than altering the truth table post-analysis, we found maintaining these multiple causal pathways to be the most transparent way to convey that there are multiple explanations for why divergent cities like Mukawa, Shinhidaka, and Chitose saw high rates of evacuation despite varying levels of social capital. Future studies should investigate in depth how varying levels of damage, social capital, and social vulnerability interact to shape evacuation, as it did in Mukawa. This suggests that social capital may have non-linear effects; causal pathways and analysis of subsets of cases are useful ways this study has undertaken to clarify the role of social capital in disasters.

7. Conclusion

This mixed methods study examined why some shelters see higher rates of evacuation than others, drawing on the case of 660 local evacuation shelters in 128 cities following the 2018 Eastern Iburi Earthquake in Hokkaido, Japan. We used large-N time-series cross sectional models and Qualitative Comparative Analysis (QCA) to determine the role of social capital in shelter evacuation rates, using separate analyses of cities facing high and low disaster damage, as well as separate analysis of short-term and long-term evacuation.

We found that the first two days after crisis, affected communities with stronger bridging ties tend to send more residents to shelters, especially if those affected communities have stronger linking social capital as well. However, in unaffected communities, bonding and bridging ties helped facilitate the spread of rumors during blackouts, exacerbating unnecessary evacuation to shelters; instead, communities with stronger linking social capital saw less unnecessary evacuation. These results highlight both the Janus-faced nature of social capital, where bonding, bridging, and linking social capital can each levy different effects of community resilience processes (Aldrich et al., 2018; Aldrich, 2012); further, they highlight that when facing uncertainty and lack of quality information, strong horizontal social ties can spread rumors rather than quash them; good disaster response requires strong trust in local government and linking ties to local officials.

Future studies should investigate further how social ties interact with shelter conditions, and whether social capital can overcome any negative perceptions by residents of shelter conditions and encourage the use of these public facilities for the most vulnerable and those in need. Further, scholars should investigate whether, following the COVID-19 pandemic, have levels of trust in government changed? If so, scholars should investigate whether these changing levels of trust have meaningfully reshaped residents' perspectives towards accessing public goods like evacuation shelters during crisis. By linking residents with local officials, and leveraging stronger horizontal ties with neighbors, scholars and policymakers can encourage necessary evacuation to local shelters and ensure that those most in need can access the resources they need when crisis next strikes.

Data availability

All code necessary for replicating this study will be made available for replication on the Harvard Dataverse (https://doi.org/10.

7910/DVN/RWILKE).

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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crm.2021.100320.

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