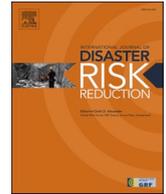




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Seen and unseen vulnerabilities: Evaluating recovery from the 2015 Nepal earthquake to inform more equitable post-disaster needs assessments

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A B S T R A C T

As disasters disproportionately impact socially vulnerable groups, it is critical to ensure that sufficient, timely, and appropriate disaster recovery aid and efforts are channeled towards such groups. Ensuring that disaster impact assessments accurately account for how different communities are affected by the studied events is thus essential, as these assessments often inform and shape subsequent disaster recovery programs. However, it is not clear whether disaster impact assessments have managed to accurately estimate and account for the post-disaster needs of socially vulnerable groups, as there have been few studies that empirically examine their performance in this area. To address this gap, this paper examines the degree to which a Post Disaster Needs Assessment (PDNA) carried out after a devastating earthquake in Nepal in 2015 accurately identified socially vulnerable groups as seen in recovery outcomes four years later. Recovery outcomes were assessed using a household survey of over 800 households living in seven districts most affected by the earthquake. We find that while the PDNA did accurately identify some of the groups that were vulnerable to poorer post-disaster outcomes, such as women and poor households, it missed other groups who had worse recovery outcomes, such as households with debt. Our analyses also suggest that Nepal's PDNA efforts to encourage equitable recovery, which was focused on income resumption and housing rebuilding only, overlooked other important recovery outcomes such as health. Future disaster impact assessments should thus pay greater attention to ensuring equitable recovery in the health domains.

1. Introduction

Disasters have been well-documented to disproportionately affect marginalized members of society, both globally, and within a country or region, for several reasons. First, populations that are most vulnerable to disasters—such as those lacking economic resources; belonging to marginalized racialized groups, ethnicities, religions and/or castes; having a disability; or having poorer health; among other characteristics—tend to be located in areas that are more exposed to hazard risks. Reasons for this exposure bias include discrimination, lack of political power, environmental mismanagement, and problematic developmental processes [1,2]. Additionally,

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marginalized communities often lack access to resources to take defensive measures prior to disaster; and also lack resources to rebuild after disasters—in part because they often receive less governmental aid post-disaster [3,4]. Thus, even seemingly small impacts can prove disruptive and catastrophic, more so than if the same levels of damage were experienced by more privileged and well-resourced individuals [5]. Furthermore, vulnerable communities are seldom effectively or comprehensively included in post-disaster reconstruction processes [6].

From an equity standpoint, it is thus critical to conduct comprehensive disaster impact assessments that account for systemic disparities in negative impacts between communities, in order to better achieve equitable recovery. Equitable recovery can be defined according to three dimensions: First, distributive equity in recovery requires the fair allocation of recovery-related resources. Second, procedural equity requires the just inclusion of minoritized voices in decision-making around recovery efforts. Third, recognitional equity involves the acknowledgement and respect of marginalized groups as part of the recovery process [7,8]. If disaster impact assessments fail to adequately account for real differences in post-disaster outcomes among communities, subsequent policies and programs based on these assessments may fail to support those who need them most, in terms of allocation of sufficient recovery resources or inclusion into decision-making processes, and end up perpetuating structural inequities and accentuating marginalization. Such an outcome would constitute a failure to achieve equitable recovery on all counts. It is thus important to identify equity-related blindspots in existing disaster impact assessment methods and highlight ways to improve them to achieve more equitable outcomes.

Several methods exist to carry out disaster impact assessments, which help gauge levels of vulnerability, evaluate disaster mitigation measures, and inform recovery and resilience-building efforts [9–11]. Many disaster impact assessment methodologies often stress the importance of focusing on equity. For instance, one of the most commonly deployed impact assessment methods, the Post Disaster Needs Assessment (PDNA), explicitly highlights the importance of “creating an enabling environment for women and girls, men and boys, communities as well as all sub-groups of the population, and governments to recover from the impact of disasters” ([12], 20). By including this statement, the PDNA guidelines include elements of recognitional equity by acknowledging that needs differ between specific subgroups of a population affected by disasters and of distributive equity by implicit sentiments to distribute recovery resources according to these needs.

However, beyond the direct costs estimated from physical damage to infrastructure and buildings, existing efforts to measure and include more indirect costs of disasters, such as business interruption costs and revenue losses arising from direct damage, as well as cultural or health impacts that are hard to quantify in monetary terms, are fraught with challenges. These challenges include time and resource constraints, given the immediate short-term pressures post-disaster [13], lack of data available [10,14,15], lack of consensus over basic concepts and methodological uncertainties [16], as well as overly short assessment time frames that preclude the ability to capture the full range of disaster outcomes [9,16]. Others have critiqued disaster assessment methodologies as being overly focused on what is easy to measure, such as physical damage, rather than what is substantively important, such as the lived experiences and needs of survivors, and in doing so fall short in their ability to guide transformative and equitable recovery [14,17,18].

Given the tremendous amount of money and resources being poured into disaster impact assessments and associated disaster recovery programs, there is a clear moral imperative to improve disaster program evaluations and impact assessments [18–20]. Despite the many well-argued critiques of disaster impact assessments, some of which are recapped above, few studies have empirically examined the degree to which disaster impact assessments have assessed differentiated disaster impacts, particularly on marginalized communities and households, in line with the recognitional and distributive forms of equity highlighted in PDNA guidelines. Such empirically-based evaluations of the disaster impact assessments are critical in guiding work to improve the methodology of disaster assessments.

This study seeks to address these empirical gaps by examining a post-disaster impact assessment that took place after the 2015 Nepal Earthquakes. On 25th April and 12th May 2015, two major earthquakes struck Nepal, which destroyed over half a million homes and took close to 9000 lives [21]. Soon after the second earthquake, a PDNA was conducted to help guide recovery and rehabilitation efforts. PDNAs are one of the most commonly cited and deployed methods of disaster impact assessments [9,22]. Of the many examples of PDNAs conducted, the Nepal PDNA has been highlighted as “a fine example of excellent collaborative direction and interagency coordination that led to exemplary outputs” ([23], 15). Other strong aspects of Nepal’s PDNA include “a focused approach that encouraged inclusion and common purposes over individual parties’ interests”; consultation with local communities and non-state actors, which was otherwise rare in other PDNAs ([23], 24); and the creation of a national recovery authority with supporting legislation and operational procedures to make effective use of PDNA outputs [23]. Nepal’s PDNA thus arguably represents the upper range of assessment quality that can be expected from a PDNA, which makes it a good case study of the assessment method.

Our research question is: To what extent did Nepal’s PDNA process accurately and comprehensively identify and guide post-disaster recovery initiatives for socially vulnerable population groups who were at risk of poorer post-disaster outcomes?

To answer this question, we first propose a set of characteristics that are typically understood to constitute social vulnerability within the Nepal context, and examine which of these might be associated with worse post-disaster outcomes. We empirically test whether these social vulnerability characteristics are associated with worse recovery outcomes, using survey data collected from a detailed household-level survey, the Informatics for Equitable Recovery (IER) Survey. Next, we compare whether the social vulnerability characteristics that predicted worse outcomes were identified and catered for, within Nepal’s PDNA report, as well as the subsequent Post-Disaster Recovery Framework (PDRF) developed based on the PDNA report. From this comparison, we explore the possible reasons for the equity-related blindspots, if any, and propose ways post-disaster needs assessment and related policies can be improved to achieve more equitable outcomes. Our findings are relevant to both Nepal and other countries in the region with similar social, economic, and cultural contexts, and which also experience environmental hazards.

2. Background

2.1. Overview of the PDNA process

A Post-Disaster Needs Assessment (PDNA) is an approach to conduct post-disaster assessments to support affected populations and governments in recovery and reconstruction, particularly when governmental capacities are exceeded by disaster impacts [24]. The PDNA process provides crucial consensus among local governments, aid organizations, and donors about crucial areas of need and priorities for aid, thus facilitating the government's request for recovery aid. As a PDNA is needed as soon as possible, ideally the first few months, after an event, a trade-off exists between the quantity and quality of post-disaster data collected to assess impacts [12]. Compared to previous established disaster assessment approaches like the Damage and Loss Assessment (DaLA), the PDNA brings equity considerations to the forefront, and has evolved with the intent of being more comprehensive and multi-sectoral, covering social and human development dimensions of recovery, in addition to more economically focused ones [23]. Currently, among the commonly conducted post-disaster assessments, the PDNA is the only comprehensive, multisectoral, and broad assessment to guide long-term recovery. In contrast, other assessments either focus primarily on damage estimation and mapping (often using remote sensing) or are geared towards guiding immediate humanitarian responses [22].

Broadly, the PDNA consists of four stages: 1. Establish baseline information to compare with post-disaster conditions; 2. Assessment of immediate disaster effects in terms of damage to infrastructure, physical assets and governance processes, amongst others; 3. Assessment of disaster impact in terms of macro-level, personal and household-level economic impacts; 4. Formulation of recovery strategy. Details of each stage has been documented elsewhere [12].

Findings and recommendations from PDNA processes typically influence the determination of resource requirements post-disaster, help affected countries corral funds from external and internal sources for recovery efforts, and guide government recovery and reconstruction efforts. Furthermore, the World Bank uses PDNAs for designing and approving disaster recovery grants and loans, and for developing extended national development programs [23].

2.2. Existing evaluations of PDNAs

While the PDNA is a well-established, well-used, and influential method of assessing disaster damage, it is not without its limitations. Hinzpeter and Sandholz [24] conducted an in-depth assessment of 39 PDNA reports completed between 2008 and 2016, and a qualitative empirical survey of 40 experts involved in these studies. Experts they surveyed reported a bias towards 'quantitative' assessments that estimate economic losses, which meant that impacts that are more difficult to quantify, such as that on community ties, individual wellbeing or the environment, received less attention. As a result, the recovery needs in sectors where quantitative assessments were difficult and which thus relied on more qualitative assessments, risked being under-catered for and thus under-funded, since donors relied on calculations in the PDNA report to allocate funds. In short, as quantitative assessments of impact typically focus on damage and losses this can lead to a bias in impact assessments towards physical impacts rather than socioeconomic needs [14].

Another evaluation of PDNAs, commissioned by the World Bank, EU, and UN, highlighted similar concerns. Jeggler and Boggero [23] examined 14 PDNAs conducted between 2014 and 2016, through interviews of different organizational representatives who participated in the studied PDNAs. They concluded that institutions tended to emphasize productive or commercial sector impacts at the expense of perceived 'softer' or less tangible concerns such as culture or inclusiveness and participation, as these are less easily quantified economically.

Furthermore, when PDNAs were deemed to be 'urgent' and thus operated on compressed timelines, less consideration was given to social or qualitative measures essential for assessing the human impact needs, which might include an assessment of the state of civil society; local community engagement and capacity; or health, educational and livelihood status of affected communities [23]. The lack of time was often cited as a reason for few field visits, or the use of consultative methods to collect inputs from affected populations. The lack of adequate qualitative data related to social conditions and human development parameters at disaggregated formats (e.g. at household or local community scale) means identifying particularly vulnerable or marginalized populations and their relative exposure to disaster impacts was particularly challenging.

Evaluations and critiques of the PDNA process, including the ones summarized here, tend to be qualitative studies. To the best of our knowledge, no systematic study has been conducted to assess the accuracy of PDNA findings based on more in-depth household and individual surveys of impacts and recovery outcomes.

2.3. Introduction to Nepal's 2015 PDNA process

To help guide recovery, reconstruction and rehabilitation efforts after the 2015 earthquakes, the Nepal government's National Planning Commission (NPC) coordinated a large-scale PDNA, involving other government ministries, private sector partners, civil society as well as development agencies like the United Nations, the World Bank, the Asian Development Bank, the European Union,

and the Japan International Cooperation Agency. One of the purported achievements of this PDNA process was how “the assessment and recovery planning process has paid particular attention to the issue of social inclusion of the most marginalized and vulnerable groups, including women, children, the aged, persons with disabilities” ([25], iii). The PDNA, which took place concurrently with on-going relief and early recovery efforts, was commissioned mere days after the May earthquake, and the assessment report was completed in less than a month [21].

The PDNA covered 23 thematic areas across social sectors, productive sectors, infrastructural sectors, and other cross-cutting sectors like governance, gender equity, and social inclusion (See Appendix A). For each sector, the team estimated total damages, covering damage to sector-specific infrastructure and assets; and losses due to changes in financial flows. Based on these estimations of damages and losses, each sector then derived a set of recovery needs, consisting of four components: 1) the reconstruction of damaged infrastructure and physical assets; 2) the resumption of production, services, and access to goods and services; 3) the restoration of governance processes; and 4) the risk reduction measures ([25], xxiv).

2.3.1. Findings and recommendations from the PDNA

The PDNA estimated approximately NPR 699 billion (USD 6.7 billion) would be needed to rehabilitate and reconstruct the nation. Of this sum, 48.7 % of recovery needs were estimated to be concentrated in the housing sector.

The PDNA report highlighted that poorer, rural locations, particularly rural central hills and mountain areas, were disproportionately affected compared to urban, less poor areas. The report also highlighted that within relatively prosperous areas such as the Kathmandu Valley households already poor or vulnerable were more exposed, particularly those in the bottom two income quintiles.

The report also highlighted gender, caste/ethnicity, disability status, and age as characteristics associated with vulnerable populations who may have experienced disproportionate impacts. When discussing housing damage and subsequent recovery, the report highlighted that the inequitable impacts from the earthquake fell onto women, Dalits (low caste), and some ethnic groups (unnamed in the report) because they had limited ownership of land which could make it hard for them to participate in housing recovery programs. Additionally, senior citizens, female-headed households, and people with disabilities were highlighted as likely to be heavily affected because they would lack the means to reconstruct their homes (pg xvii).

The PDNA report included strong statements about committing to equitable recovery, highlighting the need for efforts to have “a strong orientation towards the poorest and the most vulnerable” (pg xxi), highlighting the prioritization of distributive equity where recovery resources would be allocated towards vulnerable groups. Towards this end, the report included proposals of specific gender equality and social inclusion targeted initiatives, such as sustained support and monitoring of social protection issues, like cash transfers to most vulnerable households to reduce pressure on them to resort to negative coping mechanisms. The PDNA also recommended recovery strategies to safeguard, restore, and promote economic engagement of disadvantaged groups, such as promoting ‘alternative livelihoods’ to build resilience, and measures to support and promote the attainment of ownership and tenure rights particularly for women and vulnerable social groups; including “certification and registration of women and children to facilitate ownership of land and homes and citizenship”. Gender-responsive budgeting mechanisms within the government were proposed to be applied to all recovery and reconstruction programs (pg 63).

However, beyond this specific focus on the more ‘economic’ aspects of recovery, such as promoting income sufficiency and land ownership, there were few other concrete equity-oriented recommendations within the PDNA across most sectors. This is perhaps to be expected, as concrete recommendations would be formulated and incorporated in the subsequent Post-Disaster Recovery Framework (PDRF) that followed after the PDNA.

2.3.2. Overview of Nepal’s Post-Disaster Recovery Framework

On December 25, 2015, the National Reconstruction Authority (NRA) was established to plan and coordinate the implementation of the reconstruction and rehabilitation program. To guide the NRA’s work, the Post-Disaster Recovery Framework (PDRF) was developed for the five-year period between 2016 and 2020 (with a possible extension of one year), using the 2015 PDNA as a basis. In line with the PDNA, the PDRF sets out explicit objectives to reduce disaster risks and vulnerability, particularly of those most vulnerable. To this end, the PDRF repeatedly promises to provide “specialised assistance for those with special needs (for example, the poor, Dalits, pregnant women, single women, people with disabilities, children at risk and senior citizens)” ([25], 5) and to prioritize programs that would impact disadvantaged groups and/or locations ([25], 45). The measures proposed within the PDRF targeted at disadvantaged groups are largely centered around a) income resumption and b) housing reconstruction.

For income resumption initiatives, short-term measures include the cash transfer programs; improvement of existing administrative systems that provide quickly scalable temporary social protection schemes; and cash-for-work programs to mitigate income loss of those in affected areas (pg 7). The PDRF also emphasized that efforts would help re-establish the agricultural livelihoods of vulnerable earthquake-affected smallholder farms. For those working in the commerce and industry sectors, the PDRF highlighted the need to “promo[te] rights, decent employment, social protection, and social dialogue for ensuring representation of the informal sector” (pg 9).

In terms of housing reconstruction, the PDRF committed to giving “priority to vulnerable social groups, including women, children, people with disabilities and senior citizens, through well-established processes that provide support with reconstruction, assistance with employment and training, and better health care” (pg 14). For instance, a year into the reconstruction, an additional grant of NPR

50,000 was provided to those households deemed vulnerable, over and above the base amount disbursed to house-owners whose houses collapsed or were severely damaged (NRs 300,000) [6]. Additionally, the report promised that “efforts will be made to organize community groups to support the reconstruction of houses of single women, persons with disabilities, senior citizens, marginalized groups and communities living in remote and inaccessible areas” (pg 17). **Appendix A** includes a summary of the proposals.

2.3.3. Existing evaluations of the effectiveness of Nepal post-earthquake recovery initiatives

Rawal et al [6], in their evaluation of the effectiveness of Nepal’s post-earthquake reconstruction policies on the recovery of poor and vulnerable Nepalis, observed that “the defining criteria for the vulnerable households does not consider explicitly the structural inequities and deep-rooted social discrimination due to class and caste hierarchies” and that vulnerable groups such as Dalits, landless and chronically ill patients were left out. Furthermore, limitations of criteria aside, the authors observed that authorities had challenges accurately identifying who was considered vulnerable even within the constrained criteria, with large discrepancies between households identified as ‘vulnerable’ by the NRA, by local municipal governments, and other agencies. Authors argued that these challenges reflected the lack of inclusion and thus invisibility of vulnerable groups.

A community-based qualitative research study on three villages that were heavily affected by the earthquake found that “Already-marginalized groups with low social capital of all types were less able to access relief items and funding for rebuilding compared with those of higher social status or with political links”, which further suggests that the disbursement of funds accentuated existing vulnerabilities and inequities [26]. A similar observation was made by Shrestha et al [27], observing that those who were politically affiliated received more relief supplies than others who were not.

Additional social protection mechanisms such as cash transfers or cash-for-work schemes to support vulnerable groups that were proposed in the PDNA and PDRF were also not instituted or implemented [6]. Neither were specific guidelines nor operating procedures implemented to further the PDRF’s initial proposals to include the participation of women, vulnerable, and marginalized groups in reconstruction efforts through community-based organizations. Instead much of the post-disaster recovery efforts were top-down, centralized, and technocratic [6,27].

Other studies of post-disaster efforts reached similar conclusions about the weaknesses of actual implementation of equity-focused recovery plans, arguing that while the published disaster recovery plans seemed comprehensive and inclusive, government organizations and departments struggled with implementing the programs that were promised, including ones targeting gender equality and social inclusion [28]. In practice, scholars observed how gender-blind recovery efforts failed to address specific needs of women and girls, such as the inadequate provision of private spaces for them in temporary shelters, which in turn contributed to incidents of gender-based violence [27]. Researchers attributed these shortfalls to Nepal’s traditional patriarchal culture, and general lack of awareness around gender-related barriers to participation in recovery-related policy-making [28], as well as the exclusion of women in key disaster planning and management committees within the Nepal government [27].

Beyond critiques of the equity-focused aspects of Nepal’s recovery plans, much has also been written about how the proffered housing recovery grants were largely insufficient for full reconstruction, because of high construction and transportation costs, which in turn led to money-strapped families incurring heavy debt or failing to reconstruct [29]. The disbursement of grants was also encumbered by confusion over eligibility criteria and administrative delays [6,30,31].

2.4. Social vulnerability in Nepal

The concept of vulnerability has been defined in multiple ways, given the diverse epistemological grounding in fields such as hazard and disasters studies in geophysical sciences, geography, human ecology, political economy, and political ecology [32,33]. Some researchers focus on potential exposure to, or risk of, biophysical/technological hazards as its defining feature, while others see vulnerability in terms of inadequate coping responses when encountering hazards [34]. For this study, we adopt a working definition of “social vulnerability” as commonly understood by social scientists, which more closely maps to the latter definition of being a set of social, economic, and demographic factors that coalesce to determine people’s ability to cope with stresses [35].

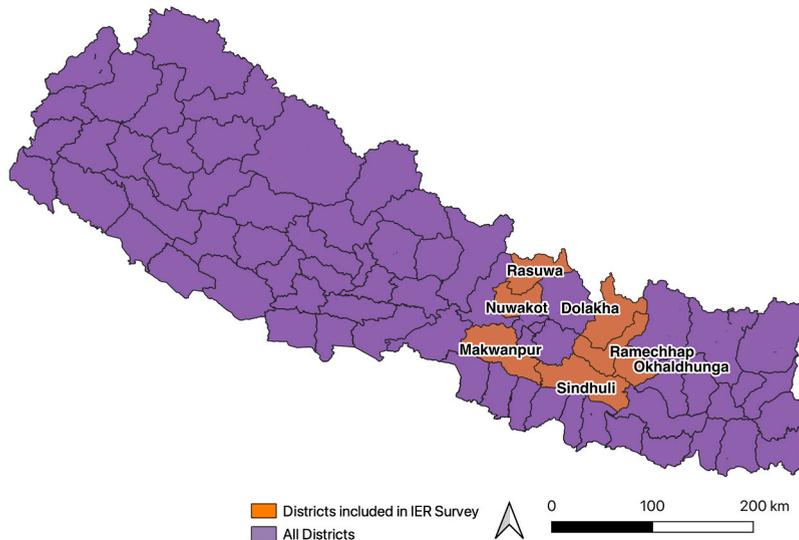
While social vulnerability is commonly described using individual characteristics (e.g. age, gender), it is important to note that these characteristics do not deterministically dictate social vulnerability. Instead, the broader societal and institutional structures and processes, such as racial/ethnic or caste-based discrimination, differential access to socio-economic-political power, and various place-based inequalities, are what generate social vulnerability among certain population groups, through marginalization, disproportionate exposures to hazards, and stymied access to resources [32,36,37]. The extent to which specific individual characteristics are associated with social vulnerability is highly context-specific [38]. For instance, women living where they have more access to legal rights, civil liberties, as well as educational, economic and other opportunities and resources would arguably be less socially vulnerable than those living in contexts where they have less access to such rights and resources [39]. Thus, any efforts to estimate social vulnerability should be adapted to the local context of its application. For our study, to operationalize the concept of social vulnerability, we focused on Nepal-specific studies—details of which we discuss in the next section on ‘Methods’.

Social vulnerability operates, and can be measured, at different spatial scales, ranging from the individual-, household-, and community-level, as well as other aggregated levels of administration such as municipality or country. For our study, we focus primarily on social vulnerability at the household-level because post-disaster aid, including the housing grants from the National Reconstruction Authority post-2015 earthquake, are typically allocated on a household basis [30,40].

3. Methods

3.1. Brief overview of IER study

Map of the seven districts included in the IER Survey



The IER study is a mixed-methods

qualitative and quantitative study of household-level impacts and recovery trajectories conducted four years after the April 2015 earthquake. The study investigates housing damage and reconstruction, along with more indirect impacts across many dimensions of household well-being. Household survey data were collected between April–June 2019 (n = 815), from 7 districts most affected by the earthquake: Dolakha, Makwanpur, Nuwakot, Okhaldhunga, Ramechhap, Rasuwa, and Sindhuli districts. Additionally, interviews were conducted with approximately 30 community leaders and affected residents. Details of the IER study are documented in elsewhere [41].

3.2. Analysis variables

3.2.1. Estimate of social vulnerability

As a measure of household-level social vulnerability, we compared and consolidated 11 broad measures proposed by various studies based in Nepal [6,36,42–47]. These measures are: total number of dependents; female-headed household; family members working elsewhere when the earthquake struck; education level of household members; ethnicity/caste; agriculture as the main source of income; sufficiency of household income before the earthquake; the employment status of family members; debt before the earthquake; and homeownership. For ethnicity/caste, we focus on three broad categories, namely ‘Dalits’, which refers those occupying the lowest caste in the Hindu caste system and who are a historically disadvantaged group in Nepal [48,49]; ‘Janajatis’, a term which refers to indigenous ethnic groups that do not fall under the Hindu caste system, many of whom occupy a lower status in Nepali society [50]; and finally all others that do not fall under these two groups.

Table 1 below summarizes these, while Appendix B provides details of how the household-level social vulnerability parameters were identified.

Table 1
Dimensions and Measures of Household Social Vulnerability, measuring respondent’s conditions/status before 2015 earthquake.

Dimension	Measures
Family structure (age, gender)	Total number of dependents (old >65 years; young <5 years) per Household Member Female-headed household (Yes/No) Head of household older than 70 years old (Yes/No) Whether they have household members working in another location (Yes/No)
Education	Highest education level of any current member of household
Ethnicity/Caste ¹	Dalits; Janajtis; Others
Poverty/Socioeconomic Status	Main source of household cash source: Agriculture vs Others Monthly household income sufficient to meet needs (Yes/No) Loans/Debt (Yes/No) Percent of household members employed
Renters/Homeownership Status	Whether the household owned their house (Yes/No)

3.2.2. Operationalization of disaster recovery

There have been several published assessments of the extent to which households have recovered from the 2015 Nepal earthquake. Most of assessments define and assess recovery along single dimensions, such as housing recovery (e.g. [14, 31]), or livelihood recovery (e.g. [51]). While such assessments are both important and necessary in assessing specific and targeted recovery efforts, such as those to help rebuild housing, or restore livelihoods, they are also limited in their ability to fully account for the complex and multidimensional phenomenon that is disaster recovery [52–55]. Insofar as the poorer recovery across multiple domains are likely to increase social vulnerability, having a more comprehensive measure of disaster recovery allows one to also better understand and tackle the causes of social vulnerability [42].

Scholars have thus sought to develop more comprehensive, multi-dimensional frameworks and measures of post-disaster recovery. An example of such a framework is the socioecological model proposed by Abramson et al. [53], which was developed and validated using data from displaced households from Louisiana and Mississippi USA, after Hurricane Katrina. Abramson et al's model defines disaster recovery according to the following five dimensions: Stable Housing, Social Roles, Economic Stability, Physical Health, and Mental Health. The proposed dimensions broadly echo other multi-dimensional recovery metrics deployed elsewhere around the world. A review of disaster recovery assessments in Asia highlight that housing, economy, perceptions of recovery and/or social–psychological quality of life are commonly measured dimensions of household-level recovery. Other dimensions include social roles and social capital, and physical health recovery, albeit less frequently [56]. Similarly, a review of evaluations of post-disaster recovery efforts, focused on Australia, New Zealand and to a lesser extent elsewhere, identified the following categories of recovery-related indicators that were commonly deployed: Economic, Social recovery (which folded in considerations of mental wellbeing), Built environment, and Natural environment [57].

Specific to recovery from the 2015 Nepal earthquakes, there have been few studies that define and measure individual or

Table 2
Dimensions of recovery [53].

Dimension	IERS Recovery Outcome Measure, as of point of survey (2019)	Measure Details
Stable Housing	Degree of repair/reconstruction completed on the previous house. Response categories are: ● "0 % (Not yet started)" ● "25 % (One quarter finished)" ● "50 % (Half finished)" ● "75 % (Three-quarters finished)" ● "100 % (Completely finished)"	1 = Completely finished repair/reconstruction 0 = Repair/reconstruction still incomplete
	Physical comfort of the current house compared to the house before the earthquake. Response categories are: ● "Much less" ● "Less" ● "A bit less" ● "Same level of comfort" ● "A bit more" ● "More" ● "Much more"	1 = Feel less physically comfortable in their house than before earthquake 0 = Feel as or more physically comfortable in their house compared to before the earthquake
Social Roles	Degree to which people in the community help each other out. Categories of responses are: ● People almost never help each other out, ● People seldom help each other out, ● People sometimes help each other out, ● People usually help each other out, ● People almost always help each other out	1 = The degree to which people in the community help each other out is less than before the earthquake 0 = The degree to which people in the community help each other out is the same or more than before the earthquake
Economic Stability	Change in monthly household cash income compared to before the earthquake. Income categories are: ● "Less than Rs. 10,000", ● "Rs. 10,000–20,000", ● "Rs. 20,000–30,000", ● "Rs. 30,000–50,000" ● "More than Rs. 50,000"	1 = Shifted to a lower category of monthly income compared to before the earthquake 0 = Stayed in the same or higher category of monthly income compared to before the earthquake
Physical Health	Assessment of individual's current general health compared to baseline health before earthquake.	1 = Perceived general health has worsened from before the earthquake 0 = Perceived general health is the same or better than before the earthquake
Mental Health	Individual's Primary Care Post Traumatic Stress Disorder (PC-PTSD) screening Score (4 item screening instrument) ¹	1 = Having a PC-PTSD score of 3 or more, which is indicative of potential PTSD 0 = Having a PC-PTSD score of 2 or less

Notes: 1. The PC-PTSD is a four-item screen that was designed for use in primary care and other medical settings. Should a respondent reply 'yes' to any three items, they would be considered to have been screened positively for potential PTSD, and follow-up tests and consultation would then need to be needed for diagnosis. The screening instrument has been widely used to screen military veterans in the U.S. for PTSD [59] as well as various other contexts, including primary care clinics; and in community settings with high-risk populations [60], and more recently to screen healthcare workers in New York City during the COVID-19 pandemic [61].

household-level recovery across multiple dimensions. To the best of our knowledge, we identified two such studies. The first study surveyed 400 households in Nepal nine months and 1.5 years after the 2015 earthquake to understand recovery trajectories, and measured recovery using 34 indicators which covered ability to rebuild and return home; access to basic services like electricity, cell phone, and Internet; impacts on herding, farming, forest product collection, and participation in wage labor and in tourism. This set of indicators however focus solely on material aspects of disaster recovery, and thus left out more qualitative and intangible aspects of recovery related to human wellbeing and social transformation—a limitation that the authors acknowledged [52]. Another study examining the recovery of small-farm households ($n = 79$) one year after the earthquake, created a set of 10 indicators that covered the following three broad categories: ‘Farming systems and livelihood’ (Farm inputs and production, water and soil, forest and pasture lands, livestock), ‘Community’ (community institutions, social and religious, self-reliance), and ‘Household’ (Housing, food security, sanitation and physical health) [58]. Based on the available studies that look at multidimensions of disaster recovery specific to Nepal, there do not seem to be a clearly validated, sufficiently comprehensive framework or indicator set that captures the multidimensional nature of recovery.

Thus, while Abramson’s et al.,’s 2010 socioecological framework of disaster recovery was not developed specifically for the Nepali context, we believe it is a comprehensive, valid and well-referenced starting point to examine post disaster recovery at a household level here in Nepal.

For this study, we operationalize recovery by measuring IER survey responses that capture Abramson et al.’s proposed five dimensions of recovery outcomes, and classifying responses into binary variables, as described in Table 2. Furthermore, as recovery is typically understood in reference to baseline, pre-event conditions, we choose to model recovery as ‘change’ between pre and post-earthquake levels of housing quality, community help, income and health, rather than absolute levels post-earthquake. For instance, a deterioration in levels of housing comfort, community help, income and health post-earthquake compared to pre-earthquake levels would constitute a clear lack of recovery, whereas a return to pre-earthquake or better levels of said outcomes would constitute recovery. One could reasonably debate whether returning to less-than-ideal conditions should be interpreted as recovery [56]. Thus, when interpreting our model findings, we included explicit acknowledgement of this potentially debateable assumption where relevant.

3.3. Proposed analytical approach

We fit a series of multilevel logistic regression models (Eqn (1.1) and Eqn (1.2)) to evaluate how predictor variables that capture household-level social vulnerability characteristics (Table 3) might be associated with the six recovery outcomes in the IER survey (Table 2).

Here, we decided to use binary logistic regression and dichotomized recovery variables to model each participant’s odds of being coded as ‘recovered’ or ‘not recovered’ for each outcome measure. Our choice of relying on binary logistic regressions, and thus a binary definition of ‘recovery’ and instead of more fine-grained categorisation of ‘recovery’ that would require ordinal or multinomial regressions hinges on several considerations:

First, utilizing an ordinal logistic regression would involve arguably holding unrealistic assumptions regarding proportional odds, whereby one assumes the relationship between the lowest category of each recovery outcome (i.e. ‘worsening’ health, income, community support etc since the earthquake) versus the other higher categories of the recovery outcome (i.e. ‘constant’ or ‘improved’ conditions since the earthquake) are the same as those that describe the relationship between the next lowest (i.e. ‘constant’) and higher recovery category (i.e. ‘improved’) [62]. Using multinomial logistic regressions would allow us to relax the assumption of proportional odds, but would require a larger sample size than either ordinal or binary logistic models to find similar effects. Given our study’s modest sample size, particularly of specific vulnerable subgroups of interest (e.g. Dalits, female-headed households) and uneven distribution across response categories resulting in some small counts of certain responses, a multinomial regression might result in overfitted results [63]. In addition to being able to side-step these constraints, a binary definition of recovery, while arguably simplistic, has the advantage of being simple to interpret. Similarly, the interpretation of modelled coefficients from a binary logistic regression, is more straightforward than those produced by more complex alternative modelling approaches [62].

As the IER survey participants were spatially clustered within different administrative units, we chose to use multilevel models with a random intercept for each VDC/municipality to account for this hierarchical structure of the data. Traditional logistic regression that do not account for this hierarchical structure would produce inaccurate standard error estimates. While it is also possible to account for clustering by adding VDC/municipality fixed effects, a multilevel random effects model has the advantage of allowing the modelling of VDC/municipality-level characteristics such as VDC/municipality-level social vulnerability scores, which the former approach does not allow [64].

Eqn (1.1) is the general model that relates household social vulnerability characteristics with each of these recovery outcomes, including individual-level ‘control’ variables of the participant’s gender and age. Subscript i indicates individual while subscript j represents VDC/municipality.

$$\text{Logit}(\text{Outcome}_{ij}) = \beta_{0j} + \beta_{1i} \text{Hhld Social Vulnerability}_{ij} + \beta_{2i} \text{Indiv Controls}_{ij} + e_{ij} \quad \text{Eqn 1.1}$$

where:

- Outcome_{ij} = Binary variable coding for different recovery outcomes (Table 2),
- $\text{Hhld Social Vulnerability}_{ij}$ = binary variables coded for each social vulnerability parameter (Table 3),
- $\text{IndivControls}_{ij}$ = individual-level control variables (age and gender).

β_1, β_2 = estimated coefficients for each predictor and control variable, and
 e_{ij} = individual-level residual

The models also include random effects, β_{0j} , as estimated through Eqn (1.2), in the form of random intercepts for each VDC/municipality to account for any unobserved VDC/municipality-level characteristics that might affect participant outcomes:

$$\beta_{0j} = \gamma_0 + u_j \quad \text{Eqn 1.2}$$

where:

γ_0 = overall intercept, and

u_j = VDC level residual

We also conducted a series of robustness checks. First we tested the addition of VDC/municipality social vulnerability estimates into the model, to test if it changes the estimated effects significantly. Here we use estimates of VDC/municipality-level social vulnerability from Aksha et al.'s social vulnerability index (2019), which has the important benefits of being contextualized to the Nepali context, and calculated using census data from 2011, capturing baseline conditions before the 2015 earthquake. Second, we tested the inclusion of a categorical variable coding for the degree of housing damage experienced from the 2015 earthquake ('mild-moderate', 'substantial damage', 'partial collapse', 'destroyed'). We also tested the addition of a binary variable coding for whether the respondent received NRA government grants to help with rebuilding of their damaged homes. Finally, using multilevel ordinal logistic regressions with the same predictor variables as the main models, we tested ordinal outcomes measures of recovery for house repair (not started; a quarter finished, half finished, three-quarters finished; 100 % finished), changes in housing comfort (worsened, constant, improved), community help (reduced, constant, improved), income (reduced, constant, increased) and general health (worsened, maintained, improved). We also fitted a multilevel linear regression modelling the raw PC-PTSD score as an outcome.

4. Results

4.1. Overview of survey population

The IER survey covered 815 participants, with an average age of 47 years old (s.d. 16.2), 47 % of respondents were women while the rest were men. At the time of the survey, the majority were employed, with only 2.5 % reporting otherwise. Table 3 summarizes respondents' household-level social vulnerability characteristics, and how they compare to the characteristics of the general population living within the 7 surveyed districts, as measured during the 2011 Nepal Census. Our study's sample population characteristics were broadly aligned with that of the general population living within the 7 districts, as far as we were able to match surveyed responses with national statistics. A few notable exceptions are worth highlighting: Relatively fewer IERS respondents had 'absentee' household members working abroad than those living in the 7 districts (4.9 % vs 18.9 %). We also saw a substantially larger percentage of IERS respondents identified as Janajatis, compared to the districts' proportion (80 % vs 60.7 %).

Table 4 provides an overview of their recovery parameters.

For household social vulnerability, measures of family members working elsewhere, elder-headed households, and lack of home ownership were dropped from subsequent analyses, due to a lack of variation as most respondents provided the same responses (See Table 3, grey cells).

ANOVA tests suggest significant correlations between being classified as Dalit, Janajati, or 'Others' with the various other household social vulnerability characteristics, namely having most of the household income from agriculture, being from an elder-headed household, and being in debt pre-earthquake. However, other than caste, pair-wise tests of correlation between all other non-caste variables found low correlation.

Similarly, pair-wise tests of correlation suggested low correlations between the different measures of recovery, except between completion of housing repair and housing comfort. Those who completed their house repairs were less likely to report worse house comfort compared to before the earthquakes, which makes intuitive sense. (See Appendix C for details of these correlational tests).

4.2. Multilevel regression models

Table 5 summarizes our regression results, where the top row lists all recovery outcomes and each subsequent row includes the odds-ratio estimate (and corresponding 95 % confidence interval (CI) and significance level, p, for the relevant household social vulnerability and individual variables included in our models.

The odds ratio represents the odds that an outcome might occur given a particular exposure or individual characteristics, compared to the odds of the outcome occurring in the absence of said exposure or characteristic. Here, an odds ratio greater than 1 thus indicates greater odds of the modelled recovery outcomes given the presence of the modelled predictor variable. Conversely, an odds ratio between 0 and 1 indicates lower odds of the modelled outcome associated with the predictor variable [65].

Reporting insufficient income pre-earthquake was associated with greater odds of poorer outcomes, including decreased housing comfort (1.8 times), worsened general health (2.1 times), and lower odds of having completed their house repair (0.5 times) four years after the earthquake. Additionally, having pre-earthquake debt was associated with almost double the odds of worse health four years after the earthquake, compared to households that did not.

Gender has a complex relationship with some recovery outcomes, namely house comfort and community help, and no relationship with others (see Table 5). Female-headed households had lower odds of worsened house comfort (0.4 times) and worsened community

Table 3
Household-level Social Vulnerability Characteristics from IERS.

	Household Measures of Social Vulnerability	Summary of respondents' characteristics	National Distribution for 7 districts
Family structure (age, gender)	Total number of dependents (old >65 years ; young <5 years) per Household Member	<p>Young 27% households who responded have at least 1 young person (younger than 5 years)</p> <p>Old 23.9% households who responded have at least 1 elderly person (including respondent themselves)</p> <p>Average Dependent ratio per household Mean(sd)=: 0.13 (0.19)</p>	Number of dependents per total population= 0.07
	Female-headed household (Yes/ No)	30.3% households were female headed	26% households were female headed
	Head of household older than 70 years old (Yes/No)	7.7% of households were headed by an elderly person	9% of households were headed by an elderly person
	Whether they have household members working in another location (Yes/No)	4.9% had a family member working elsewhere at the point of the earthquake	18.9% of households had an 'absentee' member
Education	Highest education level of any current member of household	<p>10.2% no formal education</p> <p>34.8% primary school</p> <p>44.8% secondary school</p> <p>8.0% university/ tertiary</p> <p>2.2% vocational qualification</p>	<p>Of population aged 5 years and above</p> <ul style="list-style-type: none"> • 6.21 % no formal education • 45% primary school • 30% secondary school education • 2% university and above • 0.1% others
Ethnicity/ Caste	Dalits; Janajatis; Others	<p>7.5% Dalits;</p> <p>80% Janajatis</p> <p>12% Others</p>	<p>7.6% Dalit</p> <p>60.7% Janajatis</p> <p>31.7% Others</p>
Poverty/ Socioeconomic Status	Main source of household livelihood before 2015 earthquake	<p>62.0% agriculture</p> <p>13.0% unskilled labor</p> <p>2.5% civil service</p> <p>13.8% skilled labor</p> <p>4.4% small business</p> <p>4.1% Other (e.g. remittances, pensions)</p>	<p>Population 10 years of age and over & considered economically active</p> <p>78% were in the agricultural industry</p>
	Total monthly income deemed insufficient to meet basic household needs, before 2015 earthquake	<p>26% of respondents deemed their monthly income insufficient to meet basic household needs</p> <p>40.1% earned less than 10k rupees</p> <p>31.4% earned between 10-20k</p> <p>18.7% earned between 20-30K</p> <p>8.1% earned between 30-50k</p> <p>1.7% earned more than 50k</p>	Income data not available from 2011 Census
	Loans/Debt before 2015 earthquake (Yes/No)	44.8% had some form of debt prior to the earthquake	Debt information not available from 2011 Census
	Percent of household members employed	Mean(sd)= 75.4%(21%)	62.1% of population ages 10 and over classified as economically active
Homeownership Status	Whether the household owned their house (Yes/No)	Most lived in household-owned houses. Only 0.9% (n=7) indicated they did not live in a house that was owned by their household. Furthermore, all 7 indicated they were living rent-free in houses owned by relatives	92.5% of households owned their housing

Note: the cells in grey are the measures that were dropped from the analysis because of insufficient variation.

help (0.3 times) four years after the earthquake, suggesting some resilience among these households. However, female respondents, specifically, had greater odds of worse outcomes of the same two recovery outcomes (2.2 times higher odds of worse housing comfort and 3.2 times higher odds of worse community help), such that the two effects essentially cancel each other out (see Appendix D for an explanation of this statistical inference). On these two recovery outcomes, while women in female-headed households (n = 224) fared no worse compared to men in male-headed households (n = 408), women in male-headed households (n = 160) had on average worse longer-term outcomes than the rest of their counterparts. Conversely, men in female-headed households had on average the best outcomes (n = 23) compared to the other above-mentioned groups. Gender did not have a significant relationship with other recovery outcomes.

Additionally, reporting having 'primary education or less' as the highest level of educational attainment within the household was associated with lower odds of reporting worsened general health as a result from the earthquake (0.5 times). Being Dalit or Janajati, which are ethnic/caste groups that are relatively lower status in Nepali society, as well as having a family income source pre-earthquake from agriculture were all associated with lower odds of reporting reduced income post-earthquake (0.2 and 0.3 times that of respondents who belonged to higher castes, and 0.5 times that of respondents who did not report agricultural income respectively.)

As outlined earlier, we conducted several robustness checks of our models. Including the VDC/municipality level social vulnerability measure into the models yielded largely identical estimates, which suggests our findings here are robust to differences in village-level social vulnerability. Similarly, controlling for the degree of housing damage, as well as for whether households received NRA government grants for reconstruction, yielded largely identical estimates.

Finally, our multi-level ordinal and linear regression models yielded broadly compatible findings, though with substantially lower loglikelihood scores and higher AIC scores than the binary models, which suggest poorer model fit. We thus focus on interpreting findings from our original set of models in the 'Discussion' section, with references to deviations from the ordinal models when relevant.

Appendix D includes tables summarizing results and discussion of these robustness checks.

5. Discussion

Nepal's PDNA process has been widely lauded as a successful demonstration of a post-disaster impact assessment, where multiple stakeholders, under extremely challenging conditions, pulled together to tackle the difficult task of accurately identifying and balancing post-disaster recovery needs. Much that was accomplished during the short three-week timeline was remarkable, including the production of extensive technical information and analysis; consultations with local communities; and the successful collaboration between multiple domestic and international partners [23]. At the same time, even this example of a PDNA process that used best

Table 4
Descriptive statistics about recovery outcomes from earthquake from IERS.

Stable Housing	<u>Repair/Reconstruction</u>
	19.6 % not started repairs
	3.8 % a quarter finished
	4.4 % half finished
	72.3 % completed
	<u>Quality of New House</u>
	10.5 % much more comfortable than house before 2015 earthquake
	8.2 % More comfortable
	25.6 % A bit more comfortable
	25.9 % Same as before
18.3 % A bit less	
9.0 % Less comfortable	
2.5 % A lot less comfortable	
Social Roles	<u>Community Life</u>
	92.8 % indicated similar levels of community help before and after earthquake by 2019
	3.1 % indicated increases;
Economic Stability	4.1 % indicated reductions in community help
	<u>Monthly Household Income</u>
	71.2 % indicated similar levels of monthly income before and after earthquake
Physical Health	19.2 % indicated income increase;
	9.5 % indicated reductions in income
	<u>General Health</u>
	81.2 % indicated no change in general health
Mental Health	7.4 % indicated improvement
	11.4 % indicated worsening of health
	<u>PTSD score (max = 4, indication of PTSD= >3)</u>
	3.1 % have a score of >3

practices presented equity-related blind spots. Our analyses suggest that groups that were identified as potentially being more vulnerable within Nepal’s PDNA report were not necessarily the groups that struggled most during recovery.

Our analyses suggest that belonging to a female-headed household might be somewhat ‘protective’ against worse recovery outcomes related to housing comfort and community help. These findings are surprising, given oft-held assumptions that female-headed households are less resilient to disasters than male-headed households, for several possible reasons. Scholars have argued that women may have less access to risk management strategies, land, credit, insurance and other assets or resources, which affect their ability to manage or cope with disaster risks. Female household heads are also often the sole adult member of the household, and are thus responsible for both generating income and domestic work [66]. Furthermore, published analyses of Nepal’s post-disaster efforts also suggest significant challenges in implementing proposed interventions that target gender inclusion and equity [6,27,28]. One possible and optimistic interpretation of our findings is that, even given the well-noted challenges in implementing gender-inclusive interventions in Nepal, female-headed households managed to utilize the support that was provided to recover reasonably well post-disaster, in terms of housing comfort and community support. Our findings thus provide some possible support for views that female-headed households may not be simply vulnerable, but may also have some characteristics that enable them to avoid worse recovery outcomes. For instance, other researchers have suggested that women who actively choose to establish themselves as household heads might be particularly independent, confident, and mobile, which in turn allows their households to better manage disaster risks [67,68].

At the same time however, our regression results suggest that female respondents, particularly those in male-headed households, saw poorer outcomes. Our findings are aligned with findings from other studies of the 2015 Nepal earthquake, as well as many other instances of disasters elsewhere in the world, which is that disasters tend to affect women and girls disproportionately in terms of morbidity, mortality and other negative impacts ([69,70,71]). Our findings here thus underscore the need to carefully consider not just

Table 5
Regression results of models estimating the relationship between household social vulnerability parameters and six separate recovery outcomes.

RECOVERY OUTCOMES						
	<i>Model 1</i>	<i>Model 2</i>	<i>Model 3</i>	<i>Model 4</i>	<i>Model 5</i>	<i>Model 6</i>
	House Repair Completed	House Comfort Worsened	Community Help Worsened	Reduced Income	Positive PTSD Screen	General Health Worsened
	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)
Household Social Vulnerability						
Dependents per Hhld member	1.05 (0.33, 3.33)	0.70 (0.25, 1.94)	0.78 (0.11, 5.69)	4.14 (0.96, 17.78)	0.40 (0.01, 11.17)	1.69 (0.44, 6.45)
Female Headed Hhld	1.31 (0.77, 2.24)	0.42*** (0.26, 0.68)	0.30* (0.10, 0.85)	0.64 (0.33, 1.25)	1.07 (0.21, 5.38)	1.12 (0.54, 2.32)
Elderly Headed Hhld	0.71 (0.25, 1.98)	0.62 (0.24, 1.61)	3.88 (0.79, 18.93)	1.98 (0.52, 7.53)	0.23 (0.02, 3.12)	1.36 (0.47, 3.92)
Primary education or less	0.90 (0.55, 1.47)	1.40 (0.93, 2.10)	1.41 (0.63, 3.16)	0.77 (0.42, 1.41)	1.44 (0.37, 5.56)	0.51* (0.28, 0.94)
Caste: Dalits	2.27 (0.79, 6.57)	0.34* (0.14, 0.84)	1.41 (0.24, 8.27)	0.15** (0.04, 0.58)	7.16 (0.35, 145.17)	0.76 (0.25, 2.29)
Caste: Janajatis	1.17 (0.55, 2.52)	0.54 (0.29, 1.02)	1.39 (0.36, 5.35)	0.34** (0.15, 0.74)	0.41 (0.04, 4.79)	0.35* (0.15, 0.83)
Agricultural Income	1.33 (0.80, 2.23)	0.82 (0.54, 1.25)	0.79 (0.32, 1.92)	0.47* (0.24, 0.91)	0.72 (0.25, 2.09)	0.75 (0.42, 1.34)
Insufficient Income	0.53* (0.32, 0.87)	1.78** (1.15, 2.75)	0.80 (0.30, 2.13)	1.11 (0.58, 2.14)	1.63 (0.57, 4.64)	2.09* (1.17, 3.72)
In Debt	0.79 (0.50, 1.27)	1.15 (0.77, 1.73)	0.88 (0.37, 2.09)	1.07 (0.59, 1.92)	1.03 (0.37, 2.82)	1.95* (1.11, 3.41)
Percent Hhld Employed	0.46 (0.16, 1.28)	1.51 (0.62, 3.68)	1.74 (0.28, 10.79)	0.61 (0.18, 2.11)	0.49 (0.04, 5.82)	0.49 (0.14, 1.71)
Individual Characteristics						
Female	0.77 (0.46, 1.28)	2.24*** (1.43, 3.50)	3.17** (1.35, 7.48)	1.06 (0.59, 1.91)	0.99 (0.23, 4.38)	0.93 (0.47, 1.86)
Age	1.00 (0.98, 1.02)	1.01 (1.00, 1.03)	1.00 (0.98, 1.03)	0.98* (0.96, 1.00)	1.06** (1.02, 1.11)	1.04*** (1.02, 1.06)
Intercept	7.59* (1.48, 38.82)	0.19* (0.06, 0.68)	0.01*** (0.00, 0.12)	1.43 (0.29, 6.99)	0.0002*** (0.00, 0.03)	0.05*** (0.01, 0.24)
Observations	632	737	746	741	738	749
Log Likelihood	-300.17	-378.14	-120.46	-220.19	-69.97	-219.55
Akaike Inf. Crit.	628.35	784.27	268.91	468.38	167.94	467.10
Bayesian Inf. Crit.	690.63	848.71	333.52	532.89	232.39	531.76

Note: ‘Hhld’ is short for ‘household’ Income-related and debt variables measure ‘pre-earthquake’ conditions. Reference categories: Male headed, non-elderly headed Hhld, more than primary education, non-Dalit nor Janajatis; no agricultural income, sufficient income and no debt prior to earthquake; male respondent.

*p < 0.05; **p < 0.01; ***p < 0.001.

the post-disaster needs of female-headed households, but also more generally to the gendered nature of disaster vulnerability, whether in Nepal or elsewhere [72]. We especially underscore that these findings should not be taken as reason to reduce aid to females or female-headed households. All in all, our findings suggest the need for a deeper dive into how the gender of household heads relate to the wellbeing of other household members in terms of recovery outcomes.

Another group identified as vulnerable in the PDNA report was poor households. Indeed, our analyses found having insufficient household income to be one of the most important predictor of poorer post-disaster outcomes, as it was associated with multiple worse recovery-related outcomes such as being less likely to complete house repairs; being more likely to report reduced housing comfort, as well as poorer general health compared to their more resourced peers, four years after the earthquake. Tentatively, these results suggest despite the PDNA/PDRF's emphasis on providing additional housing reconstruction support for vulnerable households to rebuild, poor families seemed to still suffer a deficit in terms of housing reconstruction. Researchers have argued that because the full award of reconstruction grants was contingent on grant recipients rebuilding 'earthquake safe buildings', which can be more expensive, low-income citizens were more likely to be excluded from this stream of rebuilding capital [36]. Others have also observed that, as of 2020, households identified by the NRA as 'vulnerable' have not yet received the proposed top-up grant housing assistance of NRs 50,000—which clearly highlights a gap between policy intent and implementation [6]. The theme of being unable to afford the costs of rebuilding also emerged strongly in our qualitative interviews, with practically all interviewees mentioning this as a major challenge within their villages. Our findings here thus echo findings from many other empirical studies: poor people have a lower ability to cope with and recover from disaster impacts than their richer counterparts. Our findings here reinforce equity concerns about the vicious cycle between poverty leading to worse post-disaster outcomes, which in turn reinforces poverty and exacerbates social vulnerability [73].

Our analyses also suggested that being in debt at baseline was associated with increased odds of reporting worsened health outcomes four years after the earthquake, when the outcome was modelled as a binary outcome indicator. As the PDNA was largely silent on the relationship between household debt and social vulnerability, this finding points to a potential blind spot in post-disaster recovery assessments. Incurring debt is a common coping response to shocks in Nepal [43]. After the 2015 earthquake. Many households had to take on debt to rebuild their damaged houses because the housing recovery grants offered were often insufficient to cover their reconstruction costs [30]. In our qualitative interviews, many respondents highlighted this very observation as well, and shared that this accrual of further debt by many households degraded and distressed their community, financially [41]. While there have been few studies analyzing the links between pre-disaster debt to post-disaster outcomes, one such study in the US have found that individuals with poor pre-disaster credit scores suffered worse disaster outcomes, in terms of credit score declines, mortgage delinquencies and foreclosure [74].

Studies have also found that poorer, remote, and female-headed households in Nepal tended to pay higher interest rates on their debt [43]. These more socially vulnerable groups are thus at higher risk of being mired in debt traps. It is thus important for post-disaster assessments to pay greater attention to household debt, to prevent already beleaguered households from getting deeper into debt, hindering their ability to recover, and further exacerbating their baseline vulnerability. A caveat to highlight is that this relationship between debt and health was not significant when we modelled post-earthquake changes in general health as an ordinal outcome with options of 'worse general health', 'no change in general health', and 'improved health' (see Appendix D).

Additionally, we found significant associations between being Dalit or Janajati, and lower likelihood of worsened health or reduced income post-earthquake. We also found associations between lower educational attainment and lower odds of worse health outcomes, as well as between relying on agriculture for income and lower odds of reduced income post-earthquake. An important factor contributing to these findings is that these groups, pre-earthquake, had worse health and income outcomes than their counterparts, and thus had less leeway to experience further worsening of said outcomes post-earthquake. For instance, respondents reporting Dalit and Janajatis castes were more likely to report poor or fair health pre-earthquake (42 % and 35 % of respondents respectively) as well as the lowest category of income of less than Rs 10,000 (32 %, and 43 % respectively) compared to other castes (33 % poor or fair health; 30 % lowest income category). Similarly, respondents from lower educated households were more likely to report poor or fair health pre-earthquake (37 % vs 34 %), while those reporting agriculture as the main source of income were slightly more likely to report having the lowest category of income pre-earthquake (41 % compared to 39 % of non-agricultural households). Thus when interpreting this finding, it is important to bear in mind that 'recovery' in the binary formulation of these outcomes might be a return to a state that was less than ideal in the first place. Additionally, these factors were not significant in the ordinal logistic regression models of general health and income changes (see Appendix D).

Our findings here underscore the importance of empirically validating how various theorized factors of social vulnerability might affect recovery, as well as the need to testing a comprehensive set of characteristics to avoid excluding any potentially vulnerable populations. Thus we recommend that the PDNA process also include a review of existing assessments of social vulnerabilities, such as pre-existing debt, within the relevant geographical context. If such assessments are lacking, the PDNA process might potentially include conducting a rapid assessment to cross-check the extent to which assumed parameters of social vulnerability actually overlap with observed or self-reported barriers to recovery, such as financial, social, and infrastructural obstacles. Doing so would enable a more tailored allocation of recovery resources.

The PDNA's and PDRF's articulated commitment to equitable recovery largely focused on income resumption and housing

rebuilding. Whilst these are indeed two critically important dimensions of recovery, our findings also suggest that focusing solely on these dimensions might be overly limiting. Our robustness checks (Appendix D, Tables D2 and D3) found receiving NRA grants to be associated with greater odds of completing house repairs and reduced odds of worsened housing comfort post-earthquake—an intuitive finding given that NRA grants were targeted as supporting house reconstruction. We also found that the suffering more housing damage from the earthquake were significantly associated with higher odds of completing house repair, as well as lower odds of worsened housing comfort. Again, this finding is intuitive, given that the assessed severity of housing damage formed the basis for disbursement of governmental grants, which in turn supported the completion of house repairs [22,40]. What was less expected was that neither housing damage nor receipt of NRA grants were significantly associated with any other recovery outcomes – a finding that aligns with our descriptive analyses of the pair-wise correlations between recovery outcomes, where we observed significant correlations between housing repairs and housing comfort but not with other recovery variables (see Appendix C, Fig C2). One interpretation might thus be that focusing on housing reconstruction alone might not be sufficient to support recovery in other, non-housing related arenas.

Our results point to health as another important dimension of longer-term recovery that need greater attention. To recap, we found that households reporting insufficient income, or were in debt prior to the earthquake had a greater odds of reporting worse health after the earthquake. As having poorer health can exacerbate poorer outcomes in the event of future disasters [75], our finding here has worrying implications about the future outcomes of these already socially vulnerable groups. Greater attentiveness to ensuring equitable recovery in the health domains, which has been flagged as much needed by other researchers looking specifically at Nepal's post-earthquake disaster assessment [17] thus needed. In our qualitative interviews, several interviewees highlighted this need for greater attention to health-related provisions. In particular, many respondents described the trauma and lasting sense of fear and uncertainty generated by the earthquake, and as well as the need for additional support for older adults in terms of medication, treatment, shelter and food[41]. Our findings here also point more generally to health being an important outcome that should be assessed as part of disaster risk reduction and recovery efforts in addition to the more 'typical' assessments of recovery from physical damage [76,77].

To better support communities in a holistic recovery, PDNAs could adopt a broader definition of recovery that encompasses economic, health, psychosocial, and environmental dimensions. Relatedly, the PDNA process, which currently prioritizes assessing quantifiable physical damage and livelihood impacts, should also incorporate assessments of community well-being, social cohesion, and health. A more comprehensive approach could guide policymakers to design interventions addressing not only housing and income but also mental health, social cohesion, and social capital. In doing so, PDNAs can better capture the full spectrum of post-disaster recovery needs. This expansion would ensure that policies are sensitive to both the immediate and long-term well-being of affected communities, thereby addressing recovery as a multifaceted and multidimensional process.

Recognizing recovery as a dynamic process, PDNAs could set the groundwork and promote scheduled follow-up assessments (e.g., quarterly or biannual) to monitor evolving recovery needs and capture impacts that may only emerge over time. These continuous assessments would provide vital, updated information on community recovery trajectories, supporting effective adaption of recovery strategies based on new or shifting priorities.

In sum, while several key dimensions of social vulnerability we found in our analyses of the IERS data corresponded with those highlighted in the PDNA/PDRF reports, there seems to be a sizeable gap between what the PDNA/PDRF process recommended would be needed to meet needs of the socially vulnerable, and what was eventually implemented. This finding underscores an urgent need for stronger accountability and monitoring processes to ensure that the formulated equity-centric recommendations from the PDNA process are implemented later in the recovery.

5.1. Limitations

The main source of data for this study is the IER household survey, which was deployed in rural districts that were most heavily impacted by the 2015 earthquake. Our findings thus may not be immediately applicable to districts that were less severely affected, and thus might have more collective resources to respond to affected households than heavily-hit districts with greater damage. There is therefore a possibility that different relationships between household-level vulnerability and disaster recovery exist in less affected, more urbanized districts. This study and its findings should thus be interpreted as a focused look at potential equity gaps relating to vulnerable populations that have been most impacted, and who arguably are in most need of post-disaster recovery support, which was also the focus of the PDNA and PDRF.

The IER household survey is also a cross-sectional survey, which precludes the ability to parse out any causal effects between the PDNA, subsequent policy interventions, and observed outcomes. Additionally, our study only captures responses at a specific timepoint (about five years) after the earthquake, which precludes the ability to examine recovery outcomes and trajectories at longer time-scales. As it is beyond the scope of this study to empirically analyze the actual policy implementation that flowed from the PDNA and PDRF processes, we relied instead on drawing connections between our analysis and key findings from other researchers who studied the post-disaster recovery efforts in Nepal. Given that this study is an exploratory and descriptive analysis of the PDNA process as implemented after the 2015 Nepal Earthquake, rather than an assessment of its causal impact, more research would be needed to pinpoint the causal mechanisms at play. Specifically, longitudinal surveys that start as early as possible post-disaster and which track

policy efforts, as well as individual outcomes over a sufficiently long period of time after the disaster, would have to be conducted in order to enable a causal assessment of the impact of post-disaster policies on recovery outcomes. Additionally, more regular and comprehensive nationwide surveys of social conditions can improve estimation of pre-disaster baselines.

While not validated specifically for the Nepal context, the four-item PC-PTSD as well as its updated 5-item screen have been deployed in Nepal [78,79]. The PC-PTSD five-item screen has also been deployed elsewhere in the region, in India [80]. While these previous deployments of the PC-PTSD within the South Asian context do provide positive assessments of the internal consistency of the PC-PTSD measure [78], and significant associations with other measures of mental health (e.g. GAD, PHQ-9 in Ref. [80]), both assessments are based on small sample sizes and cannot be considered proper validation of the PC-PTSD. While the PC-PTSD screen was chosen for this study because it is brief and easy to administer, and also possesses favourable psychometric qualities when tested in other contexts [81,82] we acknowledge the need for more research to robustly validate this measure within a Nepali context.

Relatedly, given the complex and context-specific nature of recovery after a disaster, identifying a good measure of recovery can be difficult, particularly in less-studied contexts outside the U.S [56]. Thus, it is important to systematically assess and validate measures of recovery, by testing various formulations and combinations of different indicators, so as to ascertain whether said measures are sufficiently robust, reliable, and comprehensive. As this task is beyond the scope of this study, our current formulation of recovery is necessarily limited. We thus reiterate the need to develop deeper understanding, definitions and empirical assessments of what 'recovery' might constitute, across different geographical contexts.

Finally, we were unable to fully examine several parameters of social vulnerability because of insufficient sample size. For non-homeownership and elder-headed households, these are vulnerable sub-groups that make up a relatively small proportion of populations within the study area, and thus were made up too small a sample within our study sample to model effectively. In order to fully account for the likely challenges these groups face in recovery, targeted studies would need to conduct specific over-sampling of these groups. As for households with 'absentee members', the likely difficulties recruiting this particular population, such as household heads being away and thus unable to participate, could have resulted in their under-representation in our study. Future studies would need to specifically target outreach efforts towards these households to ensure their perspectives and experiences are sufficiently accounted for.

5.2. Conclusion

Speaking to a current gap in the field, this study empirically examines how well disaster impact assessments, ostensibly committed to achieving equitable recovery, actually manage to achieve this important goal. Specifically, we compare Nepal's 2015 PDNA findings and subsequent policy recommendations against findings from a detailed household-level survey deployed four years after the earthquake and unpack whether and how the PDNA process managed to adequately identify which groups might be more vulnerable to experiencing worse post-disaster outcomes and thus might require greater support in recovery.

In doing so, we identify several potential equity-related blind spots within Nepal's PDNA process. First, while most of the vulnerable groups identified through our analysis were also accurately highlighted in the PDNA/PDRF reports as populations in need of greater support, there still exists a sizeable gap between PDNA and PDRF recommendations. For instance, our findings that belonging to a female-headed household was associated with more positive outcomes in some recovery dimensions. At the same time, being a woman was associated with worse post-disaster outcomes, which underscores the importance of directing recovery resources to women generally as a vulnerable group, and not simply targeting female-headed households. The 2015 PDNA and PDRF also paid scant attention to pre-existing household debt, which we found to be associated with worse post-disaster recovery outcomes. Future disaster impact assessments should be careful to consider the needs of households that were in debt before the event and the gender composition of households.

Our findings that poor households, and those in debt were more likely to suffer poorer post-disaster health also suggest that Nepal's PDNA and PDRF's efforts at equitable recovery are too narrowly focused on income resumption and housing reconstruction, at the expense of other important recovery outcomes such as physical and mental health. Given that good health is a critically important resource that has multiple implications on other domains of well-being, we recommend greater attentiveness to ensure equitable recovery in the health domains as part of future disaster impact assessments.

More broadly, given the pressing time constraints the PDNA process is under, expediency is prioritized, which can sometimes translate into an over-reliance on metrics of impact that prioritize ease of quantification, such as physical damage, over other more nuanced considerations, like the multiple dimensions of social vulnerability [14]. While the PDNA and PDRF took great care to identify households that might be vulnerable during Nepal's recovery process, it would have been challenging to presuppose all potential households vulnerable to negative recovery outcomes. Evaluating the equity implications of a PDNA, as we have done in this study, allows the possibility to close any disparities that might widen during the recovery.

CRediT authorship contribution statement

Shin Bin Tan: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Jamie W. McCaughey:** Writing – review & editing, Data curation. **Sabine Loos:** Writing – review & editing. **Nasala Maharjan:**

Writing – review & editing. **Sanjana Tadepalli:** Writing – review & editing, Conceptualization. **Feroz Khan:** Writing – review & editing, Project administration, Data curation. **David Lallemand:** Writing – review & editing, Project administration, Methodology, Funding acquisition, Data curation, Conceptualization.

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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.

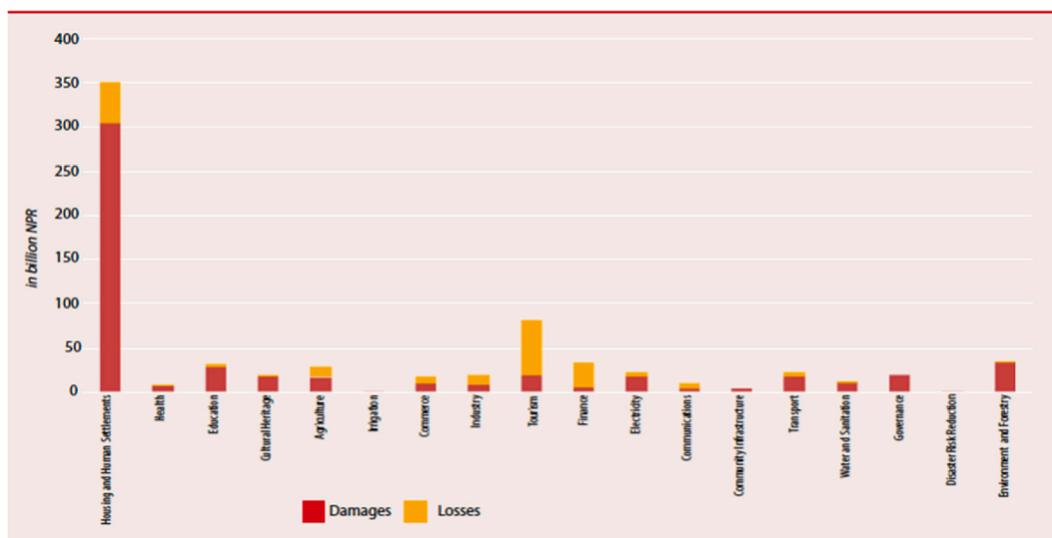
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Appendix A. Details of PDNA and PDRF proposals

Disaster effects (monetary costs) of the 2015 earthquakes were estimated along the following sectors:

- o Social Sectors (made up 58 % of estimated total costs; of which 86 % from housing sector damage)
 - § Housing and human settlements
 - § Health
 - § Nutrition**
 - § Education
 - § Cultural Heritage
- o Productive Sectors:
 - § Agriculture
 - § Irrigation
 - § Commerce
 - § Industry
 - § Tourism
 - § Finance
- o Infrastructure Sectors
 - § Electricity
 - § Communications
 - § Community infrastructure
 - § Transport
 - § Water and sanitation
- o Cross-cutting issues:
 - § Governance
 - § Disaster Risk Reduction
 - § Environment and Forestry



Source: Estimations by PDNA Team

Fig. 3. DISASTER EFFECTS ACROSS SECTORS, Source: Estimations by PDNA Team

The following paragraphs breakdown actual proposed financial requirements for proposed programs that explicitly target vulnerable populations, as proposed within the PDRF.

(A) Housing sector

1. Rural housing reconstruction program: vulnerable top-up subsidy–10,000 million NPR spread out across the 5 years
2. Urban Housing Reconstruction: vulnerable top up subsidy of 3000 million NPR spread out across 5 years
3. Rental housing for urban poor:250 million NPR over 5 years

(B) **Agriculture, livestock development and irrigation** that explicitly target vulnerable populations:

1. Targeted vulnerable group support programming (women, elderly, indigenous) through credits, grants and in-kind support: 162 million over 5 years

(C) Employment and livelihood

1. The report highlighted ‘targeted employment programme for women/elderly headed households’ but with no funding explicitly proposed
2. Similarly, there are line items for ‘cash grant support for livelihood activities’ and ‘enhancing livelihoods of marginalized people and earthquake victims in Makawanpur District’, but with no funding requirements specified.
3. Under sector ‘environment and forestry’ specifically, proposal for “empowerment and livelihood support to vulnerable groups considering gender and social inclusion”, for 2016 and 2017 (500 million NPR in total)

(4) **‘Gender and social inclusion’**. Total budget for this sector: 4641.5 million NPRK

This sector includes a variety of programs that seem to overlap with housing sector specific; livelihood specific programs. Eg.

1. ‘Special conditional cash support to most vulnerable groups to support reconstruction of their houses’, which would distribute an estimated 155 million NPR over two years.
 2. Skills development and livelihood enhancement support for vulnerable groups for economic revival (3100 million NPR over 5 years)
- (5) **‘Social Protection’** (total = 7758 million NPR)

This sector includes a described cash transfer to poor and vulnerable households (bottom 25 % in 14 affected districts) in 2016 (1856 million NPR).

Appendix B. Individual/Household-level social vulnerability parameters identified in other studies, and how these correspond to the chosen parameters included in this study

In order to identify which social vulnerability parameters to include in our analysis, we first conducted a literature review of relevant reports or studies of social vulnerability that was specific to the Nepali context, which identified parameters of social vulnerability [6,36,42–47]. We then picked parameters that were most commonly cited across the reports and studies, and which were also measured in the IER survey.

Table C1
summarizes the stocktake of social vulnerability parameters across the various studies.

Categories	Parameter	Rawal et al 2021	Hülssiep et al., 2020	He et al 2018	Walker et al., 2019	Nagami et al 2021	Bhusal & Bhattarai, 2023	Gerlitz et al., 2014*	Pandey & Bardsley, 2015
Family structure (age, gender)	Households headed by orphans of less than 16 years old	Yes (indiv)				Yes	Yes		
	Households headed by women (some specify 65 years old or higher)	Yes (indiv)	Yes (indiv)			Yes	Yes	Yes	Yes
	Households headed by elderly of 70 years old or higher	Yes (indiv)			Yes (indiv)	Yes	Yes		
	Dependency Ratio							Yes	Yes
Education	Educational levels							Yes	Yes
Caste/Ethnicity	Caste/Ethnicity	Yes (indiv)	Yes (indiv)	Yes (including indiv)					
Poverty/ Socioeconomic Status Debt and Loans	Household income		Yes	Yes	Yes				Yes
	Economic/ Poverty status								
	Employment status								
	Remittances received?							Yes	
	Single occupation household / Diversity of income			Yes				Yes	
	Occupation type (e.g. farming vs non-farming; climate sensitive occupations)			Yes				Yes	Yes
	Access to agricultural land							Yes	
Cash Crop diversity							Yes		
Asset Ownership	Household debt							Yes	Yes
	Access to loans							Yes	
	Asset ownership (e.g. land ownership; size of land etc.; livestock; household possessions etc)	Yes (indiv)			Yes			Yes	Yes
	Quality of agricultural land (slope, irrigation, soil quality etc)						Yes		
Health/ Disability	Households headed by government-authorized disabled people	Yes (indiv)			Yes (indiv)	Yes	Yes		Yes
	Household members who are seriously ill							Yes	
	Afford healthcare							Yes	
Consumption of food (food security) and other goods	Household food insecurity/ food consumption							Yes	Yes
	Consumption of non-food products							Yes	
Quality of Living Environment (including Accessibility)	Remote location		Yes (indiv)		Yes				
	Quality of building		Yes					Yes	
	Access to water, electricity, sanitation		Yes					Yes	
	Physical accessibility to necessary amenities and services (e.g. to health facilities, bus stops etc)							Yes	
Past experiences with hazard exposures	Experienced effects of climate change								Yes
	Experienced environmental and economic shocks							Yes	
	Kinship and neighborhood support; social networks							Yes	Yes
Social Networks and Participation	Political influence		Yes				Yes		
Coping/ Adaptation strategies	Level of adoption of adaptation strategies (to climate change)							Yes	Yes
	Livelihood coping strategies							Yes	

Key: Bolded and Greyed Cells indicate the chosen categories and parameters included in our analysis.

Appendix C. Tests of correlation between Model Variables

Table C1
Results from One-way ANOVA Tests of the relationship between caste categories and other social vulnerability variables

Variable	fval	pval
Dependents per Household member	0.54	0.585
Female Headed Household	1.06	0.346
Elderly Headed Household	10.88***	0
Primary education or less	1.02	0.361
Agricultural Income	5.57***	0.004
Insufficient Income	0.72	0.488
In Debt	3.59*	0.028
Percent Household Employed	2.79	0.062

Note: *p < 0.05; **p < 0.01; ***p < 0.001.

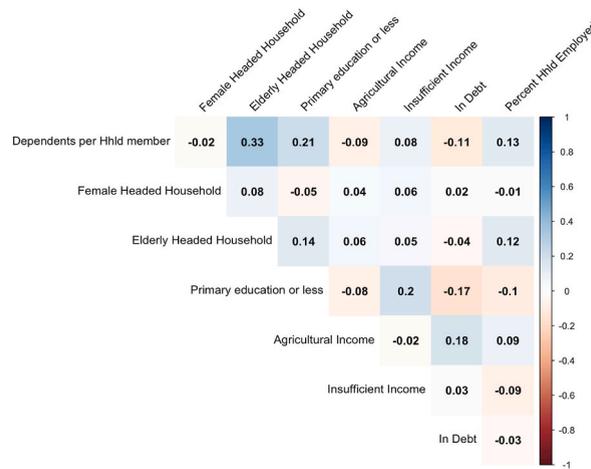


Fig. C1. Plot of pair-wise Pearson's correlation coefficients between social vulnerability variables (excluding caste)



Fig. C2. Plot of pair-wise Pearson's correlation coefficients between recovery measures

Appendix D. Statistical details and robustness checks

Interpretation of combined effect of gender of household head and gender of survey respondent

In the Results we examine the combined effect of gender of the household head and gender of the survey respondent on recovery outcomes of house comfort and community help (Models 2 and 3, Table 5). We examine this as an additive effect of the coefficients of these two variables. Table 5 reports odds ratios for ease of explanation; we calculated these by exponentiating the correlation coefficients which are in log-odds terms. These log-odds coefficients can be interpreted as additive effects, which is equivalent to multiplying the odds ratios. For worsened household comfort, relative to the reference category of males in male-headed households, females (OR = 0.4) in female-headed households (OR = 2.24) have an odds ratio of $0.4 \times 2.24 = 0.94$, which is very close to 1 indicating little substantive difference between these groups. Similarly, for worsened community help, relative to the reference category of males in male-headed households, females (OR = 0.3) in female-headed households (OR = 3.17) have an odds ratio of $0.3 \times 3.17 = 0.95$, also indicating little substantive difference between these groups. This is the basis for our interpretation that the ‘negative’ associations of being a woman and the ‘positive’ associations of belonging to a female-headed household largely cancel out. For the other comparisons noted in the text, we interpret odds ratios from single variables accordingly (i.e. for males in female-headed households, the odds ratio for gender of the household head; for females in male-headed households, the odds ratio for individual gender).

Robustness Checks

TABLE D1
With VDC/Municipality SOVI estimates

RECOVERY OUTCOMES						
	<i>Model 1</i>	<i>Model 2</i>	<i>Model 3</i>	<i>Model 4</i>	<i>Model 5</i>	<i>Model 6</i>
	House Repair Completed	House Comfort Worsened	Community Help Worsened	Reduced Income	PTSD	General Health Worsened
	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)
Household Social Vulnerability						
Dependents per Hhld member	1.05 (0.33, 3.33)	0.70 (0.25, 1.93)	0.78 (0.11, 5.68)	4.14 (0.96, 17.80)	0.40 (0.01, 11.26)	1.74 (0.45, 6.65)
Female Headed	1.31 (0.77, 2.24)	0.42*** (0.26, 0.68)	0.30* (0.11, 0.85)	0.64 (0.33, 1.25)	1.04 (0.20, 5.27)	1.11 (0.54, 2.30)
Elderly Headed	0.71 (0.25, 1.97)	0.62 (0.24, 1.61)	3.90 (0.80, 19.07)	1.98 (0.52, 7.53)	0.22 (0.02, 3.13)	1.34 (0.47, 3.86)
Primary education or less	0.90 (0.55, 1.47)	1.40 (0.93, 2.12)	1.42 (0.63, 3.19)	0.77 (0.42, 1.41)	1.45 (0.37, 5.67)	0.50* (0.28, 0.92)
Caste: Dalits	2.28 (0.79, 6.58)	0.34* (0.14, 0.83)	1.37 (0.23, 8.10)	0.15** (0.04, 0.58)	7.28 (0.34, 154.73)	0.78 (0.26, 2.35)
Caste: Janajatis	1.17 (0.55, 2.52)	0.54 (0.29, 1.01)	1.35 (0.35, 5.22)	0.34** (0.15, 0.74)	0.40 (0.03, 4.74)	0.38* (0.16, 0.93)
Agricultural Income	1.33 (0.80, 2.23)	0.82 (0.54, 1.25)	0.80 (0.33, 1.98)	0.47* (0.24, 0.91)	0.72 (0.25, 2.08)	0.70 (0.38, 1.29)
Insufficient Income	0.53* (0.32, 0.87)	1.79** (1.16, 2.77)	0.82 (0.31, 2.19)	1.11 (0.58, 2.14)	1.60 (0.56, 4.58)	2.06* (1.16, 3.66)
In Debt	0.79 (0.50, 1.27)	1.15 (0.76, 1.72)	0.89 (0.38, 2.11)	1.07 (0.59, 1.92)	1.03 (0.38, 2.83)	1.90* (1.08, 3.35)
Percent Hhld Employed	0.46 (0.16, 1.28)	1.53 (0.62, 3.73)	1.79 (0.29, 11.12)	0.61 (0.18, 2.11)	0.49 (0.04, 5.77)	0.48 (0.14, 1.66)
Individual Controls						
Female	0.77 (0.46, 1.28)	2.23*** (1.43, 3.49)	3.13** (1.32, 7.39)	1.06 (0.59, 1.91)	1.02 (0.23, 4.56)	0.95 (0.48, 1.90)
Age	1.00 (0.98, 1.02)	1.01 (1.00, 1.03)	1.00 (0.97, 1.03)	0.98* (0.96, 1.00)	1.06** (1.02, 1.11)	1.04*** (1.02, 1.06)
VDC SOVI	0.93 (0.37, 2.32)	1.16 (0.67, 2.03)	1.10 (0.69, 1.76)	0.99 (0.59, 1.68)	0.42 (0.04, 4.20)	0.78 (0.51, 1.17)
Intercept	6.73 (0.76, 59.22)	0.25 (0.05, 1.15)	0.01*** (0.00, 0.17)	1.42 (0.23, 8.65)	0.0000** (0.00, 0.06)	0.03*** (0.01, 0.18)
Observations	632	737	746	741	738	749
Log Likelihood	-300.16	-378.00	-120.38	-220.19	-69.64	-218.87
Akaike Inf. Crit.	630.32	785.99	270.76	470.38	169.29	467.75
Bayesian Inf. Crit.	697.05	855.03	339.98	539.50	238.35	537.03

Note: 'Hhld' is short for 'household' Income-related and debt variables measure 'pre-earthquake' conditions.

Reference categories: Male headed, non-elderly headed Hhld, more than primary education, non-Dalit nor Janajatis; no agricultural income, sufficient income and no debt prior to earthquake; male respondent.

*p < 0.05; **p < 0.01; ***p < 0.001.

TABLE D2
With variable coding for degree of housing damage from 2015 earthquakes

RECOVERY OUTCOMES						
	<i>Model 1</i>	<i>Model 2</i>	<i>Model 3</i>	<i>Model 4</i>	<i>Model 5</i>	<i>Model 6</i>
	House Repair Completed	House Comfort Worsened	Community Help Worsened	Reduced Income	PTSD	General Health Worsened
	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)
Household Social Vulnerability						
Dependents per Hhld member	0.86 (0.24, 3.04)	0.68 (0.24, 1.95)	0.82 (0.11, 5.91)	4.06 (0.94, 17.49)	0.40 (0.01, 12.16)	1.66 (0.43, 6.36)
Female Headed	1.17 (0.67, 2.06)	0.43*** (0.26, 0.71)	0.28* (0.10, 0.80)	0.64 (0.32, 1.25)	1.02 (0.21, 5.06)	1.12 (0.54, 2.32)
Elderly Headed	0.93 (0.31, 2.75)	0.58 (0.22, 1.52)	3.58 (0.74, 17.38)	1.92 (0.50, 7.34)	0.19 (0.01, 2.72)	1.36 (0.47, 3.94)
Primary education or less	0.71 (0.42, 1.20)	1.61* (1.05, 2.47)	1.46 (0.63, 3.38)	0.77 (0.42, 1.41)	1.60 (0.40, 6.41)	0.50* (0.27, 0.92)
Caste: Dalits	1.66 (0.55, 5.00)	0.40 (0.16, 1.00)	1.68 (0.29, 9.89)	0.15** (0.04, 0.59)	7.64 (0.38, 154.92)	0.73 (0.24, 2.22)
Caste: Janajatis	1.27 (0.58, 2.79)	0.50* (0.27, 0.96)	1.28 (0.33, 4.92)	0.33** (0.15, 0.73)	0.38 (0.03, 4.47)	0.36* (0.15, 0.85)
Agricultural Income	1.41 (0.81, 2.44)	0.81 (0.52, 1.25)	0.76 (0.31, 1.86)	0.47* (0.24, 0.91)	0.70 (0.24, 2.07)	0.75 (0.42, 1.35)
Insufficient Income	0.44** (0.25, 0.75)	1.96** (1.25, 3.07)	0.86 (0.32, 2.32)	1.13 (0.59, 2.18)	1.52 (0.51, 4.52)	2.13* (1.19, 3.79)
In Debt	0.84 (0.51, 1.37)	1.16 (0.76, 1.76)	0.82 (0.35, 1.94)	1.06 (0.59, 1.92)	1.14 (0.40, 3.23)	1.97* (1.12, 3.46)
Percent Hhld Employed	0.52 (0.18, 1.52)	1.52 (0.62, 3.77)	1.70 (0.28, 10.45)	0.60 (0.17, 2.09)	0.48 (0.04, 5.73)	0.51 (0.15, 1.76)
Individual Controls						
Female	0.82 (0.48, 1.40)	2.28*** (1.44, 3.60)	3.18** (1.34, 7.56)	1.06 (0.59, 1.90)	0.90 (0.21, 3.92)	0.94 (0.47, 1.86)
Age	1.00 (0.98, 1.02)	1.01 (1.00, 1.03)	1.00 (0.98, 1.03)	0.98* (0.96, 1.00)	1.07** (1.02, 1.12)	1.04*** (1.02, 1.06)
Degree of Housing Damage						
Substantial	4.33*** (2.20, 8.51)	0.38** (0.20, 0.72)	0.44 (0.13, 1.53)	0.82 (0.38, 1.74)	2.21 (0.54, 9.02)	1.02 (0.45, 2.33)
Partial Collapse	3.85*** (1.77, 8.39)	0.49* (0.25, 0.96)	0.54 (0.14, 2.02)	1.05 (0.41, 2.67)	0.74 (0.10, 5.43)	1.41 (0.59, 3.35)
Destroyed	11.40*** (5.49, 23.68)	0.24*** (0.13, 0.45)	0.59 (0.20, 1.75)	0.97 (0.41, 2.30)	0.76 (0.15, 3.93)	1.24 (0.59, 2.61)
Intercept	2.13 (0.45, 10.03)	0.37 (0.09, 1.42)	0.02** (0.00, 0.21)	1.51 (0.29, 7.94)	0.0002** (0.00, 0.03)	0.04*** (0.01, 0.22)
Observations	632	737	746	741	738	749
Log Likelihood	-272.48	-366.25	-119.38	-219.99	-69.10	-219.18
Akaike Inf. Crit.	578.96	766.50	272.76	473.99	172.21	472.36
Bayesian Inf. Crit.	654.59	844.75	351.21	552.33	250.47	550.88

Note: 'Hhld' is short for 'household' Income-related and debt variables measure 'pre-earthquake' conditions.

Reference categories: Male headed, non-elderly headed Hhld, more than primary education, non-Dalit nor Janajatis; no agricultural income, sufficient income and no debt prior to earthquake; male respondent.

*p < 0.05; **p < 0.01; ***p < 0.001.

TABLE D3

With variable coding for whether household received NRA grants to rebuild

RECOVERY OUTCOMES						
	<i>Model 1</i>	<i>Model 2</i>	<i>Model 3</i>	<i>Model 4</i>	<i>Model 5</i>	<i>Model 6</i>
	House Repair Completed	House Comfort Worsened	Community Help Worsened	Reduced Income	PTSD	General Health Worsened
	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)
Household Social Vulnerability						
Dependents per Hhld member	0.87 (0.24, 3.15)	0.71 (0.24, 2.08)	1.05 (0.15, 7.64)	3.63 (0.79, 16.71)	0.72 (0.03, 18.31)	1.93 (0.50, 7.49)
Female Headed Household	1.23 (0.67, 2.27)	0.40*** (0.24, 0.68)	0.36 (0.13, 1.02)	0.66 (0.33, 1.34)	0.82 (0.16, 4.36)	1.14 (0.55, 2.37)
Elderly Headed Household	1.41 (0.37, 5.29)	0.54 (0.19, 1.50)	2.71 (0.49, 15.06)	1.84 (0.43, 7.83)	0.38 (0.03, 5.78)	1.31 (0.43, 3.93)
Primary education or less	0.79 (0.46, 1.36)	1.38 (0.90, 2.12)	1.56 (0.68, 3.58)	0.82 (0.44, 1.52)	1.06 (0.25, 4.48)	0.47* (0.25, 0.87)

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TABLE D3 (continued)

RECOVERY OUTCOMES						
	<i>Model 1</i>	<i>Model 2</i>	<i>Model 3</i>	<i>Model 4</i>	<i>Model 5</i>	<i>Model 6</i>
	House Repair Completed	House Comfort Worsened	Community Help Worsened	Reduced Income	PTSD	General Health Worsened
	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)
Caste: Dalits	1.68 (0.45, 6.22)	0.39 (0.14, 1.03)	1.31 (0.22, 7.79)	0.10** (0.02, 0.52)	5.68 (0.29, 111.71)	0.66 (0.21, 2.04)
Caste: Janajatis	0.81 (0.31, 2.10)	0.62 (0.31, 1.23)	1.06 (0.27, 4.21)	0.30** (0.13, 0.70)	0.36 (0.03, 4.29)	0.30** (0.12, 0.74)
Agricultural Income	1.36 (0.77, 2.38)	0.92 (0.59, 1.45)	0.80 (0.33, 1.97)	0.44* (0.22, 0.87)	0.72 (0.23, 2.22)	0.76 (0.42, 1.37)
Insufficient Income	0.54* (0.31, 0.93)	1.82** (1.16, 2.85)	0.81 (0.30, 2.17)	1.09 (0.55, 2.14)	1.78 (0.55, 5.75)	2.20** (1.23, 3.94)
In Debt	0.59 (0.34, 1.01)	1.16 (0.75, 1.78)	0.93 (0.38, 2.26)	0.97 (0.52, 1.82)	0.91 (0.31, 2.68)	1.96* (1.11, 3.47)
Percent Hhld Employed	0.35 (0.11, 1.12)	1.57 (0.61, 4.04)	1.22 (0.19, 7.68)	0.60 (0.16, 2.20)	0.97 (0.07, 12.60)	0.47 (0.13, 1.68)
<i>Individual Controls</i>						
Female	1.08 (0.60, 1.95)	2.19** (1.36, 3.51)	2.95* (1.22, 7.14)	0.91 (0.49, 1.68)	1.11 (0.25, 4.97)	0.96 (0.48, 1.92)
Age	1.00 (0.99, 1.02)	1.01 (1.00, 1.03)	1.00 (0.97, 1.03)	0.97* (0.95, 1.00)	1.06* (1.01, 1.11)	1.04*** (1.02, 1.06)
<i>Received NRA Grants</i>	5.59*** (3.01, 10.37)	0.37*** (0.21, 0.64)	0.79 (0.27, 2.25)	0.63 (0.31, 1.29)	2.49 (0.65, 9.48)	1.46 (0.69, 3.10)
<i>Intercept</i>	3.90 (0.58, 26.08)	0.29 (0.07, 1.23)	0.02** (0.00, 0.27)	2.72 (0.46, 15.94)	0.0001*** (0.00, 0.02)	0.04*** (0.01, 0.24)
Observations	601	708	714	708	705	716
Log Likelihood	-239.47	-341.70	-114.34	-202.87	-64.04	-210.49
Akaike Inf. Crit.	508.94	713.40	258.68	435.73	158.08	450.99
Bayesian Inf. Crit.	574.92	781.83	327.25	504.17	226.45	519.59

Note: 'Hhld' is short for 'household' Income-related and debt variables measure 'pre-earthquake' conditions.

Reference categories: Male headed, non-elderly headed Hhld, more than primary education, non-Dalit nor Janajatis; no agricultural income, sufficient income and no debt prior to earthquake; male respondent.

*p < 0.05; **p < 0.01; ***p < 0.001.

DETAILED RECOVERY OUTCOMES (Ordinal/Numeric)						
	<i>Model 1</i>	<i>Model 2</i>	<i>Model 3</i>	<i>Model 4</i>	<i>Model 5</i>	<i>Model 6</i>
	Extent of House Repair Completed	Change in House Comfort	Change in Community Help	Change in Income	PTSD score	Change in General Health
	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Beta Coef (95 % CI)	Odds Ratios (95 % CI)
<i>Household Social Vulnerability</i>						
Dependents per Hhld member	1.17 (0.38–3.54)	1.26 (0.54–2.91)	0.69 (0.14–3.34)	0.36* (0.14 to 0.93)	-0.18 (-0.44 to 0.09)	1.04 (0.36–3.06)
Female Headed Hhld	1.39 (0.82–2.35)	2.29*** (1.55 to 3.38)	1.79 (0.86–3.71)	0.94 (0.61–1.45)	0.04 (-0.08 to 0.16)	0.98 (0.59–1.62)
Elderly Headed Hhld	0.69 (0.25–1.90)	1.21 (0.56–2.60)	0.35 (0.08–1.43)	1.42 (0.60–3.37)	-0.22 (-0.46 to 0.03)	0.37 (0.15 to 0.93)*
Primary education or less	0.94 (0.59–1.50)	0.77 (0.55–1.07)	0.80 (0.43–1.49)	1.01 (0.70–1.45)	0.01 (-0.10 to 0.11)	0.97 (0.64–1.47)
Caste: Dalits	2.39 (0.83–6.87)	2.66** (1.28 to 5.56)	0.59 (0.15–2.27)	2.19 (1.00–4.83)	0.13 (-0.09 to 0.35)	1.03 (0.42–2.54)
Caste: Janajatis	1.25 (0.59–2.65)	1.28 (0.74–2.23)	0.62 (0.24–1.66)	2.31 (1.25 to 4.26)**	-0.02 (-0.19 to 0.15)	1.20 (0.62–2.30)
Agricultural Income	1.30 (0.79–2.13)	1.48* (1.07 to 2.06)	1.81 (0.96–3.40)	1.52 (1.05 to 2.21)*	-0.07 (-0.17 to 0.04)	1.42 (0.94–2.15)
Insufficient Income	0.55 (0.35 to 0.89)*	0.63** (0.44 to 0.89)	1.13 (0.57–2.21)	0.68 (0.45–1.01)	0.11 (-0.01 to 0.22)	0.46 (0.28 to 0.74)**
In Debt	0.84 (0.53–1.32)	0.93 (0.67–1.28)	0.63 (0.34–1.16)	1.28 (0.89–1.83)	0.07 (-0.03 to 0.17)	0.69 (0.45–1.04)
Percent Hhld Employed	0.47 (0.17–1.28)	0.59 (0.29–1.19)	1.01 (0.26–3.88)	1.11 (0.50–2.45)	0.10 (-0.12 to 0.32)	1.53 (0.61–3.82)
<i>Individual Characteristics</i>						
Female	0.76 (0.47–1.25)	0.40*** (0.28 to 0.58)	0.50* (0.25 to 1.00)	1.18 (0.79–1.76)	0.10 (-0.01 to 0.21)	1.32 (0.83–2.10)

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DETAILED RECOVERY OUTCOMES (Ordinal/Numeric)						
	<i>Model 1</i>	<i>Model 2</i>	<i>Model 3</i>	<i>Model 4</i>	<i>Model 5</i>	<i>Model 6</i>
	<i>Extent of House Repair Completed</i>	<i>Change in House Comfort</i>	<i>Change in Community Help</i>	<i>Change in Income</i>	<i>PTSD score</i>	<i>Change in General Health</i>
	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Odds Ratios (95 % CI)	Beta Coef (95 % CI)	Odds Ratios (95 % CI)
Age	1.00 (0.98–1.01)	0.99 (0.98–1.00)	1.00 (0.98–1.02)	1.00 (0.99–1.02)	0.01 (0.00–0.01)	0.98* (0.97 to 1.00)
Observations	632	737	746	749	741	738
Log Likelihood	–444.2457	–721.546	–226.8875	–568.268	–725.260	–426.0881
Akaike Inf. Crit.	920.4914	1473.092	483.775	1166.536	1429.593	882.1763

Note: 'Hhld' is short for 'household' Income-related and debt variables measure 'pre-earthquake' conditions.

Reference categories: Male headed, non-elderly headed Hhld, more than primary education, non-Dalit nor Janajatis; no agricultural income, sufficient income and no debt prior to earthquake; male respondent *p < 0.05; **p < 0.01; ***p < 0.001.

Comparing findings between this model and the binary outcome model, we see many similarities in terms of which predictor variables were statistically significant, and the direction of the association. For instance, We found insufficient income at baseline to be significantly associated with worse odds of completing housing repair in both models.

Similarly, we see female headed households being associated with reduced odds of suffering worsening housing comfort (or in the ordinal model, increased odds of reporting constant/improved housing comfort); while the inverse being true for female respondents. Both models also concurred that those classified as Dalits had increased odds of improving housing comfort.

In both models we also see being female associated with reduced odds of improving community help after the earthquake. One key difference between the models is that the potentially protective effect of being in a female-headed household is no longer statistically significant in the ordinal logistic regression model.

When modelling change in income, the binary model found significant associations with being Dalit, Janajati and having agricultural income with lower odds of seeing a drop in income. In the ordinal model, we see similar findings, in that these characteristics were positively associated with positive change in income status—except for being Dalit, which was only marginally significant here at p < 0.051. Additionally, the ordinal model found a significant association between having more dependents and lower odds of positive income change, which the binary model did not.

For the PTSD outcomes, neither set of models found any household-level characteristics to be predictive of differences here.

Both models of general health found insufficient income prior to the earthquake and age to be significant risk factor in terms of greater odds of reporting worsened health. However, while the binary model found pre-earthquake household debt to be an additional risk factor, and having low levels of education and being Janajati to be protective—none of which were significant variables in the ordinal model.

Data availability

The data that has been used is confidential.

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