



## Article

# Modelling the Roles of Community-Based Organisations in Post-Disaster Transformative Adaptation

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**Abstract:** Disasters result where hazards and vulnerabilities intersect. The concept of vulnerability itself is mainly a social construct and the extent to which this can be overcome while transforming disaster-prone systems has often been emphasised in the critical hazard literature. However, the extent to which community-based organisations contribute to post-disaster transformation at the community level remains unexamined. This paper is aimed at examining the extent of the role of community-based organisations (CBOs) in the transformative adaptation of post-earthquake Lyttelton. Quantitative data was obtained from community members using a questionnaire survey of 107 respondents, supporting interviews, and secondary data to explain the phenomenon in this study. System dynamics and agent-based modelling tools were applied to analyse the data. The results show that while CBOs played a major role in Lyttelton's transformation by fostering collaboration, innovation, and awareness, the extent of their impact was determined by differences in their adaptive capacities. The transformation was influenced by the impacts of community initiatives that were immediate, during, and a long time after the disaster recovery activities in the community. Our research extends the discourse on the role of community-based organisations in disaster recovery by highlighting the extent of CBOs' impacts in community post-disaster transformation.

**Keywords:** disasters; transformative-adaptation; community-based organisations



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## 1. Introduction

Communities all over the world are differentially exposed to various forms of environmental hazards and the disasters that evolve often overstretch their capacity to respond. Vulnerability to disasters is variously defined, but this is generally understood in the hazard literature as not merely caused by nature but socially constructed [1–4]. The role played by communities, including associations and community-based organisations, and their approaches often adopted in responding to hazards while building social resilience have been well documented [5,6]. Community responses to hazards have been mainly autonomous and reactive (e.g., References [7–9]) and where the adaptive social systems are inherently inequitable, transformative adaptation is often required given the limits of autonomous adaptive responses [8]. Transformative adaptation means the outcome of responses to social vulnerabilities to hazards within an adaptive social system, often involving changes in the system's properties towards long-term desirable outcomes [10].

The role of community-based organisations in post-disaster response and social recovery within affected communities has also been variously discussed [6,11]. Community-based organisations (CBOs) are variously defined, but these are commonly viewed as

not-for-profit organisations that are run and serviced by members of the local community with a primary function of meeting the needs of the community [11–13]. Gil-Rivas and Kilmer (2016) show how to harness human and social resources for disaster resilience and long-term responses [6]. Other scholars show how community organisations facilitate community sustainability and resilience to hazards [11,14,15], and how CBOs promote local governance through the collective actions of organised individuals within the community has also been discussed [16]. To Drennan and Morrissey (2019), it is important for the work of the actors in disaster planning to be integrated in local-level governance and planning towards long-term impacts [11].

Engaging in integrated disaster response planning implies disaster recovery is a continuous process that starts with pre-disaster preparedness, and proceeds to immediate post-disaster response and eventual long-term recovery [6]. In spite of the established advantages of CBOs in community resilience and disaster recovery planning [11], the extent to which they contribute to transformative adaptation in disaster-prone areas has remained unexamined [17]. Yet, hazards are context-specific and an understanding of the extent to which adaptation occurs in disaster-prone areas is crucial, especially within ethnically heterogeneous urban centres in industrialised economies that have received very little scholarly attention. This study has thus responded to this knowledge gap using Lyttelton, New Zealand as an analytical case. It does so by applying agent-based modelling and system dynamics modelling approaches and tools to analyse post-disaster Lyttelton as a transformative complex adaptive social system. The time reference of this study is the aftermath of the 2010/2011 Christchurch earthquakes.

## 2. Literature and Theory

### 2.1. Vulnerability, Hazards and Transformative Adaptation

It is important to contextualise important terms that are applied in this research. An important concept in urban literature is vulnerability, which is used in a variety of ways. For instance, climate change-related literature such as the Intergovernmental Panel on Climate Change (2007, p. 883) conceive vulnerability by focusing on the source, to include the nature, intensity, and frequency of the impact of climate change to which a community is exposed and its capacity to effectively adapt [18]. Related to this view is the concept of sensitivity, which is the extent to which the community is affected by the adverse impacts of climate change [18]. Our study adopts a natural hazard's view as we conceive vulnerability as a function of exposure of a system (community) and its susceptibility to a specific set of external biophysical risks, exemplified by Birkmann's (2006) "*characteristics of a person, a group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural disaster*" ([19], p. 9). From this perspective, vulnerability has been viewed as also socially constructed, and "*... represents the system or the community's physical, economic, social or political susceptibility to damage*" ([19], p. 4) caused by an earthquake.

Adaptation is another concept that is applied in a variety of ways in the literature on climate change and hazards. Notable literature such as IPCC (2007) for instance suggests adaptation as: "*adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploit beneficial opportunities*" ([18], p. 60). This paper adopts a wider view of adaptation as has been offered by Pelling et al. (2015) [3], which includes the process of responding to hazards beyond those arising from climate change. In this view, adaptation is a process that includes reduction or elimination of undesirable factors, creation of new opportunities, and the transformation of a social system upon perturbation [3] by an earthquake. A hazard in this context is anything associated with an earthquake that may have an adverse effect on the normal activities of the residents of a place [20].

Discussions on adaptation also show distinctions between planned and unplanned or autonomous adaptation based on whether the adaptive responses are planned interventions [21,22]. Adaptation actions are also categorised based on their objectives, with those aimed at the benefit of the public referred to as public adaptation, whereas those meant

for private benefits of the initiator are referred to as private adaptation [22]. There are also categories of adaptation as anticipatory or reactive. This is according to whether the responses to hazards are anticipatory or reactive, and adaptation actions are also viewed as short-run or long-run based on the longevity of their occurrence [22].

Recent studies have also distinguished between incremental and transformative adaptation (e.g., References [8,23–25]). Incremental adaptation refers to the existing processes, actions, and behaviours in a community that are often adopted to avoid disruption in a perturbed social system [24,26,27]. Outcomes from transformative adaptation are, however, far reaching as they involve changes in the system's properties towards long-term desirable outcomes upon perturbation [8]. The view of adaptation in our study is transformative adaptation seen as a process of responding to hazards from an earthquake in a community with community-based organisations as the agents. Community-based organisations are non-state organisations that are operated by the members in local communities mainly aimed at meeting specific community needs [6].

Researchers in urban hazards have amply documented the role of community-based organisations in the provision of infrastructure and resilience-building [6,21,28–30]. They show that the absence of community organisations pre- and post-disaster has a tendency to work against community resilience and long-term recovery. Earlier studies demonstrate how the different kinds of community-based structures prior to a hazard event can mitigate the impacts and support recovery [31]. However, by the conceptual models adopted, these studies did not show the extent of the role of the CBOs in a community's transformation as a social system.

## 2.2. Complex Adaptive Systems

Complex adaptive systems theory has been variously applied to analyse adaptive processes in urban studies [32]. An understanding of roles and processes within social systems requires an understanding of social systems and complexity [33]. Complexity in a complex adaptive system takes the shape of nested systems interacting dynamically and self-organising without recourse to a higher system [34–36]. Further, complex systems self-organise, emerging without external influence, upon perturbation [34–36]. As such, the behaviour of the whole cannot be predicted by knowledge of behaviour of the parts in a complex system [33,34]. CBOs, being a part of the complex system in this study, provide valuable insights into the processes and behaviours of the Lyttelton community.

An understanding of complex adaptive systems presents a unique advantage in this study for understanding autonomous decisions and system interventions, and how they compound and lead to system emergence. Also of importance to this study is the role of disturbances in creating the needed momentum for change. Adaptive complex systems once exposed to external perturbation do learn, transform, and adapt to their external environment [34,37]. Transformative adaptation means that responses to the hazards from an earthquake involve changes in the system's properties towards long-term, more desirable outcomes [8].

## 2.3. Modelling for Understanding Complex Systems

Models are generally used in studies on complex systems to portray and provide explanations for system behaviours that have been identified through perception, observation, or measurement [38]. Although models are sometimes useful for control and prediction of system outcomes, they are mainly useful for understanding complex systems [39]. Hence, to obtain optimum benefit from system models for understanding system complexities, the accuracy of data, theoretical frames, relationships, and tools is very important.

In this study, we captured the two aggregate levels for modelling complex systems within the community using both agent-based and system dynamics modelling. The system dynamics model was used to simulate system-level interactions and behaviours, and to observe and assess the impact of interventions on the overall outcomes. The system

dynamics model in this study was used to simulate CBOs and government initiatives and interventions, and how they impact on outcomes within the community.

Agent-based modelling is used to simulate emergent phenomena within a complex system through a correct description of the system, the characteristics of individual agents, and the relationships between agents [40]. We used ABM in this study to simulate the activities of individual agents and the interactions between them, and the resultant emergence at the system level. The agents were defined by attributes, variables, and affiliations to CBOs, and the values were used to capture the agents' activities and interactions, and how they create momentum for systemic transformation.

Lyttelton, according to existing studies, is known for a variety of initiatives, social innovations, and adaptation strategies that facilitated recovery from the impacts of the 2010/2011 Christchurch earthquakes which affected the community [41]. These studies also highlighted the role community-based organisations (CBOs) played in organising these initiatives [41,42]. However, based on the conceptual and theoretical models adopted in these studies, and their thematic focus, these studies did not discuss the transformative role of CBOs in the post-disaster response in Lyttelton. To understand and capture the role of CBOs in community post-disaster recovery and transformation in this study, we used agent-based modelling and system dynamics modelling tools for understanding of (1) the social structure in Lyttelton and the existing interactions among actors and system components, and (2) the impacts of CBOs on transformative adaptation outcomes within the Lyttelton context. The simulation and model development in this study was based on an already published conceptual framework [1] and empirical data collected from a field study in Lyttelton.

### 3. Materials and Methods

#### 3.1. Study Location

The field study for this project was conducted in Lyttelton, a suburb politically part of Christchurch and geographically situated on the outskirts of the Christchurch CBD, and accessible via a tunnel. Lyttelton is a community with very clear geographical boundaries, making it is easier to define the system boundaries. Lyttelton is a port town that serves the Christchurch and Canterbury regions, and which historically was the colonial settlers' entry into the Christchurch region. The Lyttelton port has remained a major service port for the Christchurch and Canterbury region since then. Lyttelton is a community exposed to earthquakes and, being a port town, Lyttelton is also exposed to floods and tsunamis. Based on the 2013 census, the population of the community was 2859 [41] and increased to a total of approximately 3100 people in 2019. The demographics of the Lyttelton community are characterised by a relatively older and less ethnically diverse population when compared to the Christchurch central city [43]. However, Lyttelton is a close-knit community with at least 9 community organisations and groups, and a high level of participation within the groups and community at large [2,41]. Another strong feature within the community is a strong sense of place among Lyttelton residents, which further promotes community participation in communal activities. Although the 2010/2011 earthquakes brought down some of the town's historic buildings, they also created a sense of community among residents and facilitated the uptake of social groups and initiatives within the community.

#### 3.2. Data Collection Methods

The study design included developing and testing of the research hypothesis on a selected case. The case study approach was preferred as it allows a detailed study of a real-life phenomenon [44]. The study hypothesis is: Community-based organisations are significant determinants of post-disaster transformation outcomes.

This study adopted a mixed-methods research approach. This approach combines the advantages of both qualitative and quantitative research methods in gaining a basic understanding of issues and for identifying generalisable findings. An exploratory mixed-methods design was adopted in this study. The two strands of the methodology were

conducted sequentially, starting with the qualitative strand and followed by the quantitative strand. The qualitative strand was used to show the contextual transformative processes and to inform the development of a survey instrument to assess transformation, whereas the quantitative strand was used to collect more representative data from the community, which was analysed and used for the model building and validation [2]. Interviews and questionnaires were used to obtain qualitative and quantitative data, respectively.

### *3.3. Sampling and Sample Distribution*

Purposive sampling was applied in the qualitative strand whereas the quantitative strand involved random sampling. A total of 16 interviews were conducted with a range of participants including community members, representatives of community organisations, and government agencies. Participants for the survey were randomly selected, giving every adult resident of the community an equal chance of being selected. Questionnaires were randomly distributed to residents of the community through a variety of ways, namely mailboxes, community gatherings, community hubs, and different online platforms. Online community groups were used to recruit survey participants through partnerships with major community organisations. Periodic reminders were sent to these online platforms to encourage participation. Participants were permitted to take the questionnaires home for completion and were provided the option of dropping them off at identified locations in the community. A total of 107 completed questionnaires were returned including 54 responses from the online survey and 53 responses from the paper survey. Online responses were automatically saved in a spreadsheet, and those from the paper survey were manually input into an excel spreadsheet. The sample size for the survey represented nearly 4.5% of the eligible population as provided in the 2013 census and was deemed significantly representative of the population.

### *3.4. Data Analysis*

Computational models are often applied in analysing the dynamic interactions between individual agents and groups across various scales of their influence [45]. In this study, we developed a hybrid model that combines the advantages of both agent-based modelling and system dynamics modelling for analysing complex adaptive systems. Agent-based models are used in the analysis of bottom-up relationships and the mechanisms of how they contribute to system-level emergence [46]. System dynamics models are also helpful for studying complex systems by capturing system-level interactions and feedback relationships, and how they may affect agents within the system [47]. The model offered a lot of value to the study by providing a full understanding of the processes that occurred in the community following the disaster and, more importantly, the role of the CBOs in the transformation process, and how these findings can inform policy decisions on social transformation.

### *3.5. Contribution of the Study*

The value of this research is to show how small changes and processes within a disaster-affected community can induce system-wide changes, and the ways in which interventions can facilitate achievement of the desired results. Discussions about transformation in the literature have often argued for radical or sweeping changes in the affected system. However, the case of Lyttelton shows transformation as a process rather than an event. Therefore, rather than laying emphasis on the triggers of this ‘radical’ change, the processes and interactions in transformation are equally important. This study used modelling tools to simulate the complex processes and interactions that exist in the Lyttelton community and how autonomous decisions of agents lead to transformation within the community.

### *3.6. Limitation*

The main limitation of this study is in regards to its scope. The study scope is limited to the social aspects of transformation by examining the chain of socially adaptive and trans-

formative responses that are triggered by environmental hazards. Therefore, the interview questions and questionnaires focused mainly on these aspects. This study acknowledges that, although these social transformations cannot be studied in isolation due to the various interdependencies that exist within complex systems, the study tried to examine the complex and feedback processes that started with the earthquakes, their impacts on the community, the systems' response, and the variables responsible for those responses.

## 4. Results

### 4.1. The Model

The hybrid model applied in this study is intended to be a tool for analysing the process of transformative adaptation as it occurred in Lyttelton. The model parameters are specific to Lyttelton; this is to ensure that the model simulates the reality of the community. Data tables containing real data indicating past trends in employment rates, funding and membership to community organisations, and reconstruction were also used in calibrating the model. Empirical data collected from both primary and secondary sources were used for model calibration, the definition of the agents' attributes, and the values for indices used in characterising agents. Details of our models' parameterisation are discussed below and further details can be found in the published article by Ajulo et al. (2021) [2].

### 4.2. Base Model

The base model is a representation of the system as it is. Hence, our base model was developed using a combination of theoretical evidence, data from secondary sources, and empirical evidence bearing on the concept of transformative adaptation. AnyLogic software was used in the implementation of the model using data from the various sources, which were inputted as parameters and variables. The model parameters were input into the system before running each simulation whereas the values of variables were built into the model. Table 1 shows details of the model inputs for the base model. Relevant quantitative data for model calibration were obtained from the empirical study, Statistics NZ, and other secondary sources.

**Table 1.** Values for the base model parameters.

Scheme	Initial Parameters	Value	Distribution
1	Fully employed people receiving payment	0.24 out of 1	Random
2	Perceived government transparency	0.64 out of 1	Random
3	Number of buildings	1100	-
4	Yearly construction rate	0.1	-
5	Percentage of damaged buildings in 2010	0.08	Random
6	Percentage of damaged buildings in 2011	0.2	Random
7	Policy for payment of wages in emergencies	true	-
8	Commitment factor	0–1	Uniform
9	Socio-cultural weight (ATV)	0.34	-
10	Institutional weight (ATV)	0.28	-
11	Economic weight (ATV)	0.38	-
12	Residents with assets (home ownership)	0.7 out of 1	Random
13	Adaptive management weight (AV)	0.283	-
14	Innovation weight (AV)	0.340	-
15	Information behaviour weight (AV)	−0.116	-
16	Trust in government weight (AV)	−0.099	-

Table 1. *Cont.*

Scheme	Initial Parameters	Value	Distribution
17	Social network weight (AV)	0.175	-
18	Reciprocity weight (AV)	0.198	-
19	Human, financial, and physical capital weight (AV)	0.248	-
20	Governance weight (TCV)	1	-
21	Leadership weight (TCV)	1	-
22	Empowerment weight (TCV)	1	-
23	System sustainability weight (TCV)	1	-
24	Foresight weight (TCV)	1	-
25	Reflexivity weight (TCV)	1	-

Indices and threshold values were determined for the simulation. The thresholds were determined based on the most realistic model results. The threshold values for the base model were ATV = 0.7 out of 1, AV = 1.2 out of 2, and TCV = 4 out of 7.

#### 4.3. Model Inputs

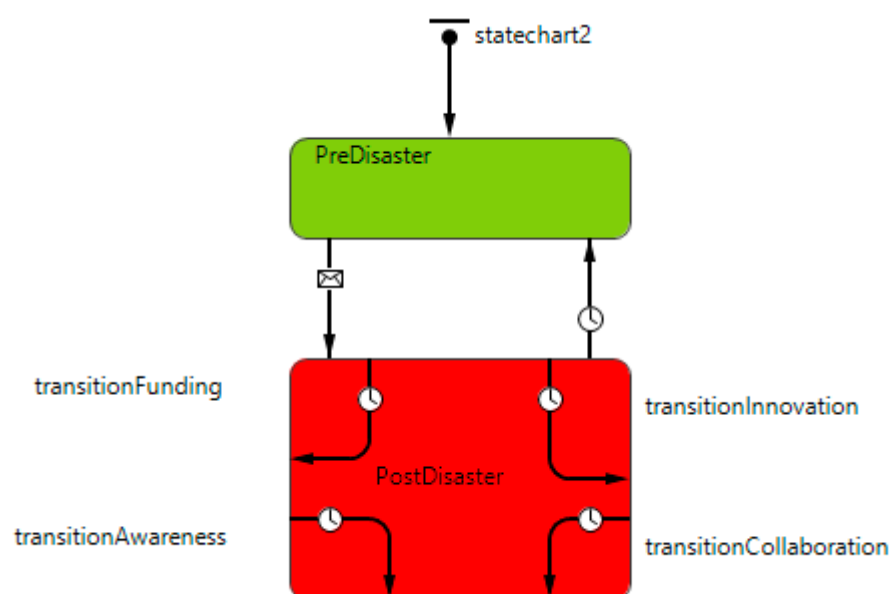
The model inputs were contextualised to suit the characteristics and interactions between CBOs and the individual family agents. Details of these inputs are discussed next.

#### 4.4. CBOs

The model captures the top-down interactions between CBOs and the individual family agents. These interactions were captured using four main attributes of CBOs that influence the transformative adaptation of family agents. These attributes, otherwise known as transitions, include innovation, collaboration, awareness, and funding (see Figure 1). The transitions form a link between the CBOs and the family agents, and demonstrate the ways in which CBOs may influence the agents' variables. Based on empirical data, certain activities within the CBOs in the aftermath of the 2010/2011 earthquakes led to an increase in innovation (via the agents' knowledge co-production variable), collaboration (via the agents' leadership and a shared vision for change variables), and awareness (via the awareness initiatives and commitment variables). Funding was likewise seen to indirectly impact on agents' transformative capacity because these funds provided the resources needed for overseeing the continued running of existing social initiatives and the creation of new ones, which led to an increase in agents' transformative capacity. The model implemented these interactions using transitions, which created an exchange between CBOs and family agents. Hence, changes in the functions and activities of CBOs create a corresponding change in the capacity of family agents based on the studies within the community. Community initiatives were created and maintained by CBOs based on available funds from the government and external grants. In our model, the funds for each initiative were calculated based on percentages and the average yearly running costs of each initiative. The community initiatives were classified into four groups:

- i. **Social capital initiatives:** The main goal of social capital initiatives is building social capital within the community. These initiatives are defined by existing social networks and reciprocity, and include community groups that facilitate network building and bonding among their members. Hence, initiatives that fall within this category are valued based on their membership level, which is factored into the AV index for the agents.
- ii. **Awareness initiatives:** Awareness initiatives are created with the goal of increasing awareness among community members. In Lyttelton, examples of such initiatives include information sessions, movie screenings, information pamphlets, and classes aimed at increasing awareness of and sensitising people to environmental hazards and preparedness. The model calculates awareness values based on an initial

- uniform distribution; however, these values may increase depending on the agents' interaction with awareness initiatives.
- iii. **Collaboration initiatives:** These initiatives are geared towards maintaining a strong relationship between the community and external stakeholders such as the city council. In the model, growth in collaboration initiatives is linked to increased political participation in the community. The values for collaboration initiatives are calculated based on innovative partnerships between the government and the community, and available funding for that. The presence and growth of collaboration initiatives leads to an increase in agents' perceived collaboration, also increasing the agents' TCV.
  - iv. **Sustainability initiatives:** Sustainability initiatives have the goal of ensuring environmental, social, and economic sustainability within the community by campaigning for waste reduction, alternative currencies (such as time banking), local agriculture, etc. Sustainability initiatives are linked to agents' perceived system sustainability and the presence and growth of sustainability initiatives will increase the agents' TCV.



**Figure 1.** CBO statechart.

#### 4.5. Scenario Test

##### 4.5.1. Hypothesis

**Hypothesis 1 (H1).** *Community-based organisations are significant determinants of transformation outcomes.*

A scenario test was conducted to test Hypothesis 1, in order to simulate the transformation outcome of agents if there were no CBOs in Lyttelton.

##### 4.5.2. Model Inputs

To test the above-written hypothesis, value inputs from the base model were maintained; however, the CBOs and their connections to the family agents were disabled. As a result, the disabled variables of the family agents included the government funding that goes to the CBOs and family agents; the knowledge co-production variable (which represents the creation of innovative ideas and knowledge at the community level); a vision for change variable (which represents the vision of CBOs to bring positive change to the

community); and adaptive management (which represents leadership towards adaptation at the community level and within CBOs). The results are shown in Figures 2–4.

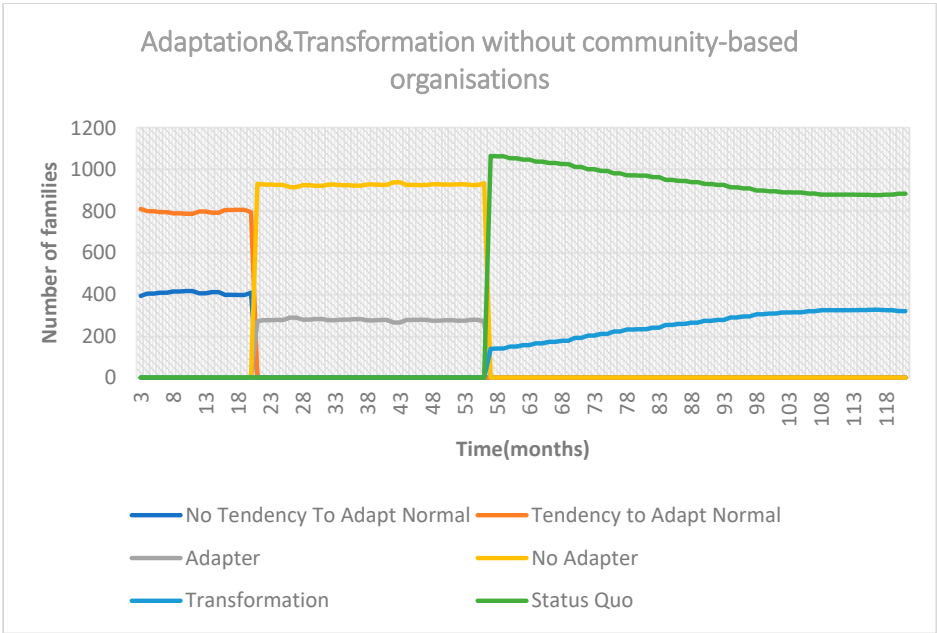


Figure 2. Adaptation and transformation outcomes for the community without CBOs.

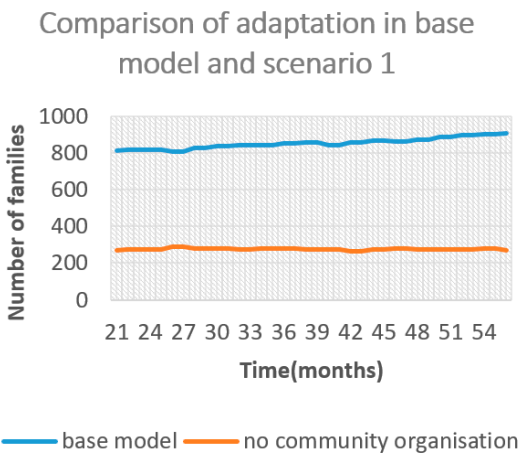


Figure 3. Adaptation outcomes for the base model and scenario test.

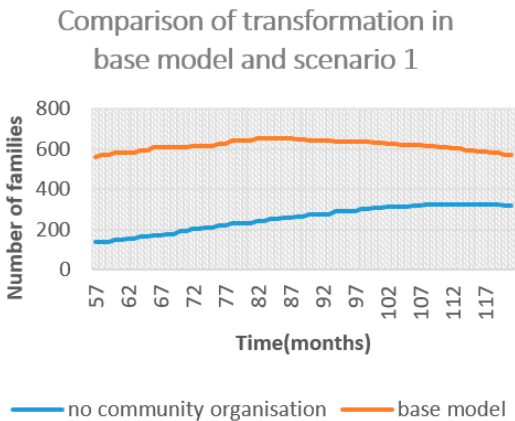


Figure 4. Transformation outcomes for the base model and scenario test.

#### 4.5.3. Model Result

The result shows no significant change in the agents' tendency to adapt; however, the results show an increase in the short-term adaptation and transformation of family agents. Figure 2 shows that about 75% of families do not adapt. At the initial stages, only 12% of the agents undergo transformative adaptation; however, the number increases with time. These results demonstrate the importance of community organisation in bringing about adaptation and transformation in Lyttelton. These results support findings from previous studies on the role of community organisations (infrastructure) in resilience-building [13,21,29,42,48,49]. Their findings indicate that the absence of community organisations (infrastructure) in communities can be a major barrier to resilience. Previous studies also highlight the value of having resilient community structures and organisations before exposure to environmental hazards rather than after [13]. According to Ozanne and Ozanne (2013) [42], community organisations are beneficial for capacity building, i.e., enhancing communication capacities, social capacities, cultural capacities, and community competencies.

The simulation result validates other studies that discuss the importance of CBOs for disaster recovery. As seen in the results, when CBOs are absent in the community, it affects both short-term adaptation and the long-term transformative adaptation of agents. This reinforces the understanding that CBOs create social spaces for knowledge sharing and problem solving, i.e., spaces where social needs are addressed and the well-being of community members are prioritised. Beyond the already stated benefits, CBOs also share valuable links with the government and with external stakeholders that help meet the funding requirement for the running of community initiatives. The results of this scenario test are significant when compared to the base model, and this indicates a strong need for funded and empowered community organisations.

### 5. Discussion

#### 5.1. Bottom-Up Emergence of Transformative Change

Complex systems evolve as an adaptive response to environmental needs and stressors. Since social systems are complex adaptive systems, they are dynamic systems where emergence is characteristically dissipative, involving multiple feedback loops [50]. Social networks serve as a connection line through which feedback loops and interactions within a social system are sustained [50]; hence, understanding social interactions is fundamental in determining the flow of information and feedback that leads to the overall system outcomes.

The results from the study highlight the strength of shared goals and vision within a community—and how small changes can have far-reaching consequences. These impacts are better understood by studying the social networks that exist within the community. Disaster recovery periods are crucial for implementing transformative changes, as seen in the case of Lyttelton, because they provide opportunities for the re-evaluation of established systems and an avenue to gravitate towards a common goal. These developmental changes can be geared towards short- and long-term goals [51]. Although disasters result in system disruptions they should, however, be taken advantage of as opportunities to introduce valuable changes to the system [52].

As a case study, Lyttelton offers a good example of bottom-up emergence brought about by the interactions and complex dynamics between different levels of the community. Hence, actions of individual agents are foundational to the social transformation in the community in that individual ideas can result in changes within community groups and initiatives, which has a ripple effect on the beliefs and lifestyles of other members of the community. For instance, our study showed how the use of time banks that provide access to services without using conventional currency can reorient mindsets and attitudes regarding wealth accumulation. Similarly, other initiatives such as the community garden, the farmers' market, and the Harbour Co-op facilitate conversations and awareness about anthropogenic climate change and disasters. These initiatives allow for adaptive solutions that are relevant to the community and a thriving environment for building community

resilience, facilitating response and post-disaster recovery while also reducing vulnerability to future disasters.

### 5.2. Transformation as a Projection of Pre-Existing Developmental Patterns

Disasters create opportunities for change [53]. However, to take advantage of the opportunities presented, it is important to implement fundamental changes; otherwise, disasters can potentially exacerbate pre-existing conditions within a community [30]. To highlight this point, a research participant said: *"I don't know that it [the earthquakes] fundamentally altered the community much because we were already doing all the things that were useful during the earthquake as a community"* (Interviewee 11). In response to further questions about the ongoing initiatives, the respondent remarked: *"These things [social initiatives] were all happening before the earthquake . . . but it's kind of like this [illustrates an accelerated pace of change with a drawing] before the earthquake, and now we're carrying on the same, maybe a little different . . . "* (Interviewee 11).

The scenario test conducted in this study shows how CBOs affect transformation outcomes in the community. CBOs were seen to significantly impact the overall transformation outcomes. CBOs were already a part of the pre-existing structures in Lyttelton and many were operational before the disaster event. Although the functional aspects of CBOs can improve with time, the situation in Lyttelton showed that post-disaster recovery and transformation are dependent on the capacity of CBOs at the time of a disaster. The scenario test result highlights the importance of long-existing and operational CBOs. These structures are influential to the culture and norms of a community and are therefore more beneficial for facilitating transformative adaptation than short-term interventions that are geared towards managing the impacts of disasters.

The model results highlight the role of social capital on transformation outcomes. Economic means (which among other factors is determined by employment status) were seen to be valuable for immediate responses and recovery. Although these impacts may vary within different cultural contexts, transformation is seen to be inherently fostered by social factors [54].

### 5.3. Community Heterogeneity and Transformative Change

Existing studies state the need for empirical studies that investigate the relationship between social heterogeneity in communities and their transformation potential [54]. Their study suggests that highly heterogeneous groups (i.e., ethnically, socio-economically, and other forms of diversity) undermine the social transformation potential of a community. However, another study conducted by Sampson and Graif (2009) [55] highlights the value of diversity in the accumulation of social capital and, by proxy, in transformation. However, the impact of diversity on social capital accumulation is determined by other intervening dimensions of social capital such as organisational participation and social control. Along these lines, one of the research participants stated that the earthquakes and facilitation by CBOs created an avenue for people to come together. As she put it,

*I guess what it did was it brought everybody much closer together and made people think about being self-reliant a lot more. Em, you know every community has sort of different bits, different segments. For a while, the barriers definitely came down between those different segments.*

(Interviewee #11)

### 5.4. The Role of Community Organisations in Achieving Transformative Adaptation

The study findings and discussions highlight the importance of CBOs in building a robust and resilient community. This finding reinforces the relevance of panarchy theory [56] for understanding complex systems interacting across multiple levels. In our study, the 2010/2011 earthquakes created a disturbance that pushed the families' agents into dissonance that was absorbed by the robustness of the CBOs which enabled transformation to occur. Although this yielded a positive outcome as desired, if left unchecked, agents'

overreliance on these supports may have damaging long-term impacts. According to Abel et al. (2006) [57], an over-reliance of smaller adaptive cycles on larger adaptive cycles may hamper their ability to self-organise.

The 2010/2011 Christchurch earthquakes were the first major hazard to affect the Lyttelton community in a long time, and the role of community organisations and initiatives was significant in facilitating transformative outcomes within the community. Community organisations create platforms for building social capital leading to increased knowledge sharing and participation. They also serve as links to governments and external stakeholders that facilitate a timely response from all relevant stakeholder and institutions in responding to the social needs of the community [58]. Community organisations serve as a driver for bottom-up initiatives and adaptation; and, as seen in the model results, CBOs play a major role in achieving both short-term adaptation and transformation. According to the simulation results from this study, CBOs do not act independently in creating the desired change within a community but their efforts are enhanced through their complex interactions with other variables within the system. An absence of CBOs and vis-à-vis the other variables leads to a significant decline in transformative adaptation outcomes in Lyttelton. Hence, the value of CBOs towards the adaptation and transformation goals of a community is discussed in the following sub-sections.

#### 5.4.1. Social Networks

CBOs create hubs for activities and initiatives geared towards a common goal which creates platforms for social interaction. These interactions provide and foster bonding and bridging social capital, which are required for both disaster responses and the management of local resources [58]. This study highlights the link between time banking and bonding social capital. In this study, membership to the Lyttelton time bank was one of the factors that determined the strength of social networks. Having captured these interactions in the model, results showed a reduction in the adaptive capacity of family agents who have very weak social networks (i.e., no membership to community organisations).

Social systems benefit from existing social networks and interactions for facilitating positive system emergence. Hence, social networks are fundamental to CBOs in achieving their desired outcomes within a community. Connectedness facilitates collective action, which is needed for transformation. A research participant put it this way:

*"We already had community connections in place, which meant that we just activated them all . . . "*

(Interviewee 9)

#### 5.4.2. Government Funding

The study indicates that funding is provided by the City Council for the running of community organisations and initiatives, and by other social groups. The presence of community organisations in some way implies that such a community may access some special funds provided for community groups. In the absence of this, the community may be left to fend for their own interests or start organising for such assistance after a disaster, which will limit the momentum for collective action and response. Interviewee 9 remarked, *"Yes, some good things have come out of it [the earthquakes]. Some more listening to each other has come out of it . . . some more funding has come too"*.

#### 5.4.3. Local Initiatives

Local initiatives serve as a foundation and medium through which CBOs mobilise change within the community. Local initiatives help increase awareness (through regular membership meetings, community bulletins and updates, and community library operations) and innovation among agents, and when these initiatives are absent, it is reflected in adaptation outcome.

#### 5.4.4. Co-production of Knowledge

A collective vision is a requisite for transformative adaptation. According to Broto et al. (2018) [23], knowledge co-production is achieved when agents are involved in social groups that coalesce around a shared vision. Knowledge co-production will be non-existent if the platforms that facilitate interactions and sharing are unavailable. In the words of Interviewee 12,

*So, working with the council is still a challenge, but what I want to say is that Lyttelton has got quite a name for itself now as an innovator, you know, that starts new things . . . and I think that's partly down to our record, so we ask questions.*

#### 5.4.5. Shared Vision for Change

Transformative adaptation is associated with changes to existing norms and systems, which leads to a fundamental overhaul of the status quo, providing a basis for positive actions. The direction of change in social systems is largely determined by societal goals [59], and these goals are set and created within social groups. In the absence of a common goal, individual agents will tend to pursue their own interests, potentially resulting in conflicts and adverse impacts on the whole community. Therefore, community organisations are instrumental in creating a shared vision within local communities.

#### 5.4.6. Adaptive Management

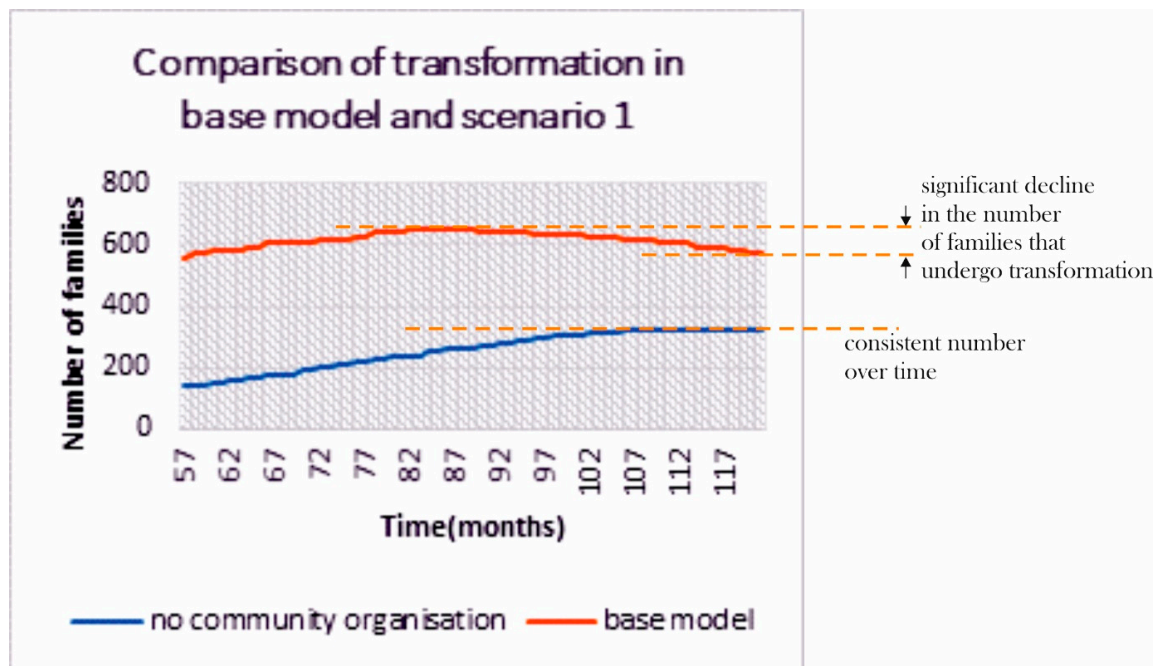
Adaptive management focuses on the coordination and management of community-level actions towards sustainability and increasing the adaptive capacity of agents [60,61]. CBOs and local governments often lead adaptive management efforts, primarily due to the need for local knowledge for adaptive management. Hence, the potential for adaptive management is reduced when community organisations do not exist.

#### 5.5. Decrease in the Number of Families That Undergo Transformation over Time

The base model results show an initial increase in the number of families that transition into the new normal state (transformation) followed by a gradual decline in the numbers. An inference can be drawn from this in relation to the complexities of the transformation process. Many factors contribute to the transformation of agents; however, these factors either became unavailable or the agents, CBOs, or governments were unable to sustain the initial momentum observed in the model results.

#### Community Organisations

The scenario test results show a significant decrease in the number of agents that undergo transformation when CBOs are unavailable. However, in addition to this obvious observation, the overall level of transformation gradually declines over time. Although the model results show that, in the absence of CBOs, the number of agents (families) that undergo transformation is significantly lower than in the base model, this number gradually increases and remains somewhat consistent after a period of time. This shows that, despite the valuable role of community organisations in facilitating social transformation, the potency of these initiatives in yielding positive social transformation decreases over time if left unchecked. This indicates that although Lyttelton offers a lot of lessons for bottom-up transformation and community initiatives, it is not a perfect situation. An acceptable outcome would be to ensure that the level of social transformation increases over time or, at the very least, is maintained. This outcome is an unintended outcome, and further analysis can provide more insight and guide future policy decisions. Figure 5 shows how the transformation outcomes of the base model differ from the results of the scenario test.



**Figure 5.** The decline in the number of families that undergo transformation in the base model when compared to the results of the scenario test.

As indicated in Figure 1, community organisations contribute to the transformative capacity of family agents through four means and, of the four, funding is seen to impact both the transformative capacity of agents and community initiatives. This is the case because funds are used to sustain ongoing initiatives run by the CBOs that facilitate transformation through innovation, collaboration, and awareness. Therefore, sensitivity tests were conducted on some variables associated with the activities of CBOs in the community to determine how much impact they have on transformation outcomes.

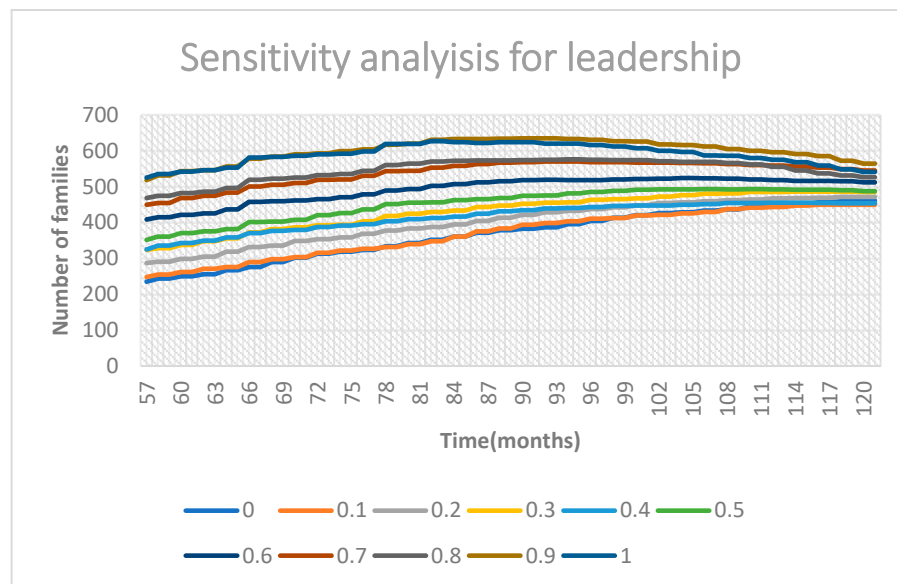
#### i. Collaboration

Collaborative efforts between community organisations and the government were highlighted by participants in the field study as an important factor in managing social initiatives that contributed to the transformation outcomes. This was factored into the hybrid model under two variables: leadership and a shared vision for change. Broto et al. (2018) [23] stated that leadership fosters collaboration in the execution of social initiatives. Moreover, collaboration is fostered through having a common goal and vision for the community. The sensitivity test results for leadership are shown in Figure 6, and the results for a shared vision for change are shown in Figure 7.

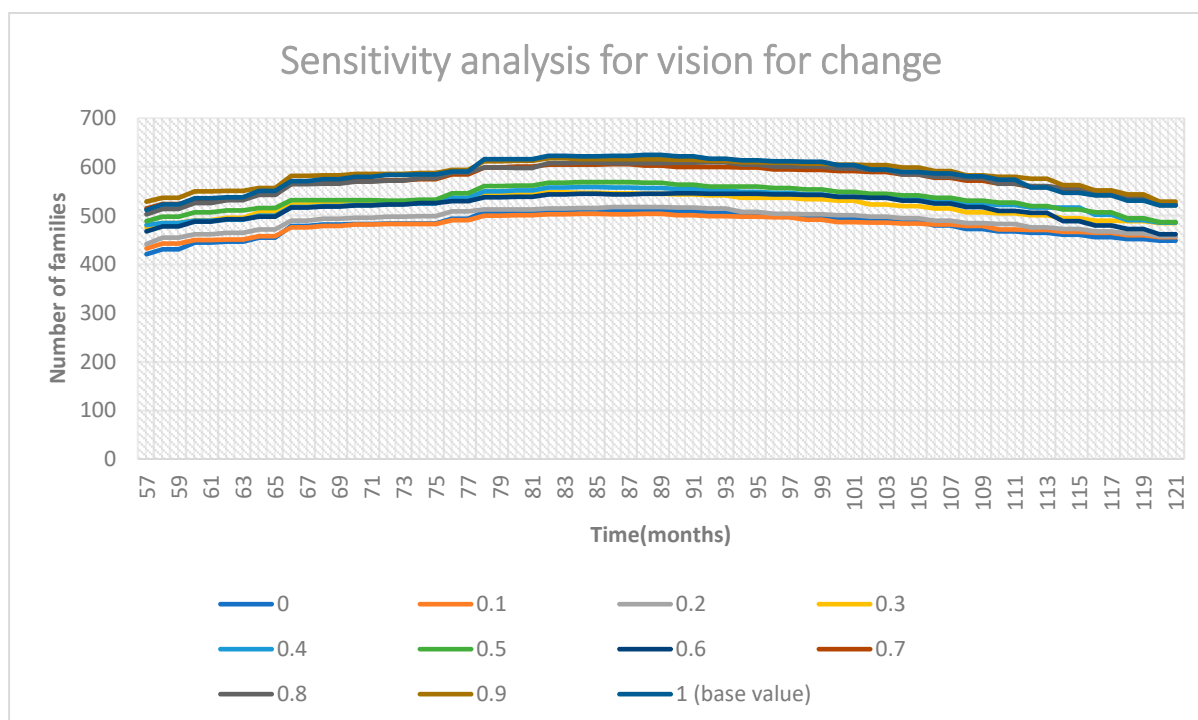
These results shows that transformation outcomes have a low sensitivity to the changing values of a shared vision for change. However, the sensitivity test for the leadership variable (Figure 6) shows that, with lower values for leadership, there is a consistent increase in the number of agents that transition to the new normal state throughout the duration of the simulation; whereas, with an increase in the numerical weight of leadership, there is an initial increase and, thereafter, a gradual decline in the number of agents that undergo transformation towards the end of the simulation.

These results show that collaboration between community organisations and the government has a significant impact on transformation outcomes; however, the decline in transformation outcomes over time is partly attributable to the leadership variable. In the model, leadership is measured based on the perceived support from the City Council, and although a high value for leadership should be a good thing, from the results, leadership does not offer very good long-term benefits for transformation. A plausible explanation for this finding is the tendency for a heavy reliance on government support, which, according to

Abel et al. (2006) [57], can potentially lead to system collapse if left unchecked. Additionally, a continued dependence on external support and aid may impede a system's self-organising ability when exposed to external stress.



**Figure 6.** The effect of different weights of leadership on transformation outcomes.



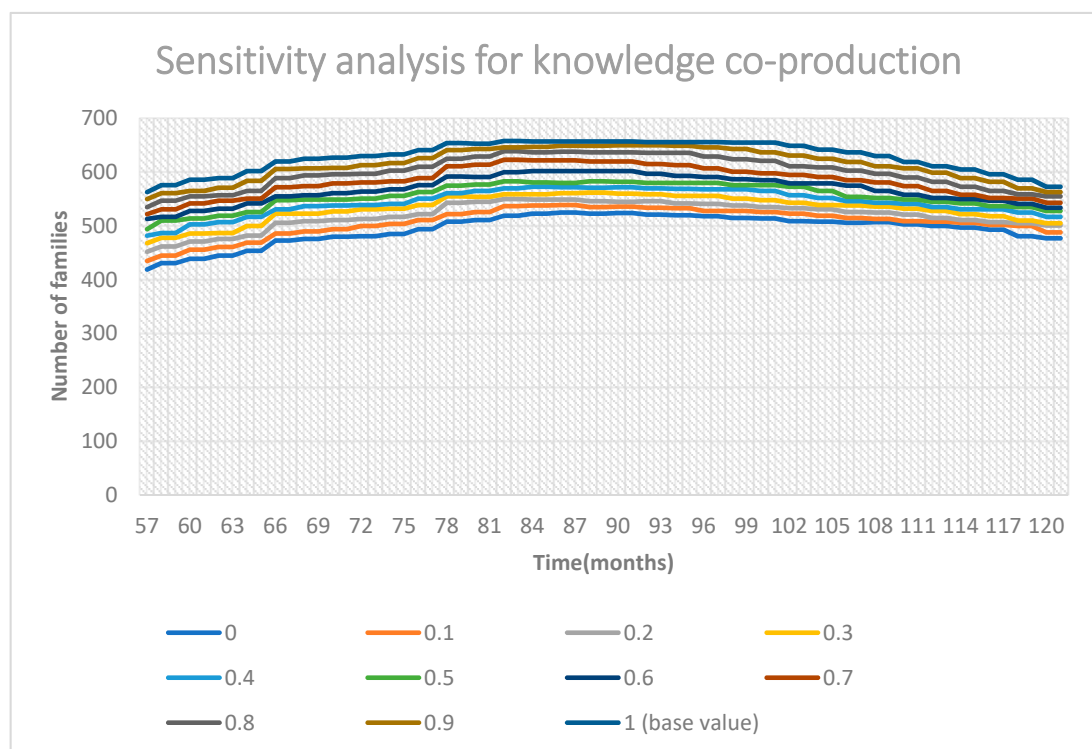
**Figure 7.** The effect of different weights of vision for change on transformation outcomes.

Collaborative efforts are encouraged between communities and the government, and this initiative is seen as a form of social capital (linking social capital) [28,58]. However, there is a need for proper management so it does not result in increased vulnerability within communities [57]. These results highlight the tendency for unintended outcomes in an attempt to build collaborative efforts; hence, the lesson here for policy decisions in the Lyttelton community is to reassess existing activities and initiatives within its CBOs to

ensure that those initiatives can be self-sustained and can achieve their set goals with or without external support.

## ii. Innovation

Innovation is essential for building transformative capacity. In this study, CBOs contribute to innovation among the agents through the co-production of knowledge variable. Knowledge co-production is a collective effort among stakeholders used to facilitate the creation of knowledge and ideas towards the achievement of set societal goals [61]. In the model, knowledge co-production is used as a variable that determines the transformative capacity of the agents. Figure 8 shows the result of the sensitivity test conducted to determine the impact of knowledge co-production on transformation outcomes.



**Figure 8.** The effect of different weights of knowledge co-production on transformation outcomes.

These results show an initial increase followed by a slight decline in the number of families that have transitioned over time. Based on this result, the potential benefits of community innovations are not reflected in the transformation outcome of the community. A research participant in this study expressed concerns about some ongoing tensions with the community. The exact words were that:

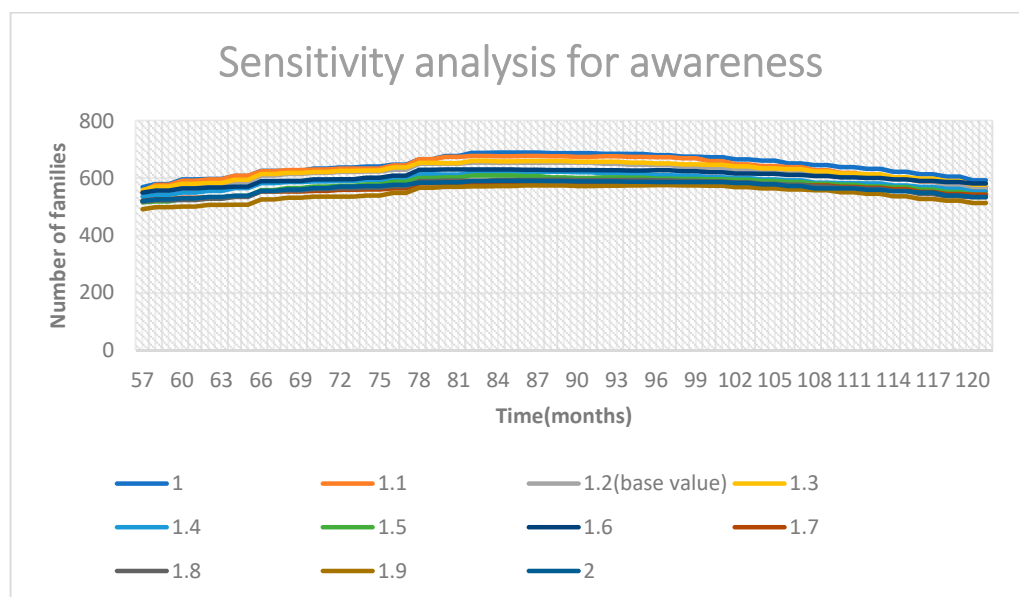
*“there’s a certain amount of resentment’ . . . . . ’ there are people out there who feel that they’ve (a community organisation/initiative) become like a bit of a club and a bit exclusive”.*

According to the model results, the negative impacts of innovation on the community are very subtle, and even though community members involved in these innovative initiatives have expressed a great deal of optimism about the potentials and opportunities the initiatives can offer in building community resilience, the positive outcomes may be short-lived. As Interviewee 8’s comment suggests, the activities of community organisations with respect to innovation will benefit from being more inclusive.

## iii. Awareness

Certain social initiatives were instrumental in creating awareness among the family agents. Our model measures the contributions of community organisations towards creat-

ing awareness in the community based on the initiatives that the CBOs engage in over time. The result of the sensitivity test is shown in Figure 9.



**Figure 9.** The effect of different weights of awareness on transformation outcomes.

The result indicates that awareness has very little impact on transformative adaptation outcomes within the community. The simulation indicated a reduction in the number of awareness initiatives in the community over time. This lack of urgency may be responsible for the results seen in Figure 9.

#### iv. System Awareness with Respect to Sustainability

System awareness with respect to sustainability represents the community's active involvement in sustainability efforts and is an indicator of transformative capacity in the model. In this study, the system awareness variable is measured based on the agents' perception of sustainability efforts within the community. The sensitivity analysis result showing the impact of this variable on transformation outcomes using different values is presented in Figure 10. The results show that as the numerical weight of the system sustainability variable increases, although with an initial increase in agents' transformation, there is also an increasing decline in long-term transformation. In other words, with an increase in system awareness, there is a higher drop in the number of agents that revert from the new normal state back to the status quo.

There are two plausible explanations for this negative impact of increasing awareness on long-term transformation:

##### (a) Unattractiveness of Change

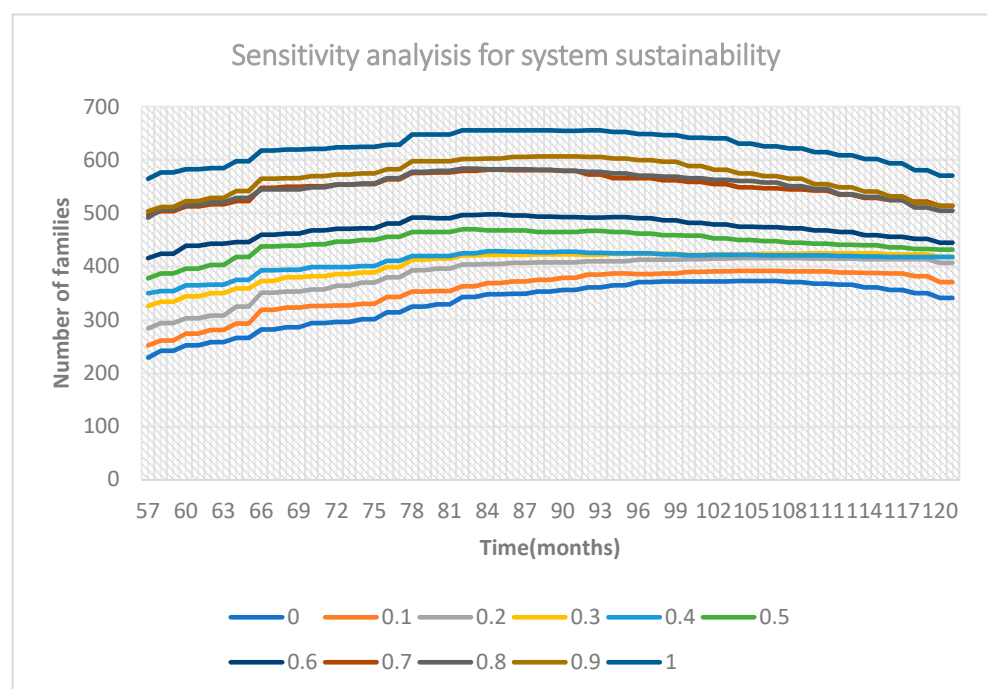
Change can be attractive, especially when popular. According to O'Connell et al. (2015) [4], the attractiveness of change is one of the many factors that can facilitate transformative adaptation and a transition towards sustainability. People may be more inclined to adopt more sustainable lifestyles because it is popular or because it gives a sense of fulfilment. However, change can also become unattractive and burdensome even after it has occurred. Some of the research participants acknowledged how valuable they thought community initiatives are, but they did not think those things are for them. As Interviewee 4 put it,

*I don't always use it [the timebank]. Like a lot of my job, we have volunteers that don't use timebank. But I have used it, though I don't use it that often . . . A lot of it is 'cause it has a lot to do with technology, not for all people.*

To sustain transformative adaptation and outcomes, alternatives should be provided to suit varying preferences or the majority of community members.

### (b) Long-term Outcomes

The model simulation in this study shows results for the period from 1 January 2009 to 31 December 2018. According to Kanie et al. (2012) [61], transformation may sometimes occur as an attempt to reverse the rapidly changing climate or existing socio-economic structures although such an attempt itself often takes time. As the simulation runs for only a 10-year period, there is a possibility of more positive outcomes of system awareness towards sustainability in the longer run.



**Figure 10.** The effect of different weights of system sustainability on transformation outcomes.

## 6. Conclusions

Community-based organisations may serve different roles within a community, including post-disaster recovery and transformation. Results from the simulations and interviews provided more insight into the bottom-up transformation process in Lyttelton, and the role of CBOs and community initiatives in bringing about transformative adaptation. Our results present the need to support bottom-up processes and community initiatives as a key highlight of our study of the Lyttelton community. In conclusion, based on a case study of Lyttelton, community organisations are seen to be major determinants of post-disaster recovery.

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**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** Data for this paper is contained in the PhD thesis of the first author and is available in the University of Newcastle Thesis Data Repository.

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## References

1. Ajulo, O.; Von-Meding, J.; Tang, P. A Conceptual Framework for Understanding Transformation: Transformative Adaption of Refugees in Nakivale Refugee Settlement. In *Resettlement Challenges for Displaced Populations and Refugees*; Asgary, A., Ed.; Springer International Publishing: Cham, Switzerland, 2018; pp. 93–104. [CrossRef]
2. Ajulo, O.; Asgary, A.; Tang, P.; Von-Meding, J. Modelling transformative adaptation: Case of post-earthquake Lyttelton, New Zealand. *Environ. Sci. Policy* **2021**, *125*, 247–262. [CrossRef]
3. Pelling, M.; O'Brien, K.; Matyas, D. Adaptation and transformation. *Clim. Chang.* **2015**, *133*, 113–127. [CrossRef]
4. O'Connell, D.; Walker, B.; Abel, N.; Grigg, N. *The Resilience, Adaptation and Transformation Assessment Framework: From Theory to Application*; CSIRO: Canberra, Australia, 2015.
5. Cretney, R.M. Local Responses to Disaster: The Value of Community led Post Disaster Response Action in a Resilience Framework. *Disaster Prev. Manag.* **2016**, *25*, 27–40. [CrossRef]
6. Gil-Rivas, V.; Kilmer, R.P. Building Community Capacity and Fostering Disaster Resilience. *J. Clin. Psychol.* **2016**, *72*, 1318–1332. [CrossRef] [PubMed]
7. Moser, C.; Satterthwaite, D. Toward Pro-Poor Adaptation to Climate Change in the Urban Centers of Low- and Middle-Income Countries. In *Social Dimensions of Climate Change-Equity and Vulnerability in a Warming World*; Mearns, R., Norton, A., Eds.; World Bank: Washington, DC, USA, 2010; pp. 231–258. [CrossRef]
8. Pelling, M. *Adaptation To Climate Change: From Resilience To Transformation*; Routledge: New York, NY, USA, 2010.
9. Kuecker, G.D.; Hall, T.D. Resilience and Community in the Age of World-System Collapse. *Nat. Cult.* **2011**, *6*, 18–40. [CrossRef]
10. Pelling, M. Toward A Political Ecology Of Urban Environmental Risk. In *An Integrative Approach to Geography and Environment-Development Studies*; Zimmerer, K.S., Bassett, T.J., Eds.; Routledge: Abingdon, UK, 2011; pp. 73–93.
11. Drennan, L.; Morrissey, L. Resilience policy in practice—Surveying the role of community based organisations in local disaster management. *Local Gov. Stud.* **2019**, *45*, 328–349. [CrossRef]
12. Mlcek, S.; Ismay, D. Balanced Management in the Delivery of Community Services through Information and Neighbourhood Centres. *Third Sect. Rev.* **2015**, *21*, 31–50.
13. Thornley, L.; Ball, J.; Signal, L.; Aho, K.L.-T.; Rawson, E. Building community resilience: Learning from the Canterbury earthquakes. *Kotuitui N. Z. J. Soc. Sci. Online* **2015**, *10*, 23–35. [CrossRef]
14. Partelow, S. Social capital and community disaster resilience: Post-earthquake tourism recovery on Gili Trawangan, Indonesia. *Sustain. Sci.* **2021**, *16*, 203–220. [CrossRef]
15. Roaf, S.; Hyde, R.; Campbell, C.; Seigert, M. Transforming markets in the built environment and adapting to climate change: An introduction. *Arch. Sci. Rev.* **2010**, *53*, 3–11. [CrossRef]
16. Patterson, J.; Schulz, K.; Vervoort, J.; van der Hel, S.; Widerberg, O.; Adler, C.; Hurlbert, M.; Anderton, K.; Sethi, M.; Barau, A.S. Exploring the governance and politics of transformations towards sustainability. *Environ. Innov. Soc. Transit.* **2017**, *24*, 1–16. [CrossRef]
17. Andersson, K. Local Governance of Forests and the Role of External Organizations: Some Ties Matter More Than Others. *World Dev.* **2013**, *43*, 226–237. [CrossRef]
18. IPCC. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment*; Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E., Eds.; Cambridge University Press: Cambridge, UK, 2007.
19. Birkmann, J.; Dech, S.; Hirzinger, G.; Klein, R.; Klüpfel, H.; Lehmann, F.; Mott, C.; Nagel, K.; Schlurmann, T.; Setiadi, N.J.; et al. Measuring Vulnerability To Promote Disaster-Resilient Societies: Conceptual Frameworks And Definitions. In *Measuring Vulnerability To Natural Hazards: Towards Disaster Resilient Societies*; Birkmann, J., Ed.; UNU-Press: Tokyo, Japan, 2006; pp. 9–54.
20. Wisner, B.; Blaikie, P.; Cannon, T.; Davis, I. *At Risk: Natural Hazards, People's Vulnerability and Disasters*; Routledge: New York, NY, USA, 2004.
21. Osbahr, H. *Building Resilience: Adaptation Mechanisms and Mainstreaming for the Poor*; UNDP: New York, NY, USA, 2007; Available online: <https://core.ac.uk/download/pdf/6248706.pdf> (accessed on 24 April 2020).
22. Malik, A.; Qin, X.; Smith, S.C. *Autonomous Adaptation To Climate Change: A Literature Review*; George Washington University: Washington, DC, USA, 2010; pp. 1–25.
23. Broto, V.C.; Trencher, G.; Iwaszuk, E.; Westman, L. Transformative capacity and local action for urban sustainability. *Ambio* **2019**, *48*, 449–462. [CrossRef] [PubMed]
24. Fussler, H.-M. Adaptation Planning For Climate Change: Concepts, Assessment Approaches, And Key Lessons. *Sustain. Sci.* **2007**, *2*, 265–275. [CrossRef]

25. O'Keefe, P.; Westgate, K.; Wisner, B. Taking the naturalness out of natural disasters. *Nature* **1976**, *260*, 566–567. [CrossRef]
26. Smit, B.; Pilifosova, O. Adaptation to climate change in the context of sustainable development and equity. *Sustain. Dev.* **2003**, *8*, 9.
27. Adams, I. Differential Vulnerability and Adaptive Responses to Climate Change-Related Hazards in Informal Urban Settlements in Accra, Ghana. Ph.D. Thesis, University of Technology Sydney, Sydney, Australia, 2019. Available online: <https://opus.lib.uts.edu.au/bitstream/10453/137134/1/01front.pdf> (accessed on 1 February 2022).
28. Islam, R.; Walkerden, G. How bonding and bridging networks contribute to disaster resilience and recovery on the Bangladeshi coast. *Int. J. Disaster Risk Reduct.* **2014**, *10*, 281–291. [CrossRef]
29. Crona, B.; Bodin, O. Knowledge, Social Networks and Leadership: Setting the Stage for the Development of Adaptive Institutions? In *Adapting Institutions: Governance, Complexity and Socio-Ecological Resilience*; Boyd, E., Folke, C., Eds.; Cambridge University Press: New York, NY, USA, 2012; pp. 11–36.
30. Gotham, K.F.; Cheek, W. Post-disaster Recovery and Rebuilding. In *The SAGE Handbook of the 21st Century City*; Hall, S., Burdett, R., Eds.; SAGE: London, UK, 2017; pp. 279–297. [CrossRef]
31. Ensor, J.; Berger, R. *Community-Based Adaptation And Culture In Theory And Practice*; Cambridge University Press: New York, NY, USA, 2009.
32. Dovey, K. Informal urbanism and complex adaptive assemblage. *Int. Dev. Plan. Rev.* **2012**, *34*, 349–368. [CrossRef]
33. Holling, C.S. Understanding the Complexity of Economic, Ecological, and Social Systems. *Ecosystems* **2001**, *4*, 390–405. [CrossRef]
34. Holling, C.S. Resilience and Adaptive Cycles. In *Panarchy: Understanding Transformations in Human and Natural Systems*; Gunderson, L.H., Holling, C.S., Eds.; Island Press: Washington, DC, USA, 2002; pp. 25–62.
35. Folke, C.; Carpenter, S.; Elmqvist, T.; Gunderson, L.; Holling, C.S.; Walker, B. Resilience and sustainable development: Building adaptive capacity in a world of transformations. *AMBIO A J. Hum. Environ.* **2002**, *31*, 437–440. [CrossRef]
36. Walker, B.; Holling, C.S.; Carpenter, S.R.; Kinzig, A. Resilience, adaptability and transformability in social-ecological systems. *Ecol. Soc.* **2004**, *9*, 5. [CrossRef]
37. Lansing, J.S. Complex Adaptive Systems. *Annu. Rev. Anthropol.* **2003**, *32*, 183–204. [CrossRef]
38. Peter, C. A Complexity-Based Perspective on Assemblage Theory: Implications for Modelling Urban Assemblages and their Role in Transitions to Sustainability. *Academia* **2019**. Available online: [https://www.academia.edu/28362812/A\\_Complexity-Based\\_Perspective\\_on\\_Assemblage\\_Theory\\_Implications\\_for\\_Modelling\\_Urban\\_Assemblages\\_and\\_their\\_Role\\_in\\_Transitions\\_to\\_Sustainability](https://www.academia.edu/28362812/A_Complexity-Based_Perspective_on_Assemblage_Theory_Implications_for_Modelling_Urban_Assemblages_and_their_Role_in_Transitions_to_Sustainability) (accessed on 10 January 2020).
39. Adger, W.N.; Agrawala, S.; Mirza, M.M.Q.; Conde, C.; O'Brien, K.; Pulhin, J.; Pulwarty, R.; Smit, B.; Takahashi, K. Assessment Of Adaptation Practices, Options, Constraints and Capacity. In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*; Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E., Eds.; Cambridge University Press: Cambridge, UK, 2007; pp. 718–743.
40. Bonabeau, E. Agent-based modeling: Methods and techniques for simulating human systems. *Proc. Natl. Acad. Sci. USA* **2002**, *99*, 7280–7287. [CrossRef]
41. Andersen, M.; Bartholemuesz, L.; Guo, Y.; Owen, C. *Volunteering in Lyttelton: Impacts and Encouraging Greater Participation*; University of Canterbury: Christchurch, New Zealand, 2014.
42. Ozanne, L.K.; Ozanne, J.L. *Developing Local Partners in Emergency Planning and Management: Lyttelton Time Bank as a Builder and Mobiliser of Resources during the Canterbury Earthquakes*; University of Canterbury: Christchurch, New Zealand, 2013.
43. Statistics New Zealand. 2013 Census Quick Stats about a Place: Lyttelton; Statistics New Zealand: Lyttelton, New Zealand, 2013. Available online: [http://www.stats.govt.nz/Census/2013-census/profile-and-summary-reports/quickstats-about-a-place.aspx?request\\_value=14876&parent\\_id=14758&tablename=&sc\\_device=pdf](http://www.stats.govt.nz/Census/2013-census/profile-and-summary-reports/quickstats-about-a-place.aspx?request_value=14876&parent_id=14758&tablename=&sc_device=pdf) (accessed on 24 June 2017).
44. Yin, R.K. *Case Study Research: Design and Methods*; Sage Publications: Thousand Oaks, CA, USA, 2013.
45. Galea, S.; Riddle, M.; Kaplan, G.A. Causal thinking and complex system approaches in epidemiology. *Int. J. Epidemiol.* **2009**, *39*, 97–106. [CrossRef]
46. Pyka, A.; Fagiolo, G. Agent-based Modelling: A methodology for neo-schumpeterian economics. In *Elgar Companion to Neo-Schumpeterian Economics*; Hanusch, H., Pyka, A., Eds.; Edward Elgar Publishing Limited: Massachusetts, MA, USA, 2007; pp. 467–487.
47. Winz, I.; Brierley, G.; Trowsdale, S. The Use of System Dynamics Simulation in Water Resources Management. *Water Resour. Manag.* **2009**, *23*, 1301–1323. [CrossRef]
48. Dodman, D.; Satterthwaite, D. Institutional Capacity, Climate Change Adaptation and the Urban Poor. *IDS Bull.* **2009**, *39*, 67–74. [CrossRef]
49. Funfgeld, H. Facilitating local climate change adaptation through transnational municipal networks. *Curr. Opin. Environ. Sustain.* **2015**, *12*, 67–73. [CrossRef]
50. Capra, F.; Luisi, P.L. *The Systems View of Life: A Unifying Vision*; Cambridge University Press: New York, NY, USA, 2014.
51. Moser, C.; Norton, A.; Stein, A.; Georgieva, S. *Pro-Poor Adaptation to Climate Change in Urban Centers*; World Bank: Washington, DC, USA, 2010.
52. Wallerstein, I. Structural Crises. *New Left Rev.* **2010**, *62*, 13–142.
53. Mochizuki, J.; Chang, S.E. Disasters as opportunity for change: Tsunami recovery and energy transition in Japan. *Int. J. Disaster Risk Reduct.* **2017**, *21*, 331–339. [CrossRef]

- 
54. Cutter, S.L.; Barnes, L.; Berry, M.; Burton, C.; Evans, E.; Tate, E.; Webb, J. A place-based model for understanding community resilience to natural disasters. *Glob. Environ. Chang.* **2008**, *18*, 598–606. [[CrossRef](#)]
  55. Sampson, R.J.; Graif, C. Neighborhood Social Capital as Differential Social Organization: Resident and Leadership Dimensions. *Am. Behav. Sci.* **2009**, *52*, 1579–1605. [[CrossRef](#)]
  56. Gunderson, L.H. *Panarchy: Understanding Transformations in Human and Natural Systems*; Gunderson, L.H., Holling, C.S., Eds.; Island Press: Washington, DC, USA, 2001.
  57. Abel, N.; Cumming, D.H.M.; Anderies, J.M. Collapse and Reorganization in Social-Ecological Systems: Questions, Some Ideas, and Policy Implications. *Ecol. Soc.* **2006**, *11*, 17. Available online: <http://www.ecologyandsociety.org/vol11/iss1/art17/> (accessed on 18 January 2020). [[CrossRef](#)]
  58. Aldrich, D.P.; Page-Tan, C.M.; Paul, C.J. Social Capital and Climate Change Adaptation. In *Oxford Research Encyclopedia of Climate Science*; Oxford University Press: Oxford, UK, 2016. [[CrossRef](#)]
  59. O'Brien, K.; Wolf, J. A values-based approach to vulnerability and adaptation to climate change. *Wiley Interdiscip. Rev. Clim. Chang.* **2010**, *1*, 232–242. [[CrossRef](#)]
  60. Lee, K.N. Appraising Adaptive Management. In *Biological Diversity: Balancing Interests Through Adaptive Collaborative Management*; Buck, L.E., Geislers, C.C., Schelhas, J., Wollenberg, E., Eds.; CRC Press: Boca Raton, FL, USA, 2001; pp. 3–24.
  61. Kanie, N.; Betsill, M.M.; Zondervan, R.; Biermann, F.; Young, O.R. A Charter Moment: Restructuring Governance for Sustainability. *Public Adm. Dev.* **2012**, *32*, 292–304. [[CrossRef](#)]