2023 Student Research Case Study Challenge: Relocation Social Insurance

UNSW Group JKB

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Executive Summary

This report was composed to design and evaluate a social insurance program to assist Storslysia in mitigating displacement risk as a result of climate-related hazard events. The program design specifies claim coverage of 30% of household goods and 12 months of temporary housing, as well as incentives such as buybacks and grants to provide opportunities for voluntary relocation to lower risk regions. Projections of economic costs over short- and long-term time frames with and without the proposed insurance program found that the scheme was able to reduce displacement costs with a high degree of certainty in the long-term under all climate scenarios. The economic capital needed would be at least ϕ 300 billion each year to remain solvent, but the scheme remains within 10% of GDP with 97.5% confidence. Moreover, the key risks were assessed through both qualitative and quantitative risk analyses, with suggested mitigation strategies. The report concludes with a recommendation of how to proceed with the implementation of the program regarding the analyses performed.

Objectives

The goal of this social insurance program is to manage the financial risks associated with catastrophe-related displacement in Storslysia. To this end, the program aims to encourage proactive relocation which lowers damage risk and comes at a lower cost than involuntary displacement. This scheme will cover the entire population of Storslysia. As well as reducing long-term costs from climate-related disasters regardless of future emissions scenarios, this scheme will provide financial support to Storslysia citizens affected by such disasters. This program will be equitable in its design such that very affluent households are not advantaged by the scheme any more than lower or middle-class households. Keeping the costs arising from relocation from exceeding 10% of GDP each year with a high degree of certainty is the aim of this program.

The following key metrics will be used to monitor the social insurance program:

Metric	Frequency
Compare costs with and without the scheme	- Annually for the first 10 years - Every 3 years after that
Number of people who voluntarily relocated each year	- Annually
Cost as percentage of GDP	- Annually
Value at risk	- Annually

For more details on each metric, see Appendix Table 1.1.

Program Design

In our program, all citizens of Storslysia will be covered for displacement costs after a climate catastrophe. However, we will distinguish between support for households who are voluntarily relocating and households who are involuntary relocating due to a natural disaster. We also distinguish between renters and owner-occupiers.

Requirements to make a claim

All households, regardless of region, are entitled to financial support for temporary housing, rebuilding their property and household-goods replacement costs. For households in regions 2, 4, 5 and 6, additional support is provided contingent upon that household relocating to regions 1 or 3, the lower risk regions. (See Appendix Table 2.1 for justification of which regions are high and low risk).

To be eligible for voluntary relocation support, a household in a highly affected region (regions 2, 4, 5 and 6) may apply for financial assistance to relocate their household to a safer region (regions 1 or 3). Both renters and owner-occupiers in highly affected regions are eligible for this support.

To be eligible for involuntary relocation support, a household must be affected by a severe weather event, causing irrecoverable damage to the home such that it is no longer fit for living.

Program coverage

Support for all households with uninhabitable homes affected by the natural disaster, regardless of the region, include the following:

- Up to 30% of housing costs will be paid out to replace household goods.
- Up to 30% of the median value of houses in that region.
- Temporary housing in the affected region is provided for 12 months.

In addition, the following benefits are included as a part of the program to assist with relocation:

	Voluntary relocation	Involuntary relocation
Owner-occupiers (Region 2, 4, 5, 6)	- Pay for the construction of a new home up to the median owner-occupier home value in the new region. - Pay a lump-sum of $10,000.	- Buy back uninhabitable homes in high-risk regions up to the median value of the home in that region, provided the household moves to a low-risk region.
Renters (Region 2, 4, 5, 6)	- Pay for home rental costs for 6 months in the new region, up to the median rent in the new region.	- Pay for home rental costs for 2 months in the new region, up to the median rent in the new region.

Incentives for voluntary relocation

Encouraging voluntary relocation is important because it results in lower costs than involuntary relocation. This is due to lower costs to find and build accommodation (no labour and material cost inflation after the disaster), zero household item replacement costs, no temporary housing costs and less psychological damage and stress on the country. Relocated households also have a lower risk profile by moving to a lower risk region.

The main incentive to encourage voluntary relocation is the grant (up to the median value of homes in the new region) to purchase a new home in a less-affected region for owner-occupiers in high-risk regions. This will eliminate the upfront costs of relocating for

households and provide most high-risk households with a higher value property in a safer location. A lump-sum payment of $10,000 will also be provided to encourage voluntary relocation for owner-occupiers. This will help cover moving costs and provide an additional financial incentive to relocate. For renters, the program will instead pay 6 months of rent to ease the transition to the new low-risk region from an at-risk region.

Other key program features

This program will limit voluntary relocations to 4% of the population of a region in the previous year. This is to avoid overloading the program with large numbers of households voluntarily relocating in the first few years and avoid the inflated material and labour costs due to excess demand. This feature also helps keep the scheme's cost under 10% of GDP in the initial years of the program. As a social insurance scheme, this program will be financed by the state, have no means testing and will provide equal benefits for all voluntary relocators. This promotes equity in Storslysia.

Justification of program features

Some justifications of features have been provided above, however more detailed reasonings and supporting evidence can be found in Appendix Table 2.1.

Timeframes for evaluation

In accordance with the final stage of the actuarial control cycle, a constant monitoring and evaluation process over short and long-term time frames will be undertaken to assess the effectiveness and relevancy within this scheme and potentially revise areas to ensure the validity of the program.

Short-term (review annually)

- Annually review the economic costs of the program versus the predicted costs and the theoretical economic costs without the program. This will help the government of Storslyia assess the effectiveness of the program in reducing the financial risk associated with catastrophe-related displacement.
- Given the high initial cost of encouraging voluntary relocations, the first 10 years will focus on ensuring that the costs of the scheme do not exceed 10% of GDP. The following years will be considered the long-term timeframe over which to program is expected to deliver savings.
- Annually review the number of people who voluntarily relocate; this is another metric of scheme success as relocated households have a lower risk profile than households that stay in high-risk areas; the model may also need updating based on the number of households that relocate, as this will affect future scheme costs.
- Annually review the new risk profile of those who voluntarily relocate to see if it is the same as the risk profile of other households in the region.

Long-term (review every 5-10 years)

- Every 5 years, aggregate the above metrics to determine if changes are needed to the policy, and if the scheme has performed as expected. This reduces annual variability and helps assess the scheme over a longer timeframe. This also reduces uncertainty for households as the scheme will not be constantly changing.

Pricing and Costs

Methodology

To accurately project the economic costs of the climate-related catastrophes for Storslysia, data was gathered from Storslysia's quarterly historical record of climate-related catastrophes ranging from 1960 to 2020, as well as economic and demographic data on each of the 6 regions. Exploratory data analysis was performed to understand the economic and demographic nature of each region and their climate risks.

A training set of data was selected for the period 1960 to 2015, leaving the last 5 years as a validation set to assess performance via various metrics. Taking a frequency-severity approach to pricing claims cost, forecasts were projected for each region using simulations from each distribution, before aggregating to a final estimate with 95% confidence intervals (see Appendix Figure 3.1, 3.2 and 3.3). A negative binomial frequency model and a gamma severity model were selected for all regions except region 1, which fit a weibull severity model.

Short-Term Projections

For this program, short-term projections refer to estimates for 2020 and are applicable for the next decade. Exceeding a decade, new inputs and modifications from the regular monitoring and evaluation procedures will be needed for more accurate projections.

Economic costs

Without the proposed insurance program, the cost of total property damage is estimated to be close to ϕ 255 million per annum. This value is comprised of a projected 53.4 climate-related disasters experienced across the whole of Storslysia each year, with an average impact of ϕ 4.8 million (see Appendix Table 3.1). Along with property damage, climate-related catastrophes also come with additional costs, including temporary housing for involuntary relocation, material and labour for rebuilding damaged properties, and replacing household items. These costs will be referred to as displacement costs. These values have been summarised in the table below. The short-term projection (2020-2030) for total economic cost is ϕ 836.6 million per annum.

	Mean Estimates	Upper Bound (97.5%)
Property Damage	ϕ 255,115,548	ϕ 9,637,762,244
Displacement Costs	ϕ 581,450,888	ϕ 25,738,567,833
Total Economic Cost	ϕ 836,566,436	ϕ 35,376,330,076

Table 1. Summary of short-term projections for annual economic cost without social insurance program.

Program costs

Under the proposed social insurance program, residents in high-risk areas (Region 2, 4, 5, 6) will be incentivised to move both before and after a hazard event occurs. This corresponds to the voluntary and involuntary costs below, respectively. In the short-term, this program will lead to higher economic costs due to extra payments to incentivise residents to move to lower-risk regions through lump-sum payments, construction of new homes, rent payments and house buy-backs (see Program Design section for full details).

From the projected values below, a slight reduction in the mean property damage and displacement cost estimates is evident, compared to costs without the program (11.69%

and 11.54% respectively). Additionally, in the short-term (2020-2030), the cost of incentivising voluntary relocation is around ϕ 12 billion, while involuntary relocation after a hazard event is only around ϕ 55.5 million. As the number of voluntary relocations declines, the scheme costs will also decline (see Appendix Figure 3.4).

	Mean Estimates	Upper Bound (97.5%)
Property Damage	ϕ 225,302,571	ϕ 8,968,316,447
Displacement Costs	ϕ 514,378,676	ϕ 23,953,318,562
Relocation Incentive Costs	ϕ 12,310,238,772	ϕ 12,310,238,772
Voluntary Costs	ϕ 12,254,805,736	ϕ 12,254,805,736
Involuntary Costs	ϕ 55,433,035	ϕ 55,433,035
Total Economic Cost	ϕ 13,049,920,018	ϕ 45,231,873,780

Table 2. Summary of short-term projections for annual economic cost (2020-2030) with social insurance program.

Long-Term Projections

The long-term projections refer to estimates 50 years into the future (i.e. from 2070).

Economic costs

Without the social insurance program and assuming the same population and climate as at present, it is expected that the frequency and severity models remain the same. The only impacting factor on total economic costs would be the rate of inflation. For simplicity, we assume 2020 prices and hence the economic cost will remain as previously in Table 1.

Program costs

With the social insurance program in place, the effects of incentivising relocation will continue to be experienced and reduce the overall property damage and displacement costs. Averaging over 10 years of economic costs (i.e. 2070-2080), gives the values in the table below. Both the mean and upper bound estimates are significantly lower than without the program (18.87% and 11.08% respectively). Moreover, the incentive cost for voluntary relocation is under ϕ 200,000, suggesting that the equilibrium population allocation in each region has almost been reached. The average displacement costs have also decreased another 8% from the initial short-term projection.

	Mean Estimates	Upper Bound (97.5%)
Property Damage	ϕ 206,962,717	ϕ 8,570,367,393
Displacement Costs	ϕ 473,142,809	ϕ 22,892,334,372
Relocation Incentive Costs	ϕ 51,065,396	ϕ 51,065,396
Voluntary Costs	ϕ 174,906	ϕ 174,906
Involuntary Costs	ϕ 50,890,490	ϕ 50,890,490
Total Economic Cost	ϕ 731,170,922	ϕ 31,513,768,160

Table 3. Summary of long-term projections for annual economic cost (2070-2080) with social insurance program.

Capital and Solvency Requirements

According to the European Union's Solvency II requirement, companies must hold enough capital to have a 99.5% confidence of surviving the most extreme expected losses during a year (Risk.net n.d.). To ensure this same level of certainty for Storslysia's insurance program,

the total economic capital in the first year of implementation would be close to ϕ 390 billion. After that, each subsequent year requires less capital to be held ending at around ϕ 346 billion needed in 2110. The amount of capital needed over the short and long-term timeframes is displayed in the graph below (see Appendix Table 3.2 for details).

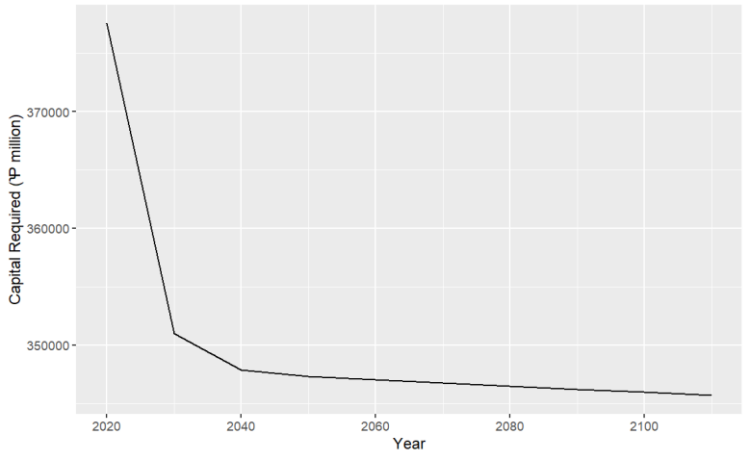


Figure 1. Graph of capital required to remain solvent with a 99.5% confidence over the short and long-term timeframes.

Assumptions

Assumptions within the modelling process, economic climate and validity of the utilised datasets were required to ensure the program generated accurate and reliable results. A summary of all the assumptions used can be seen in the table below.

#	Assumption	
01	Population	Closed population model (based on 2021 population)
02	Voluntary relocation	4% of households voluntarily relocate each year, decreasing by 20% per year
03	Displacement	20% of households impacted by climate event will relocate
04	Temporary housing	Only needed for 12 months after a hazard event and is adequate time to rebuild a house to a liveable state
05	Inflation	Average material and labour inflation after a hazard event is 25%, while in the more severe scenarios is 50%; no inflation for voluntary relocation
06	House contents	Value as proportion of house value is based on ABS data, average cost of replacing increases by 57.5% after a hazard event, with the more severe case of 75%
07	Median value	Property values of each region are estimated by median value
08	Property damage	Increases/decreases are proportional to the changes in population in the region
09	Model	Chosen frequency and severity models are correct
10	Interpolation	Data can be accurately interpolated via linear or geometric mean

Model assumptions

The model assumes the number of households affected by an event is the total property damage divided by the median value of houses in that region. It is also assumed that the property damage in a region is proportional to the population of that region.

Another assumption was the distribution of the frequency and severity of climate events perfectly follow the chosen parametric distributions within each region, and historical trends can infer future impacts. The rationale of this was to enable the forecast of expected total cost from climate events and thus the program in the short and long term, but also to account for the plausibility of the scheme to remain solvent within stressed scenarios (adverse scenarios).

Projection assumptions

The closed model assumption, in which the most recent census data (2021) about Storslysia reflects the entire population with no population growth was made within the program. Realistically this will not reflect true impacts of population movements not only in-between regions but also in and out of the country. The benefits of a closed model assumption were to simplify calculations and still draw meaning insights from the cost projections.

Lack of forecasted data required the assumption of GDP per capita to be applied as a proxy for Storslysia's future GDP growth, with a geometric average applied after 2100 when no more data was available. Furthermore, historical and future projected inflation data was transformed to reflect a base year of 2020 to ensure consistent accounting of price increases and thus real costs of the scheme.

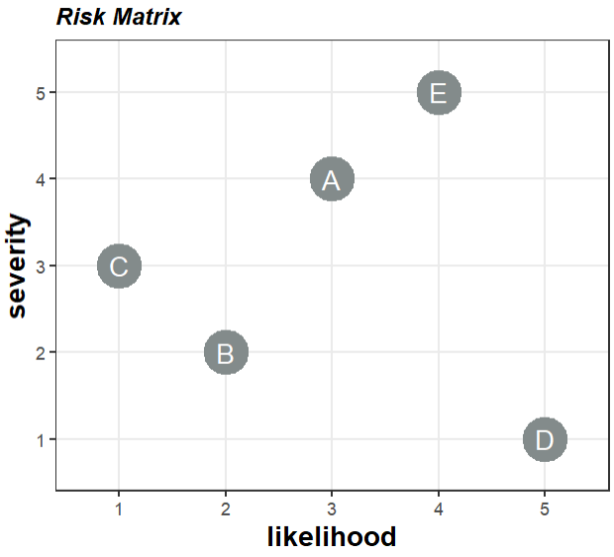
Scope assumptions

When individuals move to a new region, whether for voluntary or involuntary relocation, the risk in that new region is assumed to reflect the risk impacting them as a result of climatic events. Also, it is assumed that the population within a certain region affects risk in the region – the rationale of this is to display the improved financial benefits which can be associated with the introduction of the scheme. Intuitively, these are also reasonable assumptions as movements into new regions will expose these residents to different climate risk impacts.

Risk and Risk Mitigation Strategies

Key Risks and Mitigation Strategies

When a project is underway, unexpected factors have the potential to affect the success of a project, and thus proactive identification, assessment and action improves the chance of success in meeting project objectives (Hillson, David 2014). The risk matrix (right) illuminates the key areas of risk present within the scheme:



A) **Event risk**: Simplistic assumptions within the model calibration process cannot perfectly represent the stochastic uncertainty of future climate events, thus inhibiting the predictive capacity of the model and requiring capital reserves for the scheme. Parametric methods may severely under- (requiring additional capital to bridge the gap) or over-estimate (opportunity cost of uninvested funds) property damages which limits the reliability and validity of the program. New homes constructed in regions 1 and 3 may not have the same risk profile as other homes, and regions may not be homogeneously affected by climate change.

Mitigation: The model predictions and actual property damage will be continuously monitored in a regular basis (every quarter) to see if the simplistic assumptions made are still plausible in modelling total future climate impacts; large capital reserves recommended at the 99.5%-risk level

B) **Legislative/Governance risk:** The frequency and severity of climate events is contingent upon government's climate policy which may mitigate or accentuate Storslyia's climate disaster damages. Moreover, governance may also require changes in the scheme design.

Mitigation: Close analysis and discussions with Storslysia's governmental body will be taken at the beginning of each year to discuss if the scope of the scheme is still relevant and has adequate coverage. Different climate scenarios considered in sensitivity analysis.

C) **Inequality risk**: The scheme's inability to equally support individuals within Storslysia presents a social risk, especially since the scheme may disproportionally assist citizens of higher socio-economic status (e.g., owner-occupiers receive significantly more support than renters, who are often less affluent), impacting the wealth gap and potentially worsening the quality of life for poorer individuals, due to high premium costs within vulnerable areas where poorer individuals typically live in.

Mitigation: Specific schemes to assist lower-income and wealth individuals (such as paying up to the median value of properties in the new region) is incorporated within the program to account for this potential risk. Further, monitoring the people that take up the incentive to move can inform future changes to make it more equitable.

D) **Migration risk**: The program's attempts to transition residents from high-risk to low-risk regions is ultimately constrained by the capacity and willingness of each region to receive new residents, which will have economic repercussions due to the movement of both consumers and workers.

Mitigation: A financial compensation offered to individuals who voluntarily move in an attempt to attract movement into less-risky regions.

E) **Prediction risk**: The long-term timeframe under which this program operates results in extremely volatile forecasts when predicting climate events, which constrains the accuracy when allocating the amount of capital required for each program period, as well as premium requirements.

Mitigation: A conservative approach was undertaken in which upper bounds of higher confidence levels were used, as well as taking estimates that were averaged over a number of years to reduce variability.

Sensitivity Analysis

The sensitivity analysis is performed using the Shared Socioeconomic Pathways (SSPs) carbon emissions scenario forecasts (see Appendix Table 3.2). The projected log values of the long-term economic costs without the program are shown in the graph below. Under the best scenario (SSP1) where the world shifts to become greener and more sustainable, then the costs of climate-related disasters can be reduced below current (2020) levels. However, in the other 3 scenarios of higher carbon emissions, the economic cost will only continue to increase in the future. In the most severe scenario (SSP5), the average economic cost could increase up to 17-fold by 2150.

Certainty of Cost Estimates

Under the proposed program, there is a 97.5% confidence that costs will not exceed 10% of Storslysia's GDP in any given year as seen in the graph below. The solid lines represent the scheme cost and dashed lines represent 10% of GDP, each under the four SSP scenarios. The real GDP is modelled assuming no population growth and only increases in GDP per capita. While the scheme does not exceed 10% of GDP between now and 2100, there is the possibility it may exceed this level after 2100, particularly in the SSP5 scenario. This means that the program and underlying model assumptions must be assessed in the future to ensure it remains sustainable beyond around 80 years.

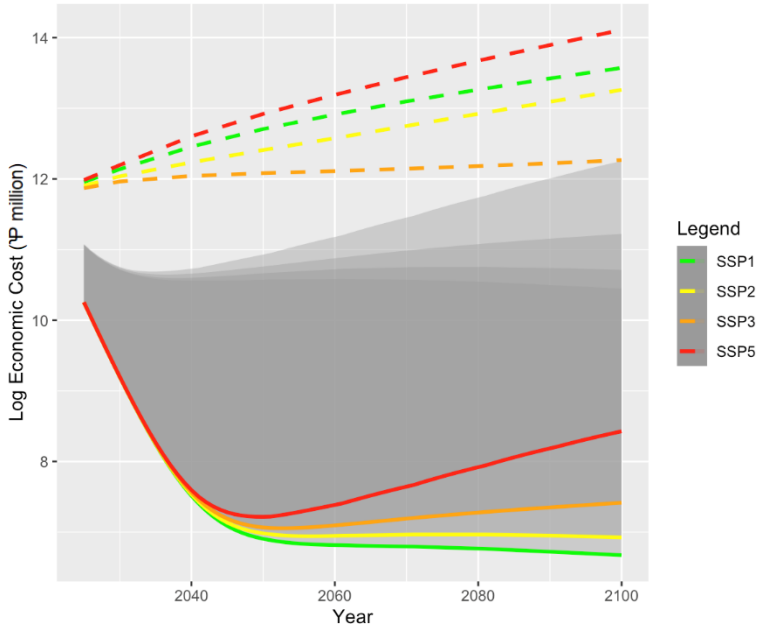


Figure 2. Projected costs under various climate scenarios compared to 10% GDP

Given constant claims (no adjusting for climate scenarios), the scheme is expected to have a negative economic benefit for 26 years. After this, the scheme delivers benefits increasing to $110 million in reduced damage and displacement costs per year. Under higher claims scenarios, the economic benefits of the scheme increase:

- Under the SSP2 scenario and the mean claims predicted, the scheme delivers positive economic benefits within 20 years reaching $180 million per year by 2065
- Under the severe claims (97.5th percentile) and SSP3 scenario, the scheme delivers economic benefits within 10 years, which can reach almost $10 billion per year (see Appendix Table 6.1 and 6.2)

The success of the scheme depends on the take-up of the voluntary relocation program, the main driver of reduced risks and reduced damage and associated costs. Secondary research suggested that between 15-20% of people would consider relocating to be away from high-risk areas without any additional financial incentive; hence, our 20% estimate of voluntary relocation is rather conservative, and take-up may be even higher (Yazzie R. 2021).

Data and Data Limitations

Data Sources

In addition to the Storlysia-specific data – housing and demographic information, historical weather-related hazards data and macroeconomic data – external data from the ABS was also utilized to inform the modelling process.

Limitations of provided data

There are inherent data limitations which inhibit the predictive capacity of the program and hence reliability. Operational risks as a result of human error when inputting, duplicate or missing values and one-off extreme values in historical data (e.g. inflation values in 2003) have impacts in the training of the model. To overcome these limitations, interpolation via linear or geometric means using surrounding data was utilised where appropriate. The rationale for this was due to calibrate the model without the influence of severe outliers.

Limitations when utilising data

The inability of historical data to perfectly capture population movements and account for unique situations within the future also presents a limitation in the modelling process, thereby limiting the accuracy of our program analysis. This is especially prevalent within the climate modelling area which has seen impacts in frequency and severity exacerbated by climate change. Compilation of data and the period of impacts has also presented a limitation as hazard event data only accounts for property damage (and does not distinguish between household goods, and material and labour costs) which is recognized and measured in days (duration). More precise calculations of property damage as well as duration of the hazard event would thus increase the predictive capacity of the models, as well as more data points to train the frequency and severity models.

Conclusion/Recommendations

In conclusion, the proposed social insurance scheme can help Storslysia mitigate their climate-related displacement risk while remaining under 10% GDP with a high level of confidence. After extensive analysis on the impact of the social insurance program over short and long-term timeframes and under different climate scenarios, the improved financial and social benefits associated with the scheme provide substantial evidence that the project should be employed given our assumptions. Although there are risk mitigation analysis and monitoring protocols incorporated within the program design of the scheme, it is quintessential to verify the plausibility of assumptions to ensure the validity and success of the scheme in achieving its objective to manage the financial risks associated with catastrophe-related displacement in Storslysia. The viability and strategy of financing the scheme must also be considered.

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Appendix

Table 1.1 *Detailed explanation and frequency of key metrics.*

Metric	Explanation	Frequency
Compare costs with and without the scheme	- Allows us to determine whether the scheme is improving the financial outcomes of Storslysia.	- Assessed annually for the first 10 years, with a full evaluation to be performed after 5 years. - Subsequently, monitor across every 3 years for the life of the scheme to have a broader view.
Number of people who voluntarily relocated each year	- Since voluntary relocation to less at-risk regions can be achieved at a lower cost than involuntary relocation after a disaster.	- Reviewed annually to determine if additional incentives are needed to encourage households to move. - In the long-term, discussions can be held regarding when to phase out the incentives.
Cost as percentage of GDP	- It has been prescribed that the scheme costs cannot exceed 10% of GDP.	- This metric will be assessed annually. - Increases in the cost as a percentage of GDP over time may indicate a change to the scheme is needed.
Value at risk	- Gives an indication of the most extreme scenarios and the level of confidence in amount of capital held	- Assessed annually along with evaluation of the costs of the scheme.

Table 2.1 *Detailed qualitative and quantitative justification of program features.*

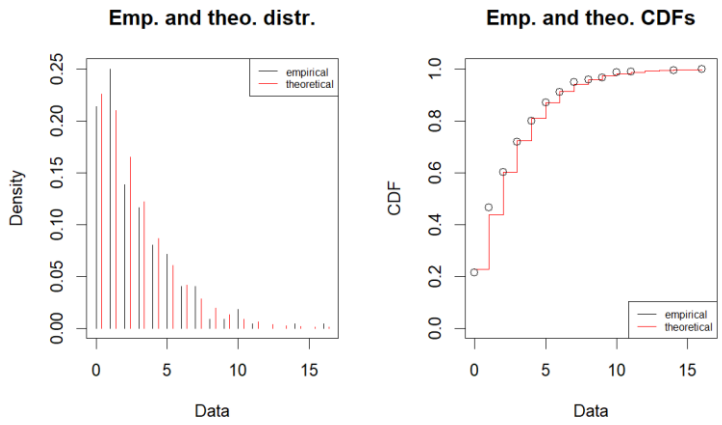
Program Feature	Qualitative Justification	Quantitative Justification
Paying owner-occupiers in regions 2, 4, 5 and 6 the value of a new home up to the median home value in regions 1 or 3, if they voluntarily relocate there	Eliminate the upfront cost of moving to a safer region; eliminate the impact of lower home values in regions 4-6 such that even households in these regions can afford moving to regions 1 and 3	The historical claims data showed that the total inflated (to 2021 dollars) per-person property damages was highest for region 5 (5607.48), followed by region 2 (5480.14), 4 (1947.02) and 6 (1098.78). Regions.1 and 3 had total historical claims of 220.38 and 483.85 respectively. Moreover, predicted damage per person for each region based on the frequency and severity modelling performed followed a similar pattern. This suggested that our scheme should relocate households from regions 2, 4, 5 and 6 to regions 1 and 3.

$10,000 lump-sum payment (voluntary owner-occupiers moving regions)	Cover moving costs and provide additional incentive to owner occupiers to move to a new, safer region	The average reduction in risk for a household moving from a high-risk to a low-risk region is $696 per year. At a discount rate of 7%, the future value of this risk reduction is worth $9952 ($696 ÷0.07) in present-value terms. Hence, a $10,000 lump-sum payment to incentivise voluntary relocation is commensurate with the economic benefits derived from this policy.
6 months rental assistance for voluntary relocators and 2 months for relocators following an event	Incentivise renting households to move to a safer region; the rental assistance for relocators following a disaster is lower to incentivise moving before being affected by a severe weather event	6 months of rental assistance in regions 1 and 3 costs $7560 and $7908 respectively, per household. This is below the present value of reduction in risk achieved at a 7% discount rate ($9952 as above). However, there are still social and other financial costs to the owner of the rental property that are not considered, hence the slightly lower value of benefits.
Buying back homes of households in high-risk regions after being affected by severe weather events if they move to a safer region, up to the median value of homes in the affected region	Provide incentive to households affected by severe weather events to move to a safer region; the buyback may not cover the full cost of constructing a new home in the new region, which provides an incentive to relocate before being affected by a natural disaster	Under the high-risk (97.5%) scenario, the voluntary relocations save $5,086 in damage and displacement costs a year, per relocation, compared to staying in a highly affected region. On average, $171,950 would be spent per-household in buying back a home in a highly affected region after an event. This implies an IRR of 2.96%. Given the 10-year risk-free rate in 2021 was 1.66%, it is reasonable to assume that this feature is economically beneficial and leads to a reduction in displacement costs for Storslysia.
Temporary housing for 12 months for all households affected by a natural disaster	Natural disasters often cause short-term declines in employment and income, creating additional financial stress. Providing free temporary housing for 12 months reduces this stress and gives owner-occupiers sufficient time to construct a new home.	
30% of housing costs as good replacement	While household goods have an estimated value of 40-75% of housing costs, this scheme will only pay for up to 30% of housing costs (up to the median household value in the affected region) to replace household goods. This is to cover essential goods only, and provide incentive to move to a safer region which will involve no property loss.	

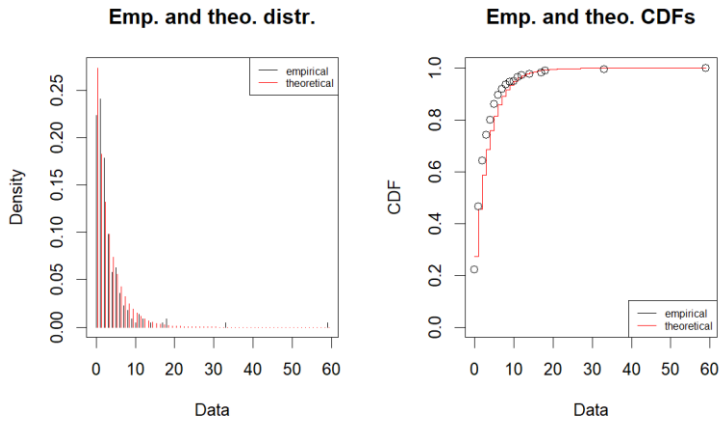
No coverage for investment properties	Investment properties are not covered under this scheme because 1) Renters are sufficiently covered; 2) Investment property owners are often wealthier, and providing additional financial support to this socio-economic group contradicts the social objectives of this program.

Figure 3.1 *Region hazard frequency data fit with their best distributions.*

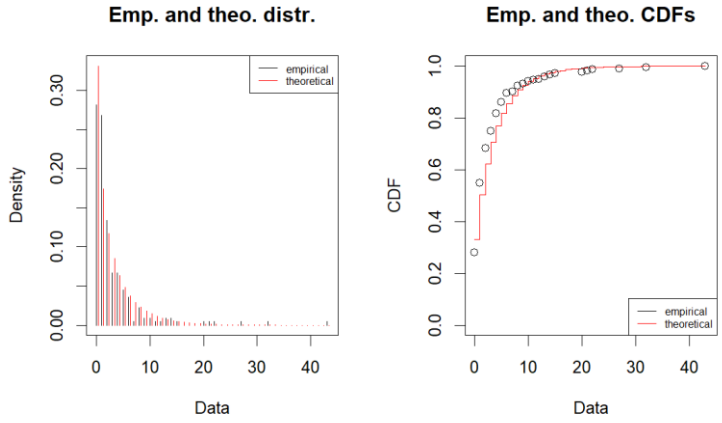
Region 1: Negative Binomial



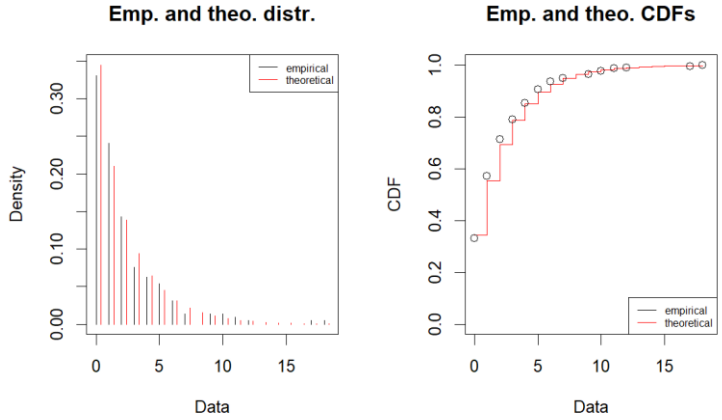
Region 2: Negative Binomial



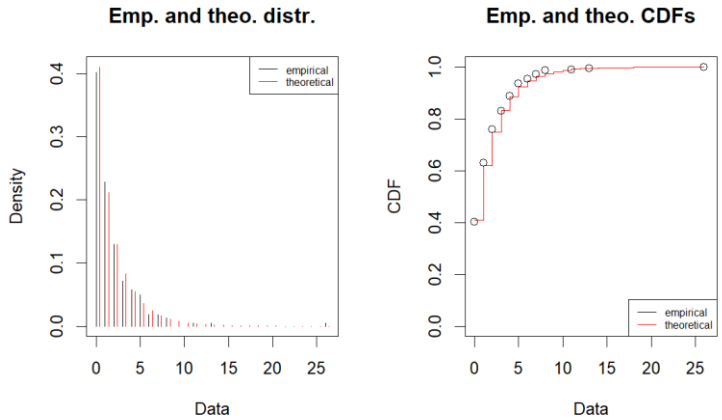
Region 3: Negative Binomial



Region 4: Negative Binomial



Region 5: Negative Binomial



Region 6: Negative Binomial

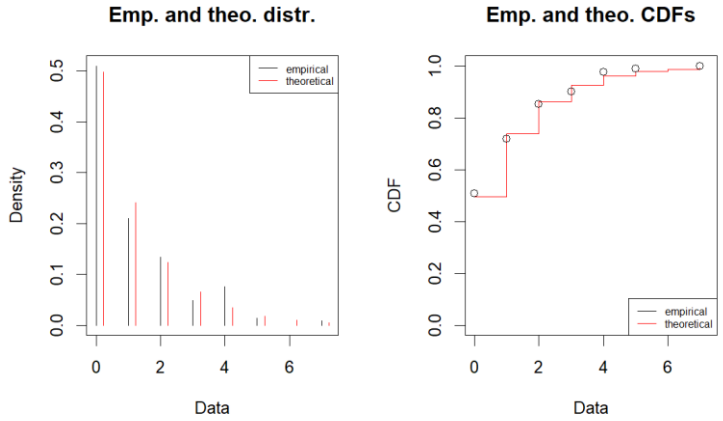
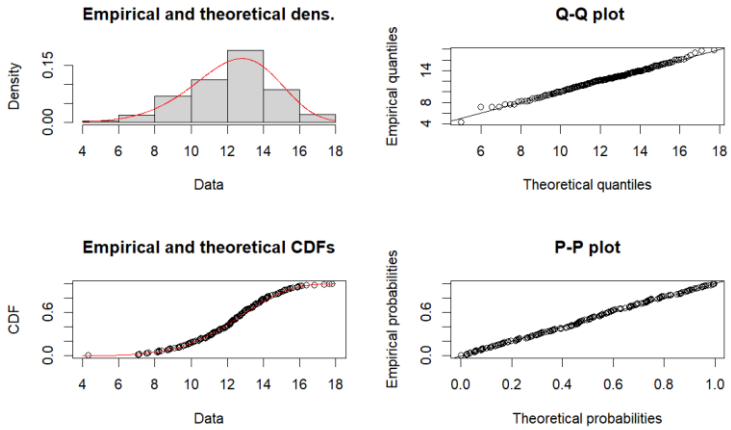
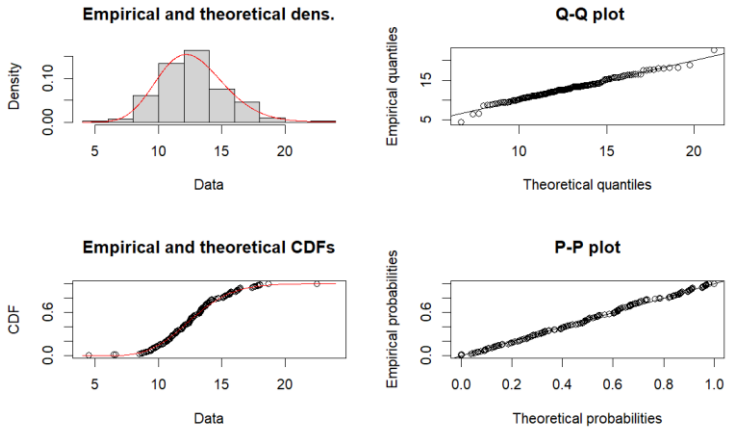


Figure 3.2 *Region hazard severity data fit with their best distributions.*

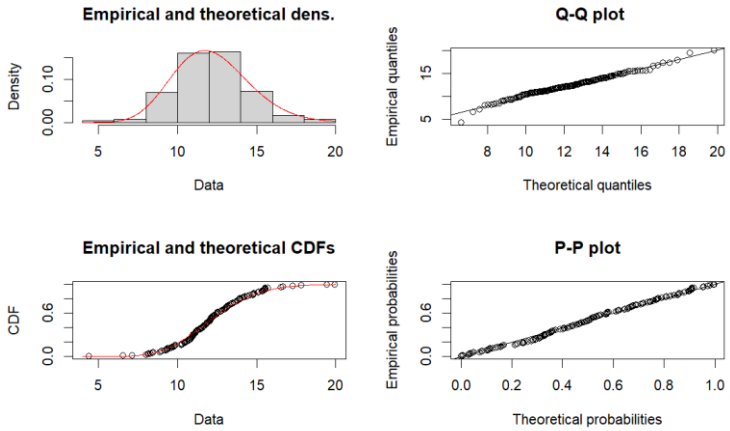
Region 1: Weibull distribution



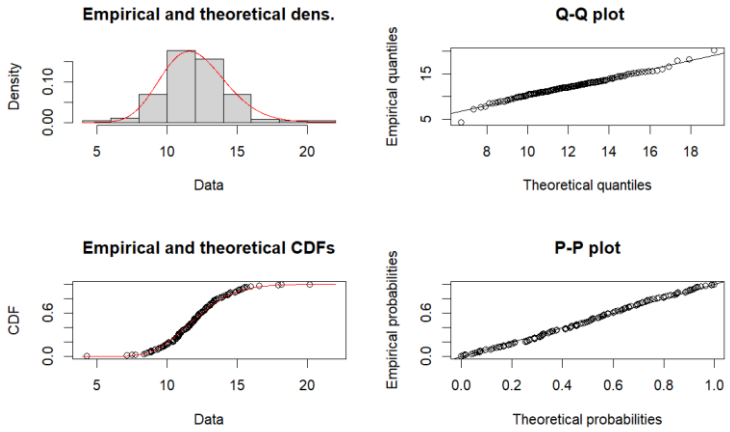
Region 2: Gamma distribution



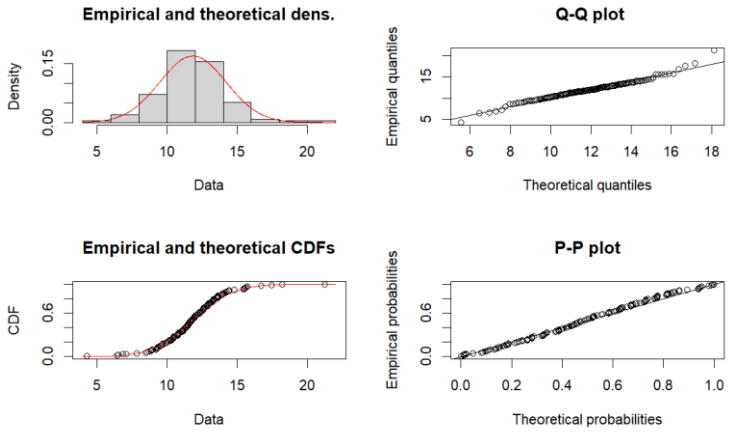
Region 3: Gamma distribution



Region 4: Gamma distribution



Region 5: Gamma distribution



Region 6: Gamma distribution

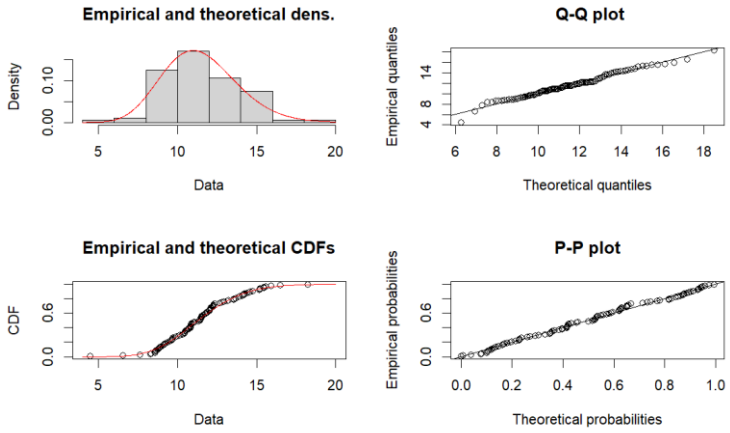
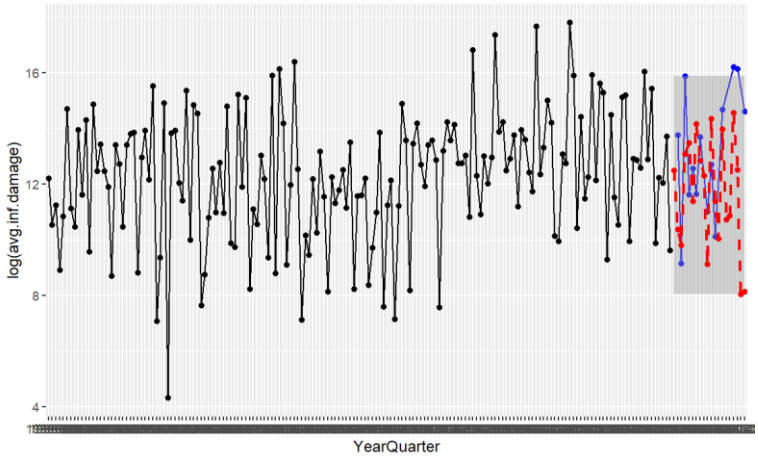
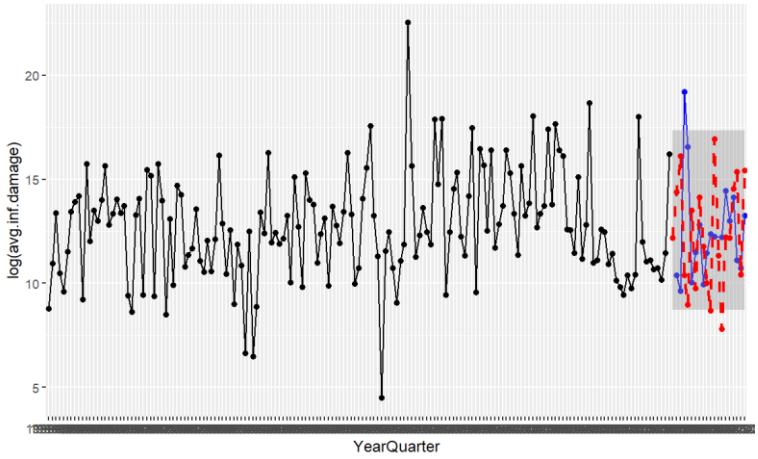


Figure 3.3 *5 -year simulated forecasts for each region with 95% confidence intervals.*

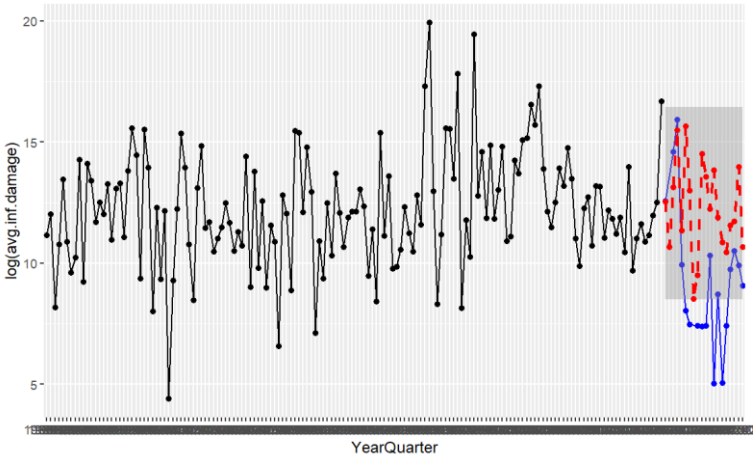
Region 1:



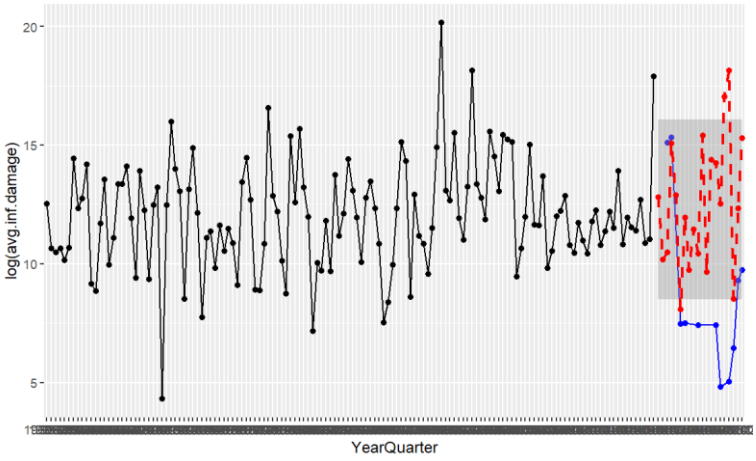
Region 2:



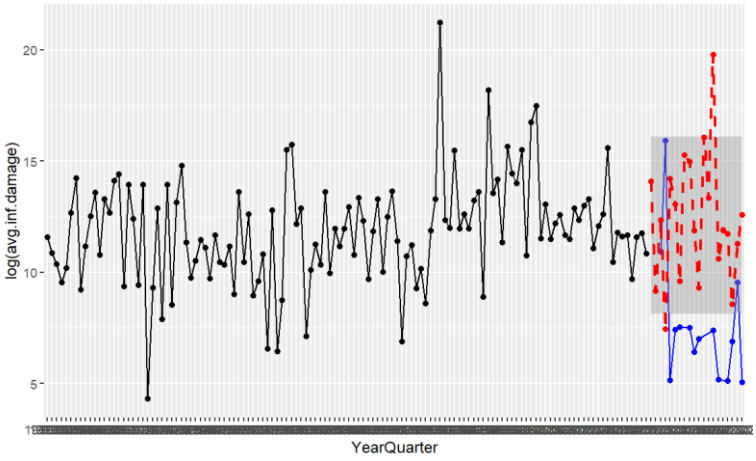
Region 3:



Region 4:



Region 5:



Region 6:

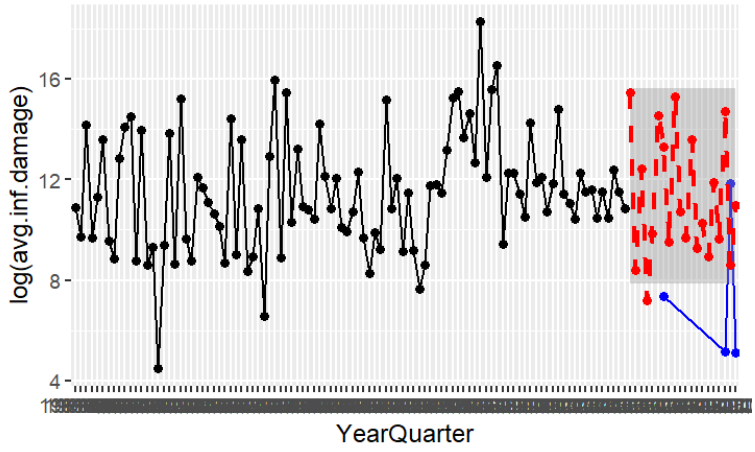


Figure 3.4 *Projected average scheme cost over 100 years.*

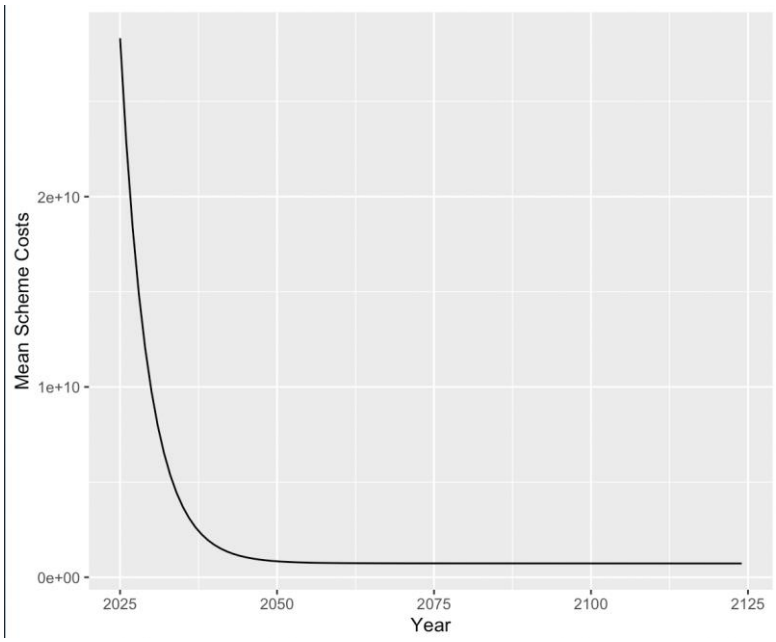


Table 3.1 *Projected short-term quarterly economic costs of climate-related disasters for Storslysia based on historical hazard data from 1960 to 2015.*

	Lower Bound (5%)	Mean Estimate	Upper Bound (95%)
Frequency	0	13.35	48
Severity	ϕ 25,206.81	ϕ 31,238,658	ϕ 81,360,002
Total Damage	ϕ 0	ϕ 63,778,887	ϕ 726,475,918

Table 3.2 *Estimated economic capital needed for the program to remain solvent with a 99.5% level of certainty.*

Year	Capital required
2020	ϕ 377,561,816,855
2030	ϕ 350,962,764,768
2040	ϕ 347,872,516,711
2050	ϕ 347,306,543,940
2060	ϕ 347,011,632,465
2070	ϕ 346,745,825,974
2080	ϕ 346,483,144,608
2090	ϕ 346,220,798,799
2100	ϕ 345,958,489,020
2110	ϕ 345,696,183,110

Table 5.1 *Additional risk and risk mitigation analysis*

Risk Type	Risk name	Explanation and mitigation of risk
Qualitative	Crowding risk	Voluntary relocation into less climate-risk areas may result in overcrowding in those areas which may have employment and financial implications within (due to increased demand) and in other regions (less demand). This may have further repercussions including a potential impact in the quality of life in certain regions.
Qualitative	Discrimination risk	Inability of the scheme to account for the social impacts of voluntary and involuntary relocation into a different region, and potential marginalization which the scheme does not account for.
Qualitative	Psychological risk	Inability of the scheme to fully assist in the displacement risk arising from climatic events due to other indirect costs associated with these events such as psychological impacts.
Quantitative	Competitive risk	External competitors take a portion of the market share within the insurance from catastrophic climate related event industry, requiring the requirement to modify the current premium pricing and level of financial support.
Quantitative	Economic forecasts risk	Future forecasted rates of inflation, GDP growth and other economic factors do not reflect true movements in these variables, impacting the accuracy of the model output.
Quantitative	Fraud risk	Individuals not in the scope of the scheme may apply successfully for the scheme for financial benefits.

Quantitative	Operational risk	Historical data in which the model is trained on is incorrect, which can be due to a culmination of factors including operational/human error (inputting data).
Quantitative	Supply constraint risks	Impacts within the capacity of the economy to replace household goods, material and labour costs may exceed the costs assumed within the model.

Table 5.2 *Projected long-term risk amplification factors (RAF) under various SSP climate scenarios.*

Risk Amplification Factor (RAF)			
The 4 climate scenarios included are: 1. Low emissions (SSP1-2.6) – Sustainability, Takin the Green Road (low challenges to mitigation and adaptation) 2. Medium emissions (SSP2-3.4) – Middle of the Road (medium challenges to mitigation and adaptation) 3. High emissions (SSP3-6.0) – Regional Rivalry, A Rocky Road (high challenges to mitigation and adaption) 4. Very high emissions (SSP5-Basline) – Fossil-Fuelled Development, Taking the Highway (high challenges to mitigation, low challenges to adaptation)			
SSP1– 2.6	SSP2–3.4	SSP3–6.0	SSP5–Baseline
1.00000	1.00000	1.00000	1.00000
1.10890	1.12346	1.15665	1.17750
1.19036	1.24834	1.32802	1.43414
1.23499	1.35957	1.50368	1.79930
1.24687	1.44094	1.69473	2.32185
1.23472	1.48054	1.89081	3.06118
1.19864	1.48348	2.06918	4.06758
1.14243	1.45965	2.23223	5.33602
1.08681	1.42166	2.39212	6.81144
1.03259	1.38416	2.55753	8.46674
0.97974	1.34717	2.72847	10.30191
0.93104	1.31067	2.90495	12.31695
0.93104	1.27468	3.08695	14.51185
0.93104	1.23919	3.27448	16.88663

Table 6.1 *Predicted economic cost of damanges and displacement without the scheme under each scenario.*

	Year	Mean_SSP1	Mean_SSP2	Mean_SSP3	Mean_SSP5	Upper_SSP1	Upper_SSP2	Upper_SSP3	Upper_SSP5	GDP_SSP1	GDP_SSP2	GDP_SSP3	GDP_SSP5
1	2020	836566436	836566436	836566436	836566436	35376330076	35376330076	35376330076	35376330076	2.300197e+12	2.320862e+12	2.308092e+12	2.331241e+12
2	2030	927668520	939848928	967614568	985056978	39228812422	39743891788	40918032183	41655628665	3.520779e+12	3.278252e+12	3.086065e+12	3.793129e+12
3	2040	995815222	1044319344	1110976958	1199753388	42110568270	44161687887	46980473868	50734610016	5.042271e+12	4.253308e+12	3.634415e+12	5.952787e+12
4	2050	1033151182	1137370629	1257928218	1505233988	43689413881	48096597082	53194680009	63652630706	6.580706e+12	5.281132e+12	4.064042e+12	8.343511e+12
5	2060	1043089592	1205442040	1417754235	1942381779	44109684682	50975169060	59953327870	82138531988	8.048883e+12	6.392236e+12	4.441062e+12	1.094242e+13
6	2070	1032925309	1238570071	1581788182	2560880441	43679862272	52376071731	66889918672	108293314103	9.472105e+12	7.667151e+12	4.836092e+12	1.385933e+13
7	2080	1002741992	1241029576	1731006537	3402800902	42403484283	52480078142	73199994667	143896052692	1.074013e+13	9.050353e+12	5.245339e+12	1.694325e+13
8	2090	955718593	1221094198	1867408695	4463935232	40414980769	51637060196	78968105286	188768804814	1.185747e+13	1.055125e+13	5.689422e+12	2.018503e+13
9	2100	909188768	1189313039	2001167302	5698222082	38447349290	50293113416	84624426702	240963749735	1.277262e+13	1.220380e+13	6.197723e+12	2.358695e+13
10	2110	863830136	1157941798	2139543756	7082990503	36529244674	48966501038	90476025460	299522188910	1.559572e+13	1.509898e+13	7.081170e+12	3.091077e+13
11	2120	819617600	1126997205	2282546423	8618232129	34659605629	47657930589	96523255323	364443768576	1.904279e+13	1.868100e+13	8.090547e+12	4.050866e+13
12	2130	778876814	1096462530	2430183667	10303946960	32936778354	46366694541	102766470055	435728488733	2.325176e+13	2.311280e+13	9.243805e+12	5.308672e+13
13	2140	778876814	1066354504	2582438759	12140126629	32936778354	45093500422	109204962129	513375995618	2.839102e+13	2.859599e+13	1.056145e+13	6.957031e+13
14	2150	778876814	1036664761	2739320062	14126787869	32936778354	43837994467	115839085308	597386996757	3.466621e+13	3.537998e+13	1.206692e+13	9.117210e+13

Table 6.2 *Predicted scheme costs under each climate scenario.*

	Year	Mean_SSP1	Mean_SSP2	Mean_SSP3	Mean_SSP5	Upper_SSP1	Upper_SSP2	Upper_SSP3	Upper_SSP5	GDP_SSP1	GDP_SSP2	GDP_SSP3	GDP_SSP5
1	2025	28360595240	28365292390	28375999698	28382726043	63640949881	63842543027	64302081249	64590763741	1.556082e+12	1.479512e+12	1.426526e+12	1.602169e+12
2	2026	22850391662	22856087908	22869072687	22877229742	57880960222	58128510078	58692808134	59047300887	1.613820e+12	1.519002e+12	1.453958e+12	1.671345e+12
3	2027	18443487478	18450154573	18465352437	18474899754	53335965529	53628757888	54296187722	54715467989	1.673700e+12	1.559546e+12	1.481917e+12	1.743508e+12
4	2028	14919263973	14926884827	14944256817	14955169922	49764014165	50101618103	50871197409	51354648104	1.735802e+12	1.601172e+12	1.510413e+12	1.818787e+12
5	2029	12101217866	12109783198	12129308154	12141573756	46971339594	47353522538	48224721156	48772009231	1.800209e+12	1.643909e+12	1.539458e+12	1.897316e+12
6	2030	9848139829	9857645710	9879314680	9892927154	44802753488	45229418828	46202016536	46813003648	1.867005e+12	1.687787e+12	1.569061e+12	1.979235e+12
7	2031	8047057080	8057503153	8081315320	8096274154	43133973351	43605115159	44679098443	45353776101	1.927533e+12	1.721572e+12	1.581516e+12	2.061682e+12
8	2032	6605635978	6619076262	6645981715	6666870256	41777111997	42385703455	43604013274	44549870394	1.990024e+12	1.756033e+12	1.594069e+12	2.147563e+12
9	2033	5453546471	5469954571	5499947144	5526703840	40741516842	41486897049	42849386908	44064878707	2.054540e+12	1.791185e+12	1.606722e+12	2.237021e+12
10	2034	4532929998	4552288947	4585368146	4617951897	39963131730	40844879079	42351546404	43835647440	2.121148e+12	1.827040e+12	1.619476e+12	2.330206e+12
11	2035	3797498121	3819797619	3855966555	3894350913	39390679275	40408541644	42059475639	43811532769	2.189916e+12	1.863612e+12	1.632330e+12	2.427273e+12
12	2036	3210218739	3235453123	3274717044	3318885911	38983095970	40136938912	41932282899	43951905705	2.260913e+12	1.900917e+12	1.645287e+12	2.528383e+12
13	2037	2741465136	2769631893	2811997159	2861941621	38707506749	39997275821	41937201311	44224181770	2.334212e+12	1.938969e+12	1.658346e+12	2.633705e+12
14	2038	2367535126	2398633820	2444107203	2499823217	38537595011	39963288602	42047977770	44602231811	2.409887e+12	1.977782e+12	1.671510e+12	2.743414e+12
15	2039	2069466245	2103497741	2152085958	2213572676	38452281948	40013931336	42243564719	45065089069	2.488015e+12	2.017372e+12	1.684777e+12	2.857693e+12
16	2040	1832088030	1869053951	1920763373	1988021941	38434699441	40132355280	42507104808	45595947164	2.568677e+12	2.057755e+12	1.698150e+12	2.976732e+12
17	2041	1643263659	1683166002	1738002475	1811035188	38471337459	40305059923	42825084172	46181321286	2.633634e+12	2.093895e+12	1.704759e+12	3.072425e+12
18	2042	1490751600	1535185903	1594387877	1680362480	38434969813	40478088663	43200234776	47153404246	2.700234e+12	2.130669e+12	1.711394e+12	3.171193e+12
19	2043	1369320356	1418285616	1481855297	1580761001	38433463564	40685967772	43610305844	48160174793	2.768519e+12	2.168089e+12	1.718055e+12	3.273137e+12
20	2044	1272754005	1326249807	1394189338	1506018621	38459850994	40921744295	44048342472	49194760524	2.838530e+12	2.206166e+12	1.724742e+12	3.378358e+12
21	2045	1196079750	1254106011	1326417347	1451164893	38508562704	41179857421	44508779312	50251652568	2.910312e+12	2.244912e+12	1.731454e+12	3.486961e+12
22	2046	1135319255	1197876039	1274560870	1412222803	38575137140	41455849306	44987151757	51326422710	2.983909e+12	2.284338e+12	1.738193e+12	3.599056e+12
23	2047	1087289798	1154377198	1235436916	1386010249	38656005074	41746151465	45479883787	52415517641	3.059367e+12	2.324457e+12	1.744958e+12	3.714754e+12
24	2048	1049445151	1121063207	1206498892	1369981141	38748309171	42047905246	45984108859	53516083571	3.136733e+12	2.365280e+12	1.751750e+12	3.834172e+12
25	2049	1019748289	1095896941	1185709369	1362098283	38849762562	42358821232	46497529796	54625829278	3.216056e+12	2.406821e+12	1.758567e+12	3.957428e+12
26	2050	996569562	1077248623	1171438279	1360731661	38958534952	42677065891	47018305704	55742915227	3.297384e+12	2.449091e+12	1.765412e+12	4.084646e+12
27	2051	978605225	1063814367	1162381468	1364577058	39073161461	43001170800	47544961344	56865864547	3.366039e+12	2.490658e+12	1.770593e+12	4.196442e+12
28	2052	962572893	1052509260	1158547866	1383352884	39089221575	43235822900	48124833234	58489681423	3.436124e+12	2.532930e+12	1.775789e+12	4.311296e+12
29	2053	949878690	1044541570	1158049799	1405456533	39109048047	43474238365	48708444460	60117113563	3.507668e+12	2.575920e+12	1.781000e+12	4.429295e+12
30	2054	939854944	1039243508	1160219443	1430220474	39131886984	43715660277	49295037185	61747410643	3.580702e+12	2.619640e+12	1.786226e+12	4.550523e+12
31	2055	931967516	1036080823	1164522491	1457110563	39157135203	43959482619	49884004014	63379969326	3.655256e+12	2.664102e+12	1.791468e+12	4.675068e+12
32	2056	925789094	1034626100	1170531465	1485699387	39184310103	44205220199	50474858131	65014304488	3.731363e+12	2.709318e+12	1.796725e+12	4.803023e+12
33	2057	920977825	1034537394	1177904353	1515644939	39213025556	44452484553	51067209366	66650026059	3.809054e+12	2.755302e+12	1.801998e+12	4.934480e+12
34	2058	917260225	1035541141	1186367523	1546673550	39242972626	44700964667	51660745006	68286820411	3.888363e+12	2.802066e+12	1.807286e+12	5.069534e+12
35	2059	914417507	1037418480	1195702052	1578566236	39273904135	44950411533	52255214423	69924435384	3.969323e+12	2.849624e+12	1.812590e+12	5.208285e+12
36	2060	912274639	1039994318	1205732786	1611147771	39305622316	45200625788	52850416742	71562668239	4.051969e+12	2.897990e+12	1.817909e+12	5.350834e+12
37	2061	910691597	1043128574	1216319590	1644277941	39337968939	45451447816	53446190972	73201355983	4.127815e+12	2.948671e+12	1.824188e+12	5.487144e+12
38	2062	907916820	1043859264	1227693539	1692635187	39295124890	45571177776	54058252168	75523206664	4.205081e+12	3.000238e+12	1.830488e+12	5.626926e+12
39	2063	905500850	1044947725	1239421611	1741333494	39252691957	45691303762	54670650622	77845180551	4.283794e+12	3.052707e+12	1.836811e+12	5.770268e+12
40	2064	903371985	1046322214	1251432042	1790301106	39210588868	45811743464	55283303501	80167195006	4.363980e+12	3.106093e+12	1.843155e+12	5.917263e+12
41	2065	901472861	1047925334	1263667414	1839480598	39168750617	45932431006	55896144415	82489183453	4.445667e+12	3.160414e+12	1.849522e+12	6.068002e+12
42	2066	899757589	1049711168	1276081790	1888826016	39127125202	46053313669	56509120152	84811092256	4.528883e+12	3.215684e+12	1.855910e+12	6.222581e+12
43	2067	898189459	1051642979	1288638418	1938300585	39085671028	46174349262	57122188065	87132878208	4.613657e+12	3.271920e+12	1.862320e+12	6.381098e+12
44	2068	896739100	1053691381	1301307893	1987874877	39044354822	46295504019	57735313971	89454506506	4.700017e+12	3.329141e+12	1.868753e+12	6.543653e+12

46	2070	894102416	1058048612	1326895983	2087233127	38962035183	46538068325	58961635616	94097183450	4.877618e+12	3.446601e+12	1.881684e+12	6.881291e+12
47	2071	892882259	1060323584	1339780717	2136983156	38920993430	46659438941	59574791799	96418191329	4.959372e+12	3.506103e+12	1.888543e+12	7.042897e+12
48	2072	890080810	1060149082	1351502737	2204951636	38804684072	46665450311	60132177259	99579642880	5.042496e+12	3.566633e+12	1.895426e+12	7.208298e+12
49	2073	887318745	1060013039	1363258947	2272934026	38688433076	46671505032	60689535636	102740731656	5.127013e+12	3.628208e+12	1.902335e+12	7.377584e+12
50	2074	884588363	1059907749	1375041633	2340922606	38572231701	46677594194	61246857852	105901448428	5.212947e+12	3.690845e+12	1.909269e+12	7.550845e+12
51	2075	881883505	1059827047	1386844625	2408911199	38456072958	46683710671	61804136632	109061785746	5.300321e+12	3.754564e+12	1.916228e+12	7.728175e+12
52	2076	879199243	1059766001	1398662987	2476894861	38339951256	46689848759	62361366147	112221737596	5.389160e+12	3.819384e+12	1.923213e+12	7.909670e+12
53	2077	876531636	1059720666	1410492767	2544869634	38223862125	46696003898	62918541725	115381299120	5.479487e+12	3.885322e+12	1.930223e+12	8.095427e+12
54	2078	873877529	1059687884	1422330806	2612832352	38107801990	46702172437	63475659623	118540466399	5.571329e+12	3.952398e+12	1.937258e+12	8.285546e+12
55	2079	871234400	1059665131	1434174575	2680780478	37991767992	46708351458	64032716841	121699236271	5.664710e+12	4.020633e+12	1.944320e+12	8.480131e+12
56	2080	868600230	1059650386	1446022052	2748711986	37875757845	46714538623	64589710977	124857606180	5.759656e+12	4.090046e+12	1.951407e+12	8.679285e+12
57	2081	865973406	1059642033	1457871618	2816625250	37759769720	46720732065	65146640103	128015574068	5.851622e+12	4.160412e+12	1.959072e+12	8.873441e+12
58	2082	861984202	1057818961	1468680528	2902332390	37580478021	46642718313	65655309645	131997453020	5.945057e+12	4.231989e+12	1.966768e+12	9.071941e+12
59	2083	858000514	1056000614	1479489574	2988012500	37401213934	46564719079	66163917654	135978819936	6.039984e+12	4.304798e+12	1.974494e+12	9.274880e+12
60	2084	854021515	1054186162	1490297926	3073664747	37221976520	46486733403	66672463137	139959673761	6.136426e+12	4.378859e+12	1.982251e+12	9.482360e+12
61	2085	850046543	1052374944	1501104922	3159288466	37042765030	46408760517	67180945300	143940013642	6.234408e+12	4.454194e+12	1.990038e+12	9.694481e+12
62	2086	846075070	1050566432	1511910030	3244883125	36863578866	46330799806	67689363503	147919838891	6.333955e+12	4.530826e+12	1.997856e+12	9.911347e+12
63	2087	842106672	1048760199	1522712827	3330448297	36684417547	46252850781	68197717239	151899148950	6.435091e+12	4.608776e+12	2.005704e+12	1.013306e+13
64	2088	838141010	1046955909	1533512973	3415983642	36505280690	46174913048	68706006096	155877943369	6.537842e+12	4.688067e+12	2.013583e+12	1.035974e+13
65	2089	834177814	1045153290	1544310195	3501488885	36326167990	46096986293	69214229748	159856221784	6.642234e+12	4.768722e+12	2.021493e+12	1.059149e+13
66	2090	830216868	1043352124	1555104278	3586963809	36147079201	46019070265	69722387931	163833983899	6.748292e+12	4.850764e+12	2.029434e+12	1.082842e+13
67	2091	826257997	1041552238	1565895046	3672408238	35968014127	45941164763	70230480436	167811229477	6.850561e+12	4.933723e+12	2.038784e+12	1.106369e+13
68	2092	822341098	1038792643	1576467933	3771867025	35790827407	45818754573	70728572944	172438645154	6.954380e+12	5.018100e+12	2.048176e+12	1.130407e+13
69	2093	818426011	1036034425	1587037334	3871289975	35613663879	45696360399	71226600760	177065459489	7.059773e+12	5.103921e+12	2.057612e+12	1.154968e+13
70	2094	814512648	1033277498	1597603158	3970676997	35436523444	45573982135	71724563774	181691672357	7.166762e+12	5.191209e+12	2.067092e+12	1.180062e+13
71	2095	810600936	1030521789	1608165335	4070028020	35259406022	45451619701	72222461901	186317283660	7.275373e+12	5.279990e+12	2.076615e+12	1.205701e+13
72	2096	806690819	1027767242	1618723808	4169342987	35082311549	45329273031	72720295071	190942293316	7.385630e+12	5.370290e+12	2.086182e+12	1.231897e+13
73	2097	802782251	1025013811	1629278531	4268621851	34905239973	45206942071	73218063228	195566701261	7.497558e+12	5.462133e+12	2.095793e+12	1.258663e+13
74	2098	798875197	1022261460	1639829467	4367864575	34728191254	45084626779	73715766328	200190507442	7.611182e+12	5.555548e+12	2.105448e+12	1.286010e+13
75	2099	794969628	1019510160	1650376588	4467071131	34551165359	44962327122	74213404336	204813711816	7.726528e+12	5.650560e+12	2.115148e+12	1.313951e+13
76	2100	791065519	1016759887	1660919870	4566241494	34374162263	44840043074	74710977221	209436314348	7.843622e+12	5.747197e+12	2.124892e+12	1.342499e+13