UNIVERSITY
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Master Thesis

Exploring the Responses to Flood Protection

An empirical study of consumer's attitudes towards flood protection, and subsequently the role of private insurance companies and the government

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Masters in Economics

30 Credits

November 2023

Institute of Economics

Faculty of Social Sciences

Preface

This thesis is the conclusion to my journey at the master thesis program at UiO. It has been a challenging and interesting experience and I have learned a lot about myself through the process.

I would not have been able to complete this thesis without the support of my family and friends, so I extend the utmost level of gratitude to them. They have been a tremendous help to me. I also want to thank my supervisor Laurence David Malafry for statistical insights guidance throughout the semester.

The program used for the regression analysis is the statistical program STATA.

The work is my own, and any errors are of my own accord.

Abstract

The purpose of this paper was analyzing decision-makers attitudes towards flood protection. To study this, a linear probability model was utilized on survey data to estimate how different attributes affected whether they thought they could protect their property or not. After the regression analysis, I also discussed the ways in which the societies' damage reparation and compensation schemes may interfere with this choice.

The main component of the paper was the regression analysis on whether respondents felt they could protect against climate related damages, such as flooding, or not. From the results, it was shown that income was not a significant effect, while greater concern for climate change, ownership of a detached house, and believing the household is responsible for mitigation increased the likelihood of protection efforts. While Vestland county has historical data on damages caused by flooding, and projections of greater floods in the future, living in Vestland county lowered the likelihood of the respondents agreeing with the ability to protect against natural damages, like flood.

Lastly, I discussed the possibility that Norway's security net of different legislations, acts on Natural Damage, Natural Damage Insurance and Natural Damage Compensation negatively affect the incentives for private preemptive protection, creating moral hazard problems.

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1. Introduction

In August of 2023, multiple parts of Norway were hit by the extreme weather referred to as "Hans", resulting in a multitude of damages on properties and local economies. The Norwegian Natural Perils Pool estimated over 10 000 instances of reported damages on private properties, household goods and public properties (Norsk Naturskadepool, 2023). While this is a singular extreme weather situation, similar situations are happening at a more rapid pace, with greater damages to local economies. Consulting firm Multiconsult reported in 2018 that the yearly insurance payments connected to flooding had quadrupled from 2011 to 2016 (Glover, 2018). This indicates that there has been a change to the regular pattern of flooding statistics. In 2021, The Norwegian Water Resources and Energy Directorate (NVE) presented a report with a prognosis for the estimated collective need for protective measures on existing buildings in Norway up until the year 2100 (NVE, 2021). This report has been an inspiration to the topic in this thesis. They evaluate security needs by studying flood zones, which buildings are at risk, and previous numbers to predict costs. They conclude that the total costs for this methodology will be about 85 billion NOK if all buildings that are exposed will be secured. 45% of this relates to flood and erosion. The numbers are unsure, with a variance with the lowest cost being 50 billion, and highest is 120 billion (NVE, 2021). People rely on private insurance companies to pay for the damages on their property, given that they have damage insurance, or the government's natural damage insurance scheme. However, with a changing climate, and heightened chances of flooding, this means higher expenditures for insurance companies. Could and should people mitigate before disaster strikes? Given these circumstances, how do we adapt to this changing climate?

According to the Ministry of Petroleum and Energy, the private individual is responsible for their own security, which includes taking precaution when using one's property, which may be exposed to flooding (Meld. St. 15 (2011-2012). While municipalities and government have a big responsibility, there is an acknowledgement that private persons are expected to act in accordance with precautious ways. In Norway, there are two different security nets for everyone. If you take up damage insurance, you are covered by fire insurance. Through the Natural Damage Insurance Act, all buildings and movable properties that are insured by fire insurance, are automatically also insured against natural damage, where the damage is not covered by another type of insurance. (Meld. St. 15 (2011-2012). The other security net is the

Natural Damage Compensation Act which is the governmental responsibility to ensure natural damages on real estate which cannot be insured (Meld. St. 15 (2011-2012). Also relevant to my analysis are GIS-maps conducted NVE which illustrates flood zones and where there has been put in place mitigation efforts by the government and municipalities. Flood zones are projections for where the riskiest areas for flooding are. These maps are used to differentiate between individuals who live in risky areas, compared to others.

The goal of this thesis is to look at the different circumstances that affect a person's inclination to protect their own property from climate related consequences. To do this I will analyze a survey-based dataset which tracks different people´s attitudes towards flood protection and other climate related damages. More specifically, I will study the socioeconomic levels of the respondents to see if there is a difference of opinions in high- and low-income respondents, different age groups, house owners versus renters, general concern of climate change, and whether the respondents are exposed to risk. A cross-sectional study will be conducted to get an overview over the consumer's stated attitudes towards flood risk, and an insight into consumer's problem under uncertainty.

1.1 The Research Question

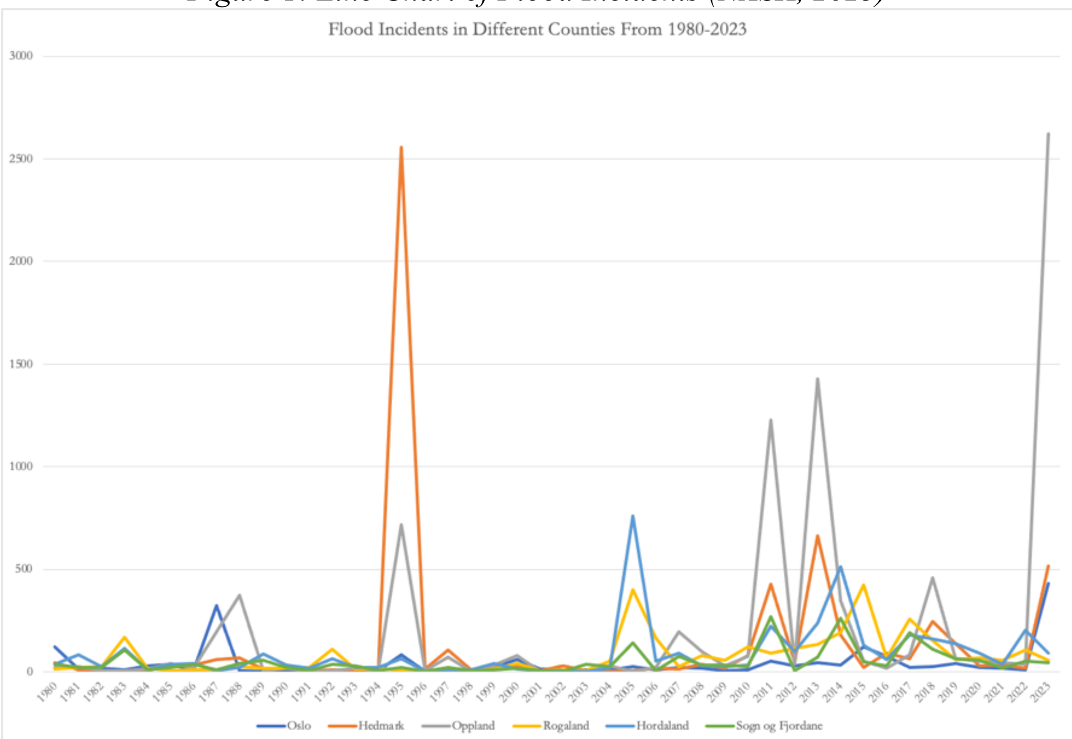
My primary research question is, what are the components that affect the household's tendency to protect its own property from flooding damages? After that, I want to further ask to what extent does the societies damage reparation and compensation schemes create problems? After the analysis, I will reflect and discuss possible possibilities to solve them. Finding out how respondents respond to questions about mitigation efforts and how they differ in different income groups and other identification variables, is an important first step to recognize the need for flood mitigation.

The Norwegian Natural Disaster Insurance is a statutory insurance scheme. Everyone who takes out fire insurance for property and contents also has natural damage cover (Naturskadeforsikring, 1989). The maximum compensation framework for natural damage incident is NOK 16 billion. The premium rate is the same for everyone, whether you live in an apartment block in Oslo or in an area prone to flooding, wind, or landslides in Western Norway. The natural damage premium that was set in January 2019 is 0.065 permille of the total fire insurance (NASK, 2023). This means that no matter where you live, either in a high-risk area or not, and how much money you have, you still pay the same lump sum premium.

The motivation for including policy implications from private and public insurance, is to discuss the possibility that people might not have a big incentive to protect their properties against flood damages if they know that the private insurance companies and/or the government will buy them out of the damages. This strong security net in Norway might disincentivize individuals from practicing mitigation efforts. Observing income levels, people with less money might not have recourses to preemptively protect. One of the questions in the survey is "To what degree you feel like you can implement mitigation that will protect your property against climate change related damages?". The question is asked after the claim that climate change leads to more heavy rain, flooding, higher sea levels, and erosion risks. The question is about the feeling of the ability to do something, and not revealed behavior, but an important first step is to recognize that everyone's input is beneficial.

1.2 Motivation for Research

Figure 1: Line Chart of Flood Incidents (NASK, 2023)



The chart is generated from NASK (Natural Damage Statistics) which is gathered from the Norwegian Natural Perils Pool. When huge flooding incidents occur, like in 1995 and 2023, there is a collection of hundreds or thousands of individual damages (NASK, 2023). All buildings and movable property insured by fire insurance is automatically insured by natural damages, which is further explained in Naturskadeforsikringsloven (NASK, 2023). While there are years where big floods have hit, like in 1995 and 2005, we see a steady incline of flood events in all counties tracked.

The increase in flooding incidents every year and the subsequent criticism municipalities and government receive, shows the relevance of analyzing and discussing the responses to flooding. While researching survey data where attitudes of Norwegians are tracked, we get an overview of the consumer's stance on protection. The way to finding the optimal roles for public and private sectors is to look closely at the role private decision-makers – households – can be expected to play (Tietenberg, 2018, p. 416).

1.3 Overview of the Thesis

To start off, I will introduce relevant theory which explains rational consumer behavior under risk. Firstly, the von Neumann and Morgenstern theory of expected utility is presented. This theory shows the classic and fundamental assumptions of a decision-maker. Then I move on to the empirics of the study. Introducing survey data and GIS-data, I will use the survey data to analyze what decision-makers' responses are in the real world. Comparing the classical assumptions of a perfect decision-maker to what people respond in a survey tracking attitudes towards flood protection will illustrate either similarities or dissimilarities between theory and real behavior. Then I move on to discussion of results and limitations of the analysis. I discuss the role of the institutions of government and insurance and its implications. To finalize the paper, I offer some concluding remarks.

2. Theoretical Framework

Before introducing the data and empirics, I will present some microeconomic theory that will be the framework in relation to the empirical analysis. The theoretical framework is a version of the von Neuman and Morgenstern model of expected utility. I also present some intuition about the theory of moral hazard.

2.1 Von Neumann & Morgenstern Expected Utility

Expected utility theory has been discussed and applied all over microeconomics, but I will focus on the theory introduced by John von Neumann and Oskar Morgenstern, which continues the work laid by Daniel Bernoulli. The theory of expected utility derived by von Neumann and Morgenstern was first discussed in their book Theory of Games and Economic Behavior published in 1944. They showcased that an agent that faces a problem under uncertainty will maximize expected utility under conditions of rational choice (Karni, 2014 p. 2).

These axioms are (Karni, 2014, p. 7-8):

Axiom 1: Completeness & transitivity

Contemplating two choices, x and x' in the set X, then either x > x' or x < x'. This simply means consumers can prefer one outcome over another outcome. Also, if we have three gambles, x, x' and x''. Then if x>x' and x'>x'', then x>x''. The consumer is consistent in their preferences. If they prefer gamble x to gamble x', and prefer gamble x' to x'', then it is safe to say that the consumer prefers x to x'' as well.

Axiom 2: Archimedean or continuity

No alternative in the set X can be infinitely more, or less, desirable than any other alternative. The upper and lower sets of preference relations are closed. There are probabilities where the decision-maker is indifferent between good and bad outcomes. A low probability of a "bad outcome", but a probability with a reward, the decision-maker will likely do it.

Axiom 3: Independence

A set of gambles is indifferent to another set of gambles if the value of outcomes is equally preferable. The alternatives are irrelevant. For x, x', and x'' in X, with $\alpha \in [0,1]$, then you only prefer x to x' if αx + (1 – α)x'' ≽ αx' + (1 – α)x''. .

When these assumptions are accepted, then the expected utility is measurable, or cardinal. (Riis, 2017, p. 583). An expected utility maximizer chooses the gamble which gives the highest value of utility. A simple representation of the expected utility model: (Karni, 2014, p. 2):

$$EU = \sum_{i=1}^{n} p_i u(x_i)$$

Expected utility of two outcomes equals the probability of the bad state times the bad state outcome, plus the probability of good state times the good state outcome (Pindyck, 2013, p. 165). The gamble in this situation is whether to secure your property against climate change consequences or not. An important aspect of expected utility is that a consumer chooses under uncertainty. The consumer choice here is between "protection of property" versus "no protection of property". For an analytical representation we can show a basic expected utility function like based on the previous model(full calculations in the appendix A.1):

(1) $EU_{no\ protection} = (1-p)\ln(Y) + pln(Y(1-f))$

(2) $EU_{protection} = (1-p)\ln(Y(1-pf\theta)) + pln(Y(1-pf\theta))$

$$Y - assets$$
$$p - probability\ of\ flood, 0 < p < 1$$
$$f - damages\ from\ flood$$
$$\theta - protection\ efforts$$

Equation (1) describes the situation where the decision-maker decides not to protect their property. It simply states that the expected utility of not protecting is the state of assets when where is no flood plus the state when there is a flood. When flood occurs, it is expected a loss in the assets times the probability of flood and the reduction from flood damage. Equation (2) represents the expected utility when protecting your property. The probability of no flood is

multiplied by assets, and assets when protecting. The probability of flood is also multiplied by assets, and assets when protecting.
Rewritten we have:

(1') $\mathrm{E}U_{no\ protection} = lnY + \ln(1-f)^p$

The state of no flood plus the state of flood with no protection.

Equation (2) is the situation when there is protection put in place.
(2') $\mathrm{E}U_{protection} = lnY + \ln\,(1-pf\theta)$

The state of no flood plus the state of flood with protection.
The optimal level of protection efforts ($\tilde{\theta}$) is: (see calculation in appendix A.1)

(3) $\tilde{\theta} = \frac{1-(1-f)^p}{pf}$

Heightened chances of flooding and greater damages from flooding leads to higher protection efforts. $\frac{\partial\tilde{\theta}}{\partial p} > 0$ and $\frac{\partial\tilde{\theta}}{\partial f} > 0$.

The probability rate, p, is the expected risk level of whether disaster strikes or not. This is estimated by the institutions such as NVE or metrological institutions as they are providers of information about risks. However, because of climate change, these estimates have become more unstable. It is harder to estimate a risk level when climate change is accelerating the events and damage levels of flooding. However, NVE projects an increase in both 200-year and 1000-year floods (Lawrence, 2011) (See Appendix for maps). The estimated risk level can also be affected by personal subjective perceived risk (Riis, 2017, p. 583). If a person does not believe their property is in danger of climate related damage, then their perceived risk level, or p, will be lower.

Risk aversion is a term for individuals who value security over risky gambles (Riis, 2017, p. 586). Risk aversion is not included in the model for expected utility but represents an important part of choice under uncertainty (Belavkin, 2014, p. 8). For a person to be indifferent between a good or bad outcome, then the probability for the good outcome must be high. A risk-averse individual will invest some of his wealth in uncertain investments if the expected return exceeds the safe interest rate (Riis, 2017, p. 587). In this case the individual will have a high $\tilde{\theta}$ if the f is large. The decision-maker will choose the level of protection to maximize their EU from final wealth over all potential states of nature, conditional on the program of public disaster relief (Lewis, 1988). If decision-makers perceive the risk of great flood damages to their property as large, then mitigation efforts are more attractive (Kunreuther, 1996).

2.2 Moral Hazard

Moral hazard theory is relevant when discussing decisions under uncertainty, especially in relation to protection and insurance. Moral hazard is the situation when an unobserved party behaves in a way that lowers the probability of a compensation. (Pindyck, 2013, p. 643). If individuals are insured against natural damage, then moral hazard refers to individuals who deliberately chooses not to protect, because they know the insurance company will pay for damages. This is directly applicable to the topic of my thesis. The theory of moral hazard will be applied when discussing the policy implications later in the paper, see Chapter 6.

3. Data Framework

In this chapter the data framework is demonstrated. First, the Norwegian Citizen Panel wave 25 is presented in Section 3.1, and later NVE's flood zones and protected areas are revealed in Section 3.2.

3.1 Survey

The data gathered for this paper is from the Norwegian Citizen Panel wave 25. The researchers responsible for the data gathering are from the University of Bergen with the analytical implementation with the analytical institution Ideas2Evidence (Skjervheim, 2022). The project is non-profit and exclusively used for research purposes. In 2022, the 25^{th} wave of the panel was conducted. The existing panel members in the 25^{th} wave where also recruited in wave 1, 3, 8, 11, 14, 16, 18, and 22, but they also recruited more members (Skjervheim, 2022). The Citizen Panel was created to review Norwegians attitudes towards important issues in society, with the members representing a cross section of the whole population. Members of the panel have been randomly chosen from the National Population Registry of Norway (Skjervheim, 2022). Their identification was sourced but is not disclosed to protect their privacy.

18 000 random people over the age of 18 were drawn from the National Population Registry. They were sent letters with information about the survey, with description of the project, privacy policy, timeframe of the project, their rights to opt out, contact information about the study's representatives, a log-in ID, and estimated time required to complete the study (Skjervheim, 2022). The response rate for the 25^{th} wave was 13.9% (Skjervheim, 2022). It is also worth noting that three members had the chance to win gift cards after completing the survey, as an incentive for people to respond. After the process of eliminating non-completing respondents, non-respondents and others, the recruitment in the 25^{th} wave resulted in 2405 new survey respondents (Skjervheim, 2022).

Weighting of the Data

In survey data you should compensate for observed bias by calculating a set of weights. The weights are calculated by taking the relation of a strata (a group within the set with similar identification qualities) with the total population, divided by the relation of a given strata in the sample and the total sample (Skjervheim, 2022). The applied formula for weight w_i for element i is:

$$w_i = \frac{N_h/N}{n_h/n}$$

(Skjervheim, 2022). The purpose of weighting the data is so the coefficients from individuals from a smaller group are not overestimated compared to individuals from larger groups. For instance, respondents in the age group "1990 and younger" are a small group in the survey and must be weighted to not be overestimated compared to the older age groups. In STATA, this weighting is measured by informing the program that the dataset is a survey. Throughout the regressions, I survey set the data, and weighted for age, education level, gender, and part of country.

Definitions of Variables

protection propensity – respondent's propensity to protect (dependent variable)

In the survey, the respondents are presented with; "Climate change is likely to bring more rain and flooding, rising sea levels and more landslides/avalanches in Norway. To what extent do you agree or disagree that you can take measures that help protect yourself and your property against the consequences of climate change" (Quote from the codebook of the dataset). There are seven categories to choose from, ranging from strongly disagree to strongly agree. While this is a statement the respondents either claim to agree or disagree with, I argue that the respondents who strongly disagree will not do measures on their property to protect against extreme weather, while respondents who strongly agree are inclined and willing to protect against climate change. I then assume that the propensity to agree with ability to protect is interpreted as an approximation of willingness to exercise protection efforts (investments). This variable tells us whether the respondent feels like they can protect their property against consequences. The variable is recoded to *measures*, a dummy that is 1 if you agree, and 0 if not. It includes somewhat agree, agree, and strongly agree.

income25 – yearly income

This variable is a categorical variable for yearly income. The first category is income below 150000 NOK. Category 2 is income from 150001- 300 000, category 3 is 300 001- 400 000, category 4 is 400 001- 500 000, 5 is 500 001 – 600 000, 6 is 600 001 – 700 000. 7 is 700 001

– 1 000 000. Lastly is category 8, which is respondents earning above 1 000 000. Using these numbers is a simple way of catching the differences between lower income persons, and upper-income persons.

eduLevel - education

Level of education of the respondent. Categorized in three categories: no education/only obligatory, upper secondary school, and higher university. This is a non-descriptive variable, but simply tracks the difference between individuals' different education levels.

ownDetached – living-situation

This is a variable for what type of living situation the respondent has. It is coded as a binary variable, that is equal to 1 if they own a detached house, and 0 if not. This variable was generated by creating a interaction term between a variable for whether the respondent owned their home, and if they lived in a detached house. This variable is included to see if there is a difference in stated ability to protect when you own a house or not. This variable is included to study whether individual's living situation affects their stated ability to protect their property.

climateWorry – concern for climate change

This variable tracks the level of concern the respondent has for climate change. There are five categories in the variable. It goes from not worried at all, not very worried, a little bit worried, worried, and very worried.

worryDamage – concern for damage on property

This variable tracks the degree the respondent is concerned with damages from climate change affecting their property. It ranges from "not worried", "a little worried", "worried", and "very worried".

Vestland – people who live in Vestland county

This is a dummy variable for people who live in Vestland county, equal to 1 if yes, and 0 if not.

cityArea – live in city area

Dummy variable for people who live in a big city. It is equal to 1 is they chose this, and 0 if not.

trustParliament – degree of trust in Norway's parliament

This is a categorical variable which ranges from "no trust at all" to "I trust the parliament a lot". It is included to see if people who place a higher trust in the government are more inclined to agree with the ability to protect.

householdResponsible – private household responsible for measures

When asked about who should be responsible for the protection against climate change, the respondents could choose between an array of agents. This variable shows the percentage of the respondents who claimed that private households are partly responsible for the protection. This is a dummy variable that is equal to 1 when if believed private households are responsible, and 0 if not.

ageGroup – age

Age group when the respondent was born. The ages are given in deciles. The first decile are people born before or in 1939. The the following deciles are 1940-1949, 1950-1959, 1960-1969, 1970-1979, 1980-1989, and lastly, people born in 1990 or later. That means that when the variable increase, the respondents get younger.

Table 1: Descriptive Statistics of Survey Data

Variable	Obs	Mean	Std. Dev.	Min	Max
Measures	2226	.748	.434	0	1
Income	7851	4.843	1.922	1	8
Education Level	13428	2.589	.584	1	3
Owner of detached	2224	.505	.5	0	1
Worried about climate	9678	3.424	1.104	1	5
Worried about damage	2231	1.753	.767	1	4
Live in Vestland	13740	.141	.348	0	1
Live in city area	8000	.228	.419	0	1
Trust parliament	9678	3.482	.869	1	5
Household responsible	2231	.38	.486	0	1
Age group	13740	4.055	1.569	1	7

About 74.8% of respondents respond that they agree they can put in place measures that protect them from extreme weather-related damages. That is a large average of the population who makes this claim. The average income lies around 500 000 NOK. The mean level of education is between upper secondary school and higher education. About half of the respondents own a detached house. Many are worried about climate change, mean of 3.4, but most are only a little worried about damage to property from climate change. 14% of the sample lives in Vestland county, and 22% of the sample lives in a big city. When asked who they held responsible for protecting against extreme weather-related damages, 38% claimed that private households held responsibility. Lastly, the mean age group are people born in the 60's.

Figure 2: Histogram of whether respondent agrees with ability and yearly income

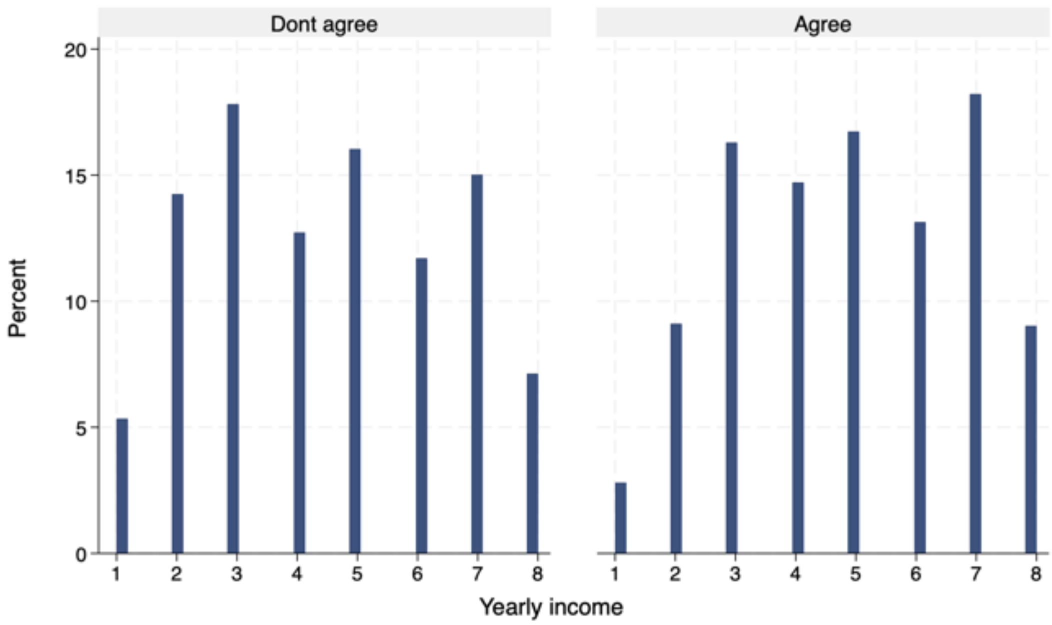


Figure3: Histogram of whether respondent agrees with ability and concern for climate change

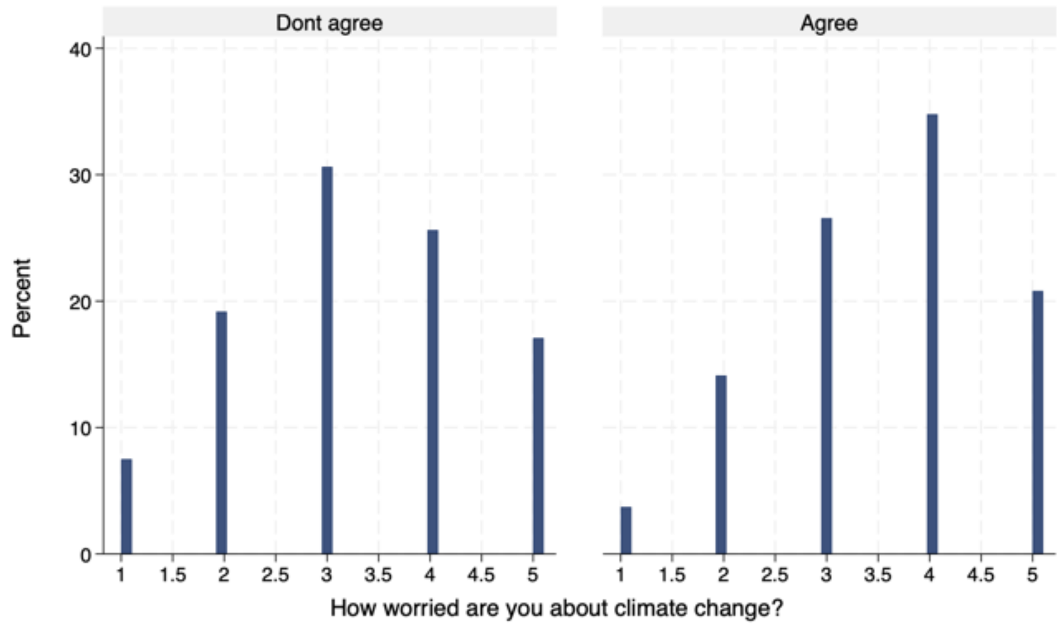
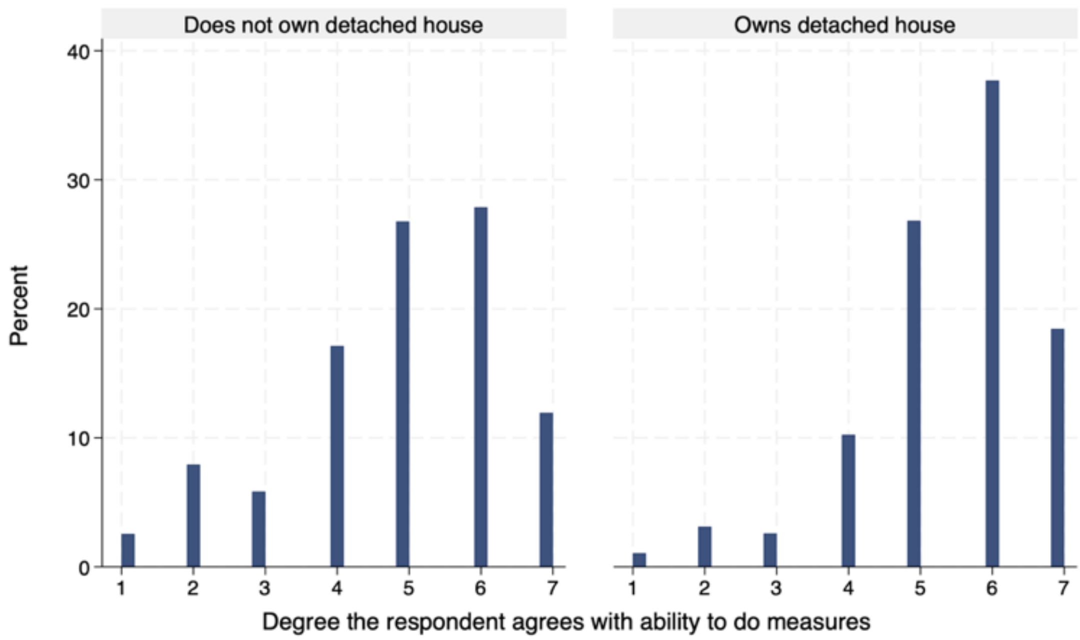


Figure 4: Histogram of owning a detached house and ability



Histograms are visual presentations of the relation between two variables. There is a slight inclination to protect when having a higher yearly income and worrying more about climate change. Individuals who own their own detached house are also more inclined to agree with ability to protect their own property.

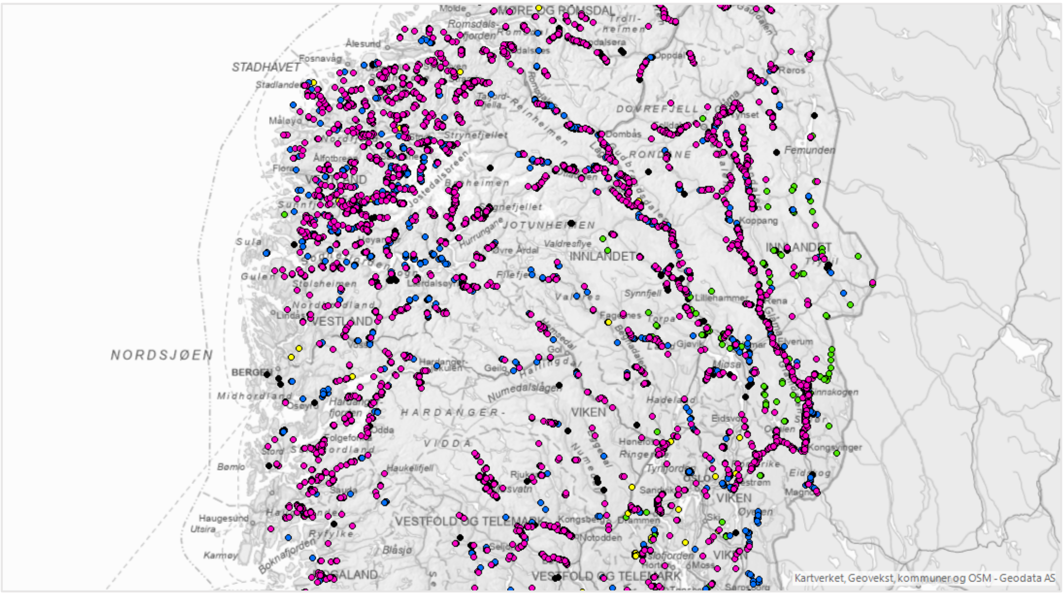
3.2 NVE

The Norwegian Water Resources and Energy Directorate (NVE) is a part of Norway's Petroleum and Energy Department. They are leading the responsibilities for the governmental management tasks within flood and avalanche prevention (NVE, 2023). They provide data that is available for everyone, where you can see maps for flood zones, protection measures, and others.

Figure 5: Map of areas with risk of flood (Generated with NVE's map generator - Atlas)

This maps the areas of caution in relation to flood incidents. It maps where there are risks of flooding. There is higher density of flood risk in Vestland county compared to the neighboring counties.

Figure 6: Map of flood protected areas (Generated with NVE's map generator – Atlas)



The blue dots are flood protection measures implemented by NVE. Using this map and the map of flood-zones while looking at a specific county, like Vestland, we can support the use of that variable in the regression. There are more flood-zones and security measures put in place in that county compared to the neighboring counties. In the maps in Appendix 3, the projections of 200- and 1000-year floods in Vestland county are projected to increase (Lawrence, 2011). When analyzing respondents who live in Vestland county, are they responding differently than other respondents?

3.3 Limitations of the data

There are limitations to using a survey-based dataset for analyzing consumer behavior. For one, it does not tell us about revealed behavior. We can assume and predict what they might do, given their answers, but it would be hypothetical. This is a bias, called the hypothetical bias, where respondents are presented with theoretical choices, rather than actual choices. (Tietenberg, 2018, p. 80). This is common with survey data. Another bias associated with survey data is information bias. Information bias can occur when respondents must value elements, which they have little information on (Tietenberg, 2018, p. 79). In this case, information about the propensity for flood risk and security policy in each county, is not necessarily easily available information to the respondent. Information bias refers to situations where respondents in a survey do not know all the details about the context surrounding a decision. They are free to answer their perceived ability to do protection measures, but they might not know the details about expected damage, probability for damage, and such. They have their own idea about the perceived risks. This can lead to a bias when studying survey data and is important to keep in mind when interpreting the results.

Furthermore, the survey does not ask whether you have insurance. Take-up rate for insurance. If you have insurance, you might suffer from moral hazard. If you don’t have insurance, you are more risk averse. According to a consumer survey (Finn.no, 2020), 93% of Norwegians have some sort of damage insurance. And fire insurance is covered in all damage insurances. That is a relatively large number, so we can assume that those numbers translate to the sample in the survey. This part will be discussed further in chapter 6.

In surveys, there is no way to check if the respondents are truthful. There can be differences between the income they claim to have versus the actual income, or they can lack consistency in their stances. While keeping these biases in mind, I assume the cross-section sample is a representation of the average Norwegian.

The data used for the empirical analysis of the research question has limitations. However, I use theory to explain the attitudes of rational decision-makers and connect it to data on consumer attitudes that we can see similarities with. The goal of this thesis is to uncover some details about the attitudes to flood protection, or protection against climate change damages. Acknowledging that the dataset could be stronger, and implementing a panel data study, or a difference in difference model where we study the behaviors of consumers before and after a major flooding event could be productive. However, using what data that we have, combined with some classical theory about consumer behavior, there is a lot of nuance and interesting points that are worth mentioning.

4. Empirical Analysis

In this chapter I will present the empirics of the analysis. I will use a linear probability model with data from the Norwegian Citizen Panel to uncover some responses from Norwegian citizens about mitigation efforts.

4.1 Method – OLS estimation with binary dependent variable

The method used in this analysis is an ordinary least squares estimation method using cross-sectional data. The dependent variable is a binary dependent variable. That means that the coefficients are the change in the probability that the dependent variable, y = 1, because of a unit change in the explanatory variables, X. (Stock, 2020, p 395). The goal is to find the combination of explanatory variables that gives the best estimate of the dependent variable. OLS is a regression method to minimize the sum of squared residuals. The residuals (ε_i) are all the variation in y that is not explained by the included variables. You choose the coefficient $\tilde{\beta}$ such that the sum of squared residuals is minimized (Verbeek, 2017, p. 7).

$$S(\tilde{\beta}) \equiv \sum_{i=1}^{N} \left(y_i - x_i'\tilde{\beta}\right)^2$$

$\left(y_i - x_i'\tilde{\beta}\right)$ is the difference in estimation, also called the residuals ε_i. The OLS-method minimizes that.

For the linear regression model, $y_i = x_i'\beta + \varepsilon_i$, we must draw some assumptions about the error term. The Gauss-Markov assumptions are as follows:

1. $E\{\varepsilon_i\} = 0, i = 1, \dots, N$. The expected value of the error term is zero. The error term includes all the variables might explain the dependent variable but are not included in the model. This assumption states that the value of those observations is zero.
2. $\{\varepsilon_i, \dots, \varepsilon_N\}$ *and* $\{x_1, \dots, x_N\}$ are independent. There is no correlation between the independent variables included in the model and the error terms.
3. $V\{\varepsilon_i\} = \sigma^2$. The variances for the error terms are equal, which refers to the term homoscedasticity.
4. $cov\{\varepsilon_i, \varepsilon_j\} = 0, \;\; i, j = 1, \dots, N, \quad i \neq j$. There is zero correlation between the error terms of individuals i and j.

Under these assumptions, the estimator is said to be unbiased and after repeated sampling, the OLS estimator will be averagely equal to the true value (Verbeek, 2017, p. 16). For more specific statistical inference we need another assumption:

5. $\varepsilon \sim NID\ (0, \sigma^2)$. The error term is normally, identically distributed, with a mean equal to zero, and covariance matrix $\sigma^2 I_n$. (Verbeek, 2017, p. 19). The variables have a normal distribution.

Also, when these Gauss-Markov assumptions are fulfilled, we can use a simple t-test to compute if the null hypotheses are valid under a known distribution (Verbeek, 2017, p. 23-34). This is computed by the equation:

$$t_k = \frac{b_k - b_k^0}{se(b_k)}$$

Where t_k is the t-statistic, b_k is the regressed coefficient, b_k^0 is the hypothesized value of b_k, and $se(b_k)$ is the standard deviations of the regressed coefficient. The t-statistic is simply the difference in the actual value and the predicted value, divided by the standard errors of that value (Verbeek, 2017, p. 23-24).

The linear regression model used:

$$y_i = \beta X + e$$

Where X is a set of control variables, and y is the dependent variable. β is the coefficient that describes the effect X has on y. e is the residual variable, that contains all the variance in y that is not explained by the included variables. The model used is a linear probability model, where the dependent variable is binary, and the independent variables explains the probability of a change in y.

$\Pr(Y = 1 \mid X_1, X_2, X_3, \dots, X_k) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k$ (Stock, 2020, p. 396).

What is the probability that the dependent variable is one given the independent variables, and their coefficients. After estimating a model, another way to test the results is to look at goodness-of-fit. The measure of goodness-of-fit is the proportion of the variance in the dependent variable that is explained by the control variables (Verbeek, 2017, p. 20). If the residuals are zero, then the goodness-of-fit is 100%. Goodness-of-fit is calculated by $R^2 = \frac{Var\{\hat{y}_i\}}{Var\{y_i\}}$. The variance of the predicted y divided by the variance of the actual y.

I considered doing a probit estimation model instead of the linear probability, or in addition, but decided against it. The reason is that the computational challenges with the linear probability model have been met and both models can be expected to yield equivalent result. The methods differ, in that linear probability models yield results outside of the [0,1] range, while a probit model stays within the range (Stock, 2020, p. 397). In a linear probability model coefficients can be negative; however, probabilities cannot be negative. In the model however, when coefficients are negative, a unit increase in that variable causes a probability decrease of the corresponding coefficient. The probability of agreeing with the ability to protect is less likely to occur. It is also suggested that a linear probability model using OLS estimation was sufficient for my purposes, because computational challenges are met.

4.2 Equations

To start off, I will use a simple linear probability model with only income as the independent variable and will further expand to include more control variables. The regression will be run on the dependent variable, that we call protection propensity, which reveals if the respondent agrees that they can take measures that protect themselves against climate change. Note that this constitutes an important interpretive step in this empirical analysis, as the propensity to agree with ability to protect is interpreted as an approximation of willingness to exercise protection efforts (investments). This interpretive step will be discussed further below. The full linear probability model is as follows:

$$
\begin{aligned}
&protection\ propensity \\
&\qquad = \beta_0 + \beta_1 income_i + \beta_2 education_i + \delta_1 OwndetachedHouse_i \\
&\qquad + +\gamma_1 climateWorry_i + \gamma_2 damageWorry_i + \theta_1 Vestland_i + \theta_2 cityArea_i \\
&\qquad + \beta_3 trustParliament_i + \beta_4 householdResponsible_i + \beta_5 ageGroup_i + \varepsilon_i
\end{aligned}
$$

This is the linear regression showcasing how different variables will whether the respondent agrees that they can to measures. The main independent variable is income. How will different income groups respond to the propensity of protecting against climate change damages? Then, further expanding to explore living situation and whether the respondents own a home or not, the aim is to see whether respondents feel a bigger sense of protection propensity when they have more control over their property. Furthermore, fear of climate change is analyzed. The goal is to see whether a personal perceived risk about the implications of climate change has any effect on ability. Also, a variable for whether the respondent is worried climate change will cause damages to their homes. Relating to the maps of flood zones and security measures, a variable for living in Vestland county is included. Then, variables for trust in the Norwegian parliament and whether they think private households are responsible are included. The last control variable is age group. The reason for this variable is to see if older respondents differ in their propensity from younger respondents.

4.3 Hypotheses and Predictions

Considering the theory and data, can we draw some similarities between the two, and test some predictions on consumer theory? Will the data confirm some classic theory about consumer behavior under uncertainty?

1. *How does increased income influence choice under uncertainty?*

One might think that when studying income levels, individuals with less endowment might not have the resources to preemptively protect their income. They have other needs to finance before spending money on protecting their property against a damage that may or may not occur. The presentation of the expected utility showed that income did not necessarily affect the choice to protect versus not protect. It is fair to assume that individuals who own less have a greater sense of protection of what they have, compared to individuals with an abundance of capital. However, regarding the question the respondents are asked; if they agree with the ability to protect, I argue that higher income individuals will agree more Therefore, the hypothesis is that increased income will raise the protection propensity of the decision maker. Hypothesis:

$$\frac{\partial protection\ propensity}{\partial income} > 0$$

2. *Does ownership of house and education level affect the protection propensity?*

While this may have some correlation with income, it is interesting to assess the effect ownership of a house has on inclined ability to protect. Property rights, the autonomy to do control your property, creates incentives for owners to protect their property, in contrast to renters, who will have less motivation to pay for reinforcements on someone else's property.

(Tietenberg, 2018, p. 417). An assumption is that if a respondent owns a house, versus if they rent, they have more to lose. They could want to protect because they might have more sentimental connection to the property, compared to non-owners. They own something that is exposed to damage and would wish to protect that. This leads to the hypothesis that owning a detached house will increase the probability that the respondent will agree with propensity to do measures. Education is included to differentiate between different groups, and an assumption is that higher education level leads to higher protection inclination.
Hypothesis:

$$\frac{\partial proteciton\ propensity}{\partial ownHouse} > 0$$

$$\frac{\partial protection\ propensity}{\partial education\ level} > 0$$

3. *Do people who worry about climate change want to protect their property more?*

A greater concern about the effects of climate change might make a decision-maker more inclined to protect their property. This relates to the expected utility function presented in chapter 2. A greater p (probability of flood) is also affected by personal perception of flood risk, which is affected by concern with climate change. Therefore, the hypothesis is that when individuals are more worried about climate change, it raises the ability to protect. Another hypothesis is that the concern the respondent has for their house being in risk of being damaged by climate, will also raise their ability to protect, based on the same theory.
Hypotheses:

$$\frac{\partial protection\ propensity}{\partial worryClimate} > 0$$

$$\frac{\partial protection\ propensity}{\partial worryDamage} > 0$$

4. *Will location affect the ability level of the decision-maker?*

Given that they live in a county that has historical counts of big flooding costs in the past, and projections of greater floods in the future, does that affect their protection propensity? If a flood has occurred in an area recently, people might act more risk averse and protect more to prepare for future damages. Also, heightened risk/probability of damage happening lowers the expected utility, which guides the decision-maker in protecting their property. Using the county Vestland as an example, given that that county has high levels of flooding and rain occurrences. Is there a higher level of ability to protect in that county compared to the rest of

Norway? Using the theory of expected utility while utilizing data from NVE, it can be assumed that a decision maker in Vestland county has a higher ability rate. Testing the dummy for living in a city area, provides insight into the differences of living in a big city and not.

Hypotheses:

$$\frac{\partial protection\,propensity}{\partial Vestland} > 0$$

$$\frac{\partial protection\,propensity}{\partial cityArea} < 0$$

5. *Will trust in government and belief that household is responsible affect ability?*

In relation to moral hazard and a strong security net for Norwegian residents, I hypothesize that a stronger trust in the Norwegian parliament reduces the propensity to protect. The parliament is responsible for mitigation efforts and trusting that effort can reduce the incentives to privately protect. Believing that private households are responsible for and household responsible raise ability.

Hypotheses:

$$\frac{\partial protection\,propensity}{\partial trustParliament} < 0$$

$$\frac{\partial protection\,propensity}{\partial householdResponsible} > 0$$

6. *Do individuals become more risk averse with age?*

Younger individuals have riskier attitudes. (Source). However, in relation to climate, are younger individuals more averse? That relates more to concern about climate change, so the hypothesis is that older individuals are more risk averse and will want to protect more.

Hypothesis:

$$\frac{\partial protection\,propensity}{\partial age} > 0$$

5. Results

In this chapter I present the results of the OLS regression. Further I test whether the results are significant and discuss some results from the regression.

5.1 Linear Regression

Table 2: OLS regression for protection propensity

Binary dependent variable: *Respondent agrees with ability to protect against climate change consequences*						
Yearly income	0.0102	0.0116	0.0199*	0.0207*	0.0175	0.0167
	(1.03)	(1.12)	(2.02)	(2.10)	(1.89)	(1.82)
Education Level		-0.0623	-0.0938**	-0.0855**	-0.0798**	-0.0785**
		(-1.95)	(-3.13)	(-2.89)	(-2.91)	(-2.86)
Own detached house		0.143***	0.164***	0.147***	0.156***	0.150***
		(4.46)	(5.36)	(4.56)	(5.16)	(4.94)
Concern for climate change			0.0719***	0.0723***	0.0362**	0.0376**
			(4.57)	(4.72)	(2.61)	(2.69)
Concern for damage			0.0117	0.0133	0.0245	0.0243
			(0.54)	(0.63)	(1.27)	(1.26)
Living in Vestland				-0.0798	-0.0614	-0.0632
				(-1.61)	(-1.30)	(-1.34)
Living in city area				-0.0712	-0.0632	-0.0557
				(-1.78)	(-1.59)	(-1.39)
Level of trust in Parliament					0.0657***	0.0675***
					(3.90)	(3.92)
Believe household is responsible					0.162***	0.168***
					(5.68)	(5.60)
Age group						-0.0122
						(-1.18)
_cons	0.697***	0.762***	0.524***	0.530***	0.334***	0.377***
	(13.29)	(9.49)	(5.85)	(6.08)	(3.36)	(3.78)
N	1535	1501	1501	1499	1499	1499
Linearized model						
R^2	0.00247	0.0366	0.0705	0.0781	0.130	0.132

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Hypothesis 1: Increased income leads to higher ability rate.

One of the hypotheses made in the previous section was that a higher income positively affects the rate of ability to implement protection. If the responders feeling of being able to mitigate against flood risk translates to actual behavior, then there are some interesting results from the data. Higher income does increase the perceived mitigation efforts. The results from the first simple OLS regression is $measures_i = 0.697 + 0.0102 income_i + \varepsilon_i$. There is a very small increase of 1.02% in ability rate from a unit increase in income, but a positive effect, nonetheless. Using the t-statistic to test whether the result is statistically significant, with a significant level of 5%, we have a critical value of 1.96. The t-value of the income coefficient is 1.03, which is lower than the critical value, and we cannot confirm the coefficient. The first regression reports an R^2 of 0.00247, meaning that 0.25% of the rate of "measures" is explained by only income. From the correlation table in Appendix A.2, the estimated correlation between measures and income level is 0.092.

Hypothesis 2: Ownership of house increases the ability to protect.

Further expanding the model to include education and whether you own a detached house gives the regression: $protection\ propensity = 0.762 + 0.0116 income_i - 0.0623 educ_i + 0.143 ownDetached_i + \varepsilon_i$. The t-value for education level is just below the critical value of 1.96, which means that we cannot confirm the result that higher education lowers the ability to protect. If the respondent owns a detached house, they are about 14% more likely to protect. The t-value is above the critical value, and we can with 95% certainty claim the result that ownership of a house will have a positive effect on the ability to protect against climate related damages. Expanding the model to include education level and ownership of house increased the R^2 of the model to 3.66%. The correlation between ownership of detached house and protection propensity is 19.9%.

Hypothesis 3: Concern about climate change increase the ability to protect. Hypothesis 3': Concern about damage to property from climate change increase ability to protect.

Next, we include concern of climate change and damages from climate change. The regression now looks like this: $protection\ propensity = 0.524 + 0.0199 income_i - 0.0938 educ_i + 0.164 ownDetached_i + 0.0719 climateWorry_i + 0.0117 worryDamage_i + \varepsilon_i$. Worrying more about climate change increases your inclination to protect your property by 7.2%. This is statistically significant with a 95% rate. An increase in concern of having your home damaged by extreme weather raises the rate of precaution by 0.0117. However, this is not a statistically significant result, so the hypothesis about concern for damage cannot be confirmed. The coefficient for concern climate change coincides with hypothesis that heightened perceived risk of the decision-makers will lead to protection. When controlling for these variables, the coefficients for income and education levels are now statistically significant. This means that when individuals are more worried about climate change, and damage to their property, then income level is more significant to the level of measures. The inclusion of climate variables nearly doubles the explanation rate, R^2 , where 7.05% of the variables explains the rate of measures.

Hypothesis 4: Living in Vestland increases ability to protect. Hypothesis 4': Living in a city area reduces ability to protect.

The regression expands to: $protection\ propensity = 0.53 + 0.0207 income_i - 0.0855 eduLevel_i + 0.147 ownDetached_i + 0.0723 climateWorry_i + 0.0133 worryDamage_i - 0.0798 Vestland - 0.0712 cityArea + \varepsilon_i$ when controlling for living in Vestland and big city. Further when controlling for whether the respondent lives in the county Vestland, we see a negative correlation between living in Vestlandet and ability rate, with a coefficient of -0.0798. However, when testing the significance, we cannot conclude with 95% certainty that this is a significant find. The regression also tracks the effect of living in a big city. This has a negative effect on the measure rate with -7.1%, but this is not significant.

Hypothesis 5: Trusting the parliament decreases ability to protect. Hypothesis 5': Believing household is responsible for mitigation increases ability to protect.

Including variables for the degree the respondent trusts the parliament and whether they believe private households are responsible for mitigation efforts, expands the model to: $protection\ propensity = 0.334 + 0.0175 income_i - 0.0798 eduLevel_i + 0.156 ownDetached_i + 0.0362 climateWorry_i + 0.0245 worryDamage_i - 0.0614 Vestland - 0.0632 cityArea + 0.0657 trustParliament_i + 0.162 householdResponsible_i + \varepsilon_i$. Trusting the government more increases the chance of measures by 6.57%. The hypothesis was that government trust would lead to lower ability to protect. However, we can with a 95% probability claim that strengthened trust in the Norwegian parliament positively impacts the respondent's inclination to protect their property. If the respondent believes the household is responsible for the protection against climate change related damages, like flooding, the chances of also agreeing with the ability to protect rises with 16.2%. It is fair to say that believing the private household is responsible for protecting against flood related damages, has a positive relationship with agreeing that you can take measures to protect against climate change related damages. This is also statistically significant with a 95% probability. Including these two variables nearly doubles R^2, and now 13% of the independent variables explains the variance in measures.

Hypothesis 6: Older people are more risk averse and want to protect.
$protection\ propensity = 0.377 + 0.0167income_i - 0.0785eduLevel_i + 0.15ownDetached_i + 0.0376climateWorry_i + 0.0243worryDamage_i - 0.0632Vestland - 0.0557cityArea + 0.0675trustParliament_i + 0.168householdResponsible_i - 0.0122ageGroup + \varepsilon_i$. Younger individuals are less likely to protect, with a -1.2% coefficient. This is not statistically significant.

$\widehat{protection\ propensity} = \beta_0 + \beta_1 + \beta_2 + \delta_1 + \gamma_1 + \gamma_2 + \theta_1 + \theta_2 + \beta_3 + \beta_4 + \beta_5 = 0.7429$. There is a 74.29% change the average Norwegian agrees with the ability to protect their property against climate change consequences, like flooding, given the control variables.

5.2 Testing the Results

The only time R^2 is equal to one is when there are no residuals (Verbeek, 2017, p. 21). All the variance in the dependent variable would be explained by every control variable. This is very unlikely. In the results, the goodness-of-fit is rising with the inclusion of new variables. This diminishes income as an explanatory variable, considering that only 0.25% of the variance in measures is explained by income. Fear of climate change and believing that private households are responsible for protection had a much bigger goodness-of-fit. Including these variables, nearly doubled R^2 in each inclusion, respectively. A low goodness-of-fit, or R^2, does not necessarily mean that the results are wrong or insignificant, it just means that there might be other variables not included in the model that are more significant when explaining the degree of which the respondents believe they can take measures to protect their property against extreme weather, like flooding. R^2 is not the best measure of significance. For every new variable you add to the model, the R^2 will increase. However, in the situation where the R^2 raises a lot, like when including variables like ownership of house and whether the respondent believes household is responsible, it signifies that those variables are descriptive of the dependent variable. Further, testing the hypotheses using the t-statistic, confirmed the significance of variables.

5.3 Discussion of the results

The result from the regression provides some interesting insights into the respondents stated attitudes. Firstly, the only independent variable that is estimated is income. The results in the first equation are not significant. When controlling for concern for climate and if the respondent lives in Vestland county and a big city, the coefficient for income is significantly positive. A higher income increases the probability that the respondent agrees with approximately 20%. Individuals with higher income are better equipped with resources to spend money on private mitigation efforts. When including more variables, the income variable becomes less significant again. A reason for the low correlation between income and propensity to protect (see Appendix about correlation matrix), may be caused by the possibility that people in the same income group do not share the same opinions. It leads to the assumption that income is not important when deciding to protect vs. not protect.

Education was included to differentiate between different groups. The result that higher education level lowers the probability to protect goes against the hypothesis. It is hard to find the reason for this result. One can suggest that individuals with a higher education level are familiar with more information about the responsibility distribution of climate adaption and expects the government or municipalities to protect. The coefficient of education level is not significant at first, but becomes significant later when including more variables.

Owning a detached house provides about a 15% likelihood of agreeing with the ability to do measures. This is statistically significant throughout the model. It is also intuitive, as having property rights not only gives autonomy to protect property, but also, owning property brings sentimental value to the owner. This is hard to assess monetarily. Heightened perceived risk levels increased propensity and is consistent with theory.

The inclusion for the living in the county Vestland and living in a city area was to provide some geographical insights. The reason for Vestland as a variable, was because of the historical data and assumptions that Vestlandet as a high-risk county when it comes to extreme weather and flood zones. From the NVE data, there are many dense flood zones in Vestland county and high projections of future flooding events, see maps in A.3 in Appendix. However, the regression showed a negative coefficient of living in Vestland county, which lowered the likelihood of agreeing with protection. This result is not statistically significant. Also, in Appendix A.4, the histogram shows great similarity between the different counties in propensity to agree with ability to protect. Living in Vestland is not providing vastly different opinions than other counties. This negated the hypothesis.

Further, the inclusion of trust in parliament and the variable for thinking private households are responsible, gave more statistical insights. The inclusion for trust in parliament was to see if it could give some insights to the policy implications in Norway. I will later discuss the security net the Norwegian government provides for residents, but the hypothesis was that a greater trust in the parliament would reduce the probability of believing in the ability to take measures. The results indicated that greater trust in the parliament increased the probability of protection propensity with 6.57% and was statistically significant.

While 74% of the average respondent in the last model agrees with propensity to agree. It is interesting to discuss the policy implications from Norway's insurance schemes which might lead to moral hazard. The stated preferences from the survey are very revealing, but it is still interesting to discuss the possible lack of protection put in place by private households. From studies done in other countries on revealed behavior, the willingness to pay for flood insurance has been low, more on this in the next section.

6. Policy Implications

I will now move on to discuss society's damage reparations and compensations schemes, and how they create problems. I will be discussing the government's role in this in Section 6.1 below, and subsequently private insurance's role in the following Section 6.2.

6.1 The Role of the Government

In the introduction of this paper, I mentioned some of the responsibilities NVE has on flood and erosion warnings. While the governmental role and climate politics often refer to climate mitigation – how to reduce emissions accelerated by climate change, another important aspect of climate politics is climate adaption – given that climate change is happening, how do we prepare our society? (Junker, 2021, p. 438). One might ask, how much can the private household do? While private households have the responsibility to be self-assured and prepared for disasters, the government and municipalities have the superior responsibility of the climate mitigation execution, particularly the municipalities. (Sandberg, 2020). The legislator (Stortinget) has implemented laws to distribute responsibility to the municipalities, the government, and to private insurance firms. In 1989 the Natural Damage Insurance Act was adopted, which regulates the private insurance responsibility, and expanded fire insurance to include natural damages (Naturskadeforsikring, 1989). The Natural Damage Act was later adopted in 1994 and is a law that puts the main responsibility on municipalities to mitigate protective efforts against natural damages (Naturskadeloven, 1994). Further, the law was expanded to an act on compensation for natural damage, which regulates governmental compensation after natural damage, when not insured through regular insurance (Naturskadeerstatningsloven, 2014). Through these legislative acts, the government has placed legal responsibility on three different agents, local municipalities, private insurance companies, and the government. In sum, the government has created a public safety net with regards to natural damages through legislation. This legislative safety net is complemented by budgetary transfers to the Governmental agency NVE, to enable NVE to manage funds to finance reparations of flood harm by local government.

The act on compensation for natural damages (Naturskadeerstatningsloven, 2014) is a great security net for Norwegian citizens. If residents are hit by extreme weather and private insurance is off the table, the government protects them. This is considered a great solidarity measure from the government. However, from an economic analytical standpoint, one can argue that it leads to moral hazard problems (Pindyck, 2013, p. 643). If a decision-maker knows that the monetary damage from flooding is going to be borne by another party, then incentives for private protection efforts are reduced. This challenges the assumption that households are acting in accordance with the expectations set by the Norwegian government. However, as the policy choice on division of responsibility shows, climate adaption is not an independent task for one agent in society, all members of society must contribute. Given the moral hazard implications of the security net for Norwegian citizens, I argue that it has a negative effect on protection efforts done by private households and that the expectation of self-assurance is weak.

6.2 The Role of Private Insurance

One might think that market forces in the form of household demand for insurance and private sector supply of insurance would cause the financial reparation of flood harm to naturally emerge in the form of appropriate flood insurance, as both are based on rational responses to risks and uncertainty. However, evidence from a survey from Californian households indicates that residents in risk-prone areas are not taking mitigation prevention voluntarily (Kunreuther, 2006). Flood coverage has been required since 1973 as a condition for a federally insured mortgage, however, less than 40% of the 2005 Hurricane Katrina victims has flood insurance (Kunreuther, 2006). It suggests that even in a risk-prone area, where there typically is a need for flood protection, homeowners did not have flood insurance coverage. Another high-risk area for flooding, due to its low-lying delta, is the Netherlands. In the Netherlands, where they did not have flood insurance (as of 2010, they do now), it was shown that consumer's willingness to pay for flood insurance was low, because they underestimated the risk of flooding (Botzen, 2012). However, it was hard for the respondents in the survey to conduct probability estimations of flooding events (Botzen, 2012). Private individuals do not have full information about the damage risks. These examples do not reflect the situation in Norway. In Norway, buyers of insurance do not need to think about the choice of purchasing flood-insurance, as flood-related damages is covered in the Natural Damage Insurance act.

With increasing happenings of flooding, and higher costs, this means high costs for insurance companies. This, in combination with individuals with low willingness-to-pay, is a recipe for market failure. (OECD, 2016). Low levels of insurance coverage in the event of a flood are likely to lead to greater pressure on governments to provide compensation (where such compensation is discretionary). Higher levels of government compensation are, in turn, likely to further reduce demand for insurance coverage. This has been termed the "disaster syndrome" (Kunreuther, 2000). (OECD, 2016, p. 58).

The public fund put in place was, in 1980, subsequently developed by the Natural Damage Insurance Act, into a hybrid public/private insurance institution ("pool"), where a statute now dictates that natural damage, including flood harm, is covered by private insurance, financed by part of the premium for fire insurance (Forskrift om instruks, Norsk Naturskadepool, 1979, § 11). Fire insurance as a part of damage insurance is now widely accepted as an efficient part of the insurance. A main principle in the natural damage insurance act is the so called "Solidarity Principle", where all insured pay the same premium, regardless of their location and corresponding risk exposure (Eidal, 2021).

Although these insurance schemes from both the governmental and private insurance market are generally accepted as efficient programs, there are unintentional effects. Moral hazard problems may arise if decision-makers lose incentives to preemptively protect and follow assumed behavior placed by insurance companies. This effect was hard to capture in the model, as willingness-to-pay, and take-up rate for private insurance was not included in the survey.

A possible solution to the moral hazard problem, due to both governmental and private insurance policies, could be differentiation of premiums. Differentiating the premium rate for natural damage insurance through the fire insurance, removing the "Solidarity Principle", and using a rate which reflects risk levels of where people or companies choose to build, could incentivize agents to build in less risk-prone zones. Climate risk is impossible to clearly predict, so a uniform premium on damage insurance might not be the most effective system in the future, this is also something the government discussed in 2018. (NOU 2018:17, p. 111). In the same report, they discuss the government's responsibility of providing information about climate risks to private agents. NVE is the provider for flood risk information, and that information is available to everyone. Focusing more on this provided information and making it more accessible to private households, can lower the information bias and provide more accurate risk perceptions for residents.

7. Concluding Remarks

7.1 Summary

The purpose of the thesis was to look at what affects households' choice to take protective measures on their property. Specifically, I was considering income as a variable to see if there are any differences between lower and higher income individuals. My research revealed that income was not a very important factor to whether the respondents thought they had the ability to protect. There was a positive coefficient, but it was not statistically significant. My analysis further revealed that the correlation between measures and income was only 9.2%, see the correlation matrix in the Appendix, A2. After completing the regression and studying the results, I found that ownership of house, concern about climate change and the belief that the household is responsible were a lot more relevant a greater likelihood of agreeing with ability to protect property.

After the regression analysis, I discussed ways in which public and private policy can interfere with the choice of protecting against natural damages. Norway has a great security net because of legislative acts put in place. I could not trace the effect of moral hazard in the analysis, but it is a very interesting topic and should be researched further.

7.2 Further research

For further analysis, there is an array of interesting questions and analyses that should be explored. Researching revealed behavior of decision-makers over several years, combined with studies of flood zones and where flood protection has been put in place, can provide the necessary insight for a more direct demand function for flood protection from the consumer's standpoint. Another interesting topic could be a difference-in-difference model, where behavior before and after a big flood is analyzed.

Ideally, a panel data- or time series analysis would be appropriate for researching this question more thoroughly. The question of whether the respondents think they can do anything to protect their own properties is only asked in the 25th round. There are variables that are repeated throughout rounds, like income, county, and more personal identification variables. I would recommend asking the respondents more questions relating to willingness-to-pay for protective measures. This could of course also lead to some bias, as respondents are not always truthful in surveys. However, assuming they answer according to their inclined behavior, it might serve the research better using a more concise willingness-to-protect or willingness to pay for flood insurance variable. In my analysis, we must assume that the respondents' answers about protecting their property translates to inclined behavior. When using a fixed effects model, for example, you can look at how their attitudes towards the ability to protect and mitigate against damages change as their income changes, or if they move to another location.

Acknowledging that the dataset could be stronger, and implementing a panel data study, or a difference in difference model where one studies the behaviors of consumers before and after a major flooding event could be productive. However, using what data available, combined with some classical microeconomic theory about consumer behavior, and a linear probability model there is a lot of nuance and interesting points that have been mentioned. Hopefully, this topic will be researched further, and by the relevance of the topic, I am sure it will.

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Appendix

A.1 *Mathematical explanation of vNM utility equation when choosing protection efforts*

The von Neuman and Morgenstern model implemented for the choice between protecting versus not protecting against flood:

(1) $EU_{no\ protection} = (1-p)\ln(Y) + pln(Y(1-f))$

The expected utility of no protection is equal to the probability of no flood multiplied by assets, plus the probability of flood multiplied by your assets minus the damage of flooding.

(2) $EU_{protection} = (1-p)\ln\,(Y(1-pf\theta)) + pln(Y(1-pf\theta))$

The expected utility of protection is the probability of no flood multiplied with assets minus the probability of no flood damages times the efficiency rate of protection.

$lnY - assets$
$p - probability\ of\ flood, 0 < p < 1$
$f - damages\ from\ flood$
$\theta - how\ much\ the\ protection\ costs?\ or\ efficiency?$

Is $EU_{no\ protection} \geq or\ = or\ \leq\ EU_{protection}$?

Rewriting (1):

$$EU_{no\ protection} = (1-p)\ln(Y) + pln(Y) + pln(1-f)$$

$$\Rightarrow\ EU_{no\ protection} = lnY + pln(1-f)$$

$$\Rightarrow\ (1')\ EU_{no\ protection} = lnY + \ln(1-f)^p$$

Rewriting (2):

$$EU_{protection} = (1-p)lnY + (1-p)\ln(1-pf\theta) + plnY + pln(1-pf\theta)$$

$$\Rightarrow\ (2')\ \mathrm{EU}_{protection} = lnY + \ln\,(1-pf\theta)$$

When is $U_{no\ protection} = U_{protection}$? When is the decision-maker indifferent between protecting versus not protecting? When θ is large then $U_{no\ protection} > U_{protection}$. Proof:

$$EU_{no\ protection} = EU_{protection}$$

$$lnY + \ln(1-f)^p = lnY + \ln(1-pf\theta)$$

(Income is not relevant)

$$\ln(1-f)^p = \ln\,(1-pf\theta)$$

$$\Rightarrow (1-f)^p = (1-pf\theta)$$

$$\Rightarrow \frac{(1-f)^p}{(1-pf)} = \theta$$

$$(3)\ \tilde{\theta} = \frac{1-(1-f)^p}{pf}$$

$\tilde{\theta}$ is the level of protection efforts where the decision-maker is indifferent between each endgame. Higher chances of flooding will increase protection efforts, and greater damages will also lead to higher protection efforts.

A.2 Correlation Matrix

Table 3: Correlation Matrix between variables

Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) Measures	1.000										
(2) Income	0.092	1.000									
(3) Education Level	0.038	0.286	1.000								
(4) Own a detached house	0.199	0.079	0.019	1.000							
(5) Worry about climate	0.092	-0.008	0.269	-0.104	1.000						
(6) Worry about damage	0.109	-0.023	0.042	0.028	0.332	1.000					
(7) Live in Vestland	-0.033	-0.017	-0.034	-0.035	-0.038	0.010	1.000				
(8) Live in City Area	-0.087	0.132	0.140	-0.287	0.122	0.017	0.023	1.000			
(9) Trust parliament	0.136	0.080	0.158	-0.023	0.278	0.071	0.005	0.041	1.000		
(10) Household responsible	0.152	0.114	0.160	-0.006	0.192	0.057	-0.021	0.062	0.106	1.000	
(11) Age group	-0.034	0.121	0.042	-0.116	0.079	0.061	-0.002	0.190	0.033	0.129	1.000

A.3 Maps of Change in Flood

Figure 7: Projected percentage changes in the 200-year flood between 1961-1990 reference period and the 2021-2050 future period, based on the median of the ensemble of hydrological projections. (Lawrence, 2011).

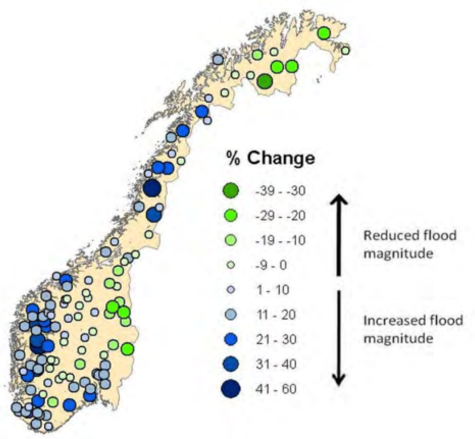
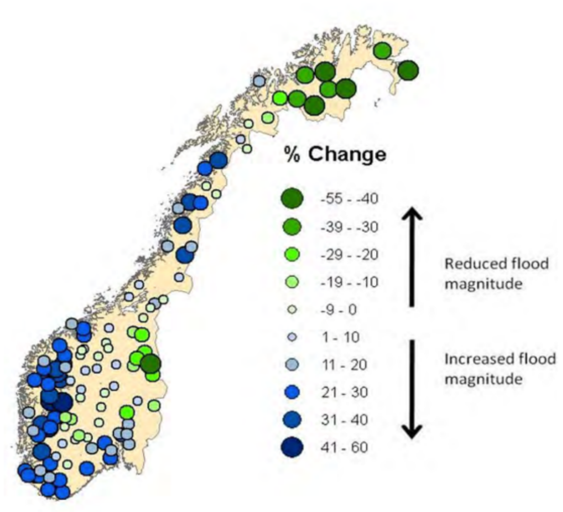


Figure 8: Projected percentage changes in the 1000-year flood between 1961-1990 reference period and the 2071-2100 future period, based on the median of the ensemble of hydrological projections. (Lawrence, 2011).



A.4 Histogram Over all Counties

Figure 9: Histogram over propensity to agree with ability and county