Final Project Report

Solomon Nyamekye (SN66)

Tue., Apr. 30

Table of contents

# 1. Introduction

In this final project, we delve into the significance of integrating the risk premium into house elevation models. We explore how it affects expected average damages (EAD), net present value (NPV), and overall cost-benefits analysis. Equity risk premium model assumes that investors demand a higher return or benefits for accepting the additional risk associated with investing in the market and adding this to the house elevation model, integrates risk-reward trade-off of elevating homes (Investopedia 2021).

By analyzing real-world examples and leveraging asset pricing models, we highlight the practical implications of considering risk in elevation strategies.

## 1.1 House information

Zillow was used for the identification of a single-family residence with 4 bedrooms and 4 bathrooms situated approximately 0.56 miles from Galveston Pier 21, TX. The distance from the gauge was estimated using Google Maps, while the elevation of the house above Mean Sea Level (MSL) was determined using the USGS National Map Viewer. The estimated value of the house and area of the house were from Zillow. - Depth-damage function from depth-damage functions from the HAZUS model developed by the USArmy Corps of Engineers (U.S. Army Corps of Engineers 2017) were used. The USACE Galvestion District Damage function with ID 85 was selected. The USACE Galveston functions are based on flood damage records, as well as post event surveys and are widely used by the Galveston district where the selected building is located. The selected description is a good fit for the selected building (the function is for hotels/motels) which is a popular hotel in the region that serves mostly fishermen in the area. Below are the details for the selected house.

* Galveston Pier 21, TX - Station (ID: 8771450):
* Latitude: 29° 18.6 N, Longitude: 94° 47.6 W.
* Historical water level extremes: Max (ref MHHW) 12.11 ft (Sep 08, 1900), Min (ref MLLW) -6.28 ft (Jan 11, 1908).
* Mean tidal range: 1.02 ft.
* Harbour House Hotel:
* Address: 21 Galveston, Texas 77550.
* Estimated distance from gauge: 319 feet (inland).
* Estimated building elevation: 6.0 feet.
* House Value: 200,00 USD

## 1.2 Problem Statement

The objective is to investigate the influence of equity risk premiums on expected annual damages (NPV) and the cost-benefit analysis associated with house elevation decisions.

By incorporating the risk premium into the house elevation model, it can encourage and assist homeowners in making informed decisions regarding house elevation, taking into account both upfront costs and benefits. Furthermore, elevated homes usually qualify for lower flood insurance premiums, and the inclusion of the risk premium allows us to determine the compensation homeowners receive for their decision to elevate their homes; risk-reward trade-off.

## 1.3 Selected Feature

* The chosen feature entails the incorporation of Equity Risk Premium (ERP) into our house elevation model. ERP is a crucial metric that reflects the price of risk in equity markets. By integrating ERP, we can directly account for its impact on the cost of equity for homeowners investing in elevation.
* This allows us to adjust the expected return on elevated homes, taking into consideration the physical and financial risks involved. Furthermore, elevated homes with lower risk may qualify for reduced flood insurance premiums. The house elevation model is now designed to support homeowners make informed decisions that balance both physical risk and financial implications.
* By integrating ERP, we bridge the gap between climate science and financial realities, ensuring that our elevation choices are both effective and economically sound.

# 2. Literature Review

The concept of a risk premium is integral to understanding investment returns, representing the expected yield of an asset beyond the risk-free rate of return. This premium serves as a form of compensation for investors, offering a reward for assuming the additional risk associated with a particular investment over that of a risk-free asset (Investopedia 2021). Specifically, the equity risk premium (ERP) denotes the surplus return that investing in the stock market provides over the risk-free rate, constituting the equity cost. The greater the potential for capital loss, the higher the compensation an investor anticipates.

While many studies have explored house elevation, only a few have tackled the financial risks (equity risk premium) involved in such a project. Botzen, Aerts, and Bergh (2013) have concentrated on the willingness to pay (WTP) for flood insurance and the WTP for risk elimination through elevation. Furthermore, Xian, Lin, and Kunreuther (2017) proposed an optimal elevation strategy to minimize the sum of upfront elevation costs and cumulative expected losses, including risk-based insurance premiums over the house’s lifespan (Xian, Lin, and Kunreuther 2017). Their innovative approach also suggested a voucher program linked with optimal elevation analysis, tailoring the voucher cost to factors such as loan length and interest rates, thereby indirectly compensating homeowners for the equity risk premium associated with the capital investment in home elevation.

# 3. Methodology

## 3.1 Implementation

The equity risk premium (ERP) can be estimate by;

Where:

( R\_a ) = Expected return on an equity investment, ( R\_f ) = Risk-free rate of return, ( \beta\_a ) = Beta of the equity investment, ( R\_m ) = Expected return of the market

* λ \* [risky expected rate of returns - risk-free return]
* λ is the beta coefficient that ranges from 0 to 1
* (risky expected rate of returns - risk-free return) represent the variance or standard deviation
* To implement risk premium (equity risk premium), we introduced a new parameter λ to our state of the world, sow. λ is sampled using normal probability distribution.
* λ is added to our “draw\_sow function”

#we add the beta coefficient to our sow  
function draw\_sow()  
 λ = rand(Normal(0.06, 0.0004))  
 slr = rand(slr\_scenarios)  
 surge\_params = draw\_surge\_distribution()  
 discount = draw\_discount\_rate()  
 return SOW(slr, surge\_params, discount, λ)  
end

## 3.2 New function for run simulation

* New function, “run\_sim\_risk” is created with modification of the expected annual damages (EAD) to incorporate the ERP into computation of the “EAD”.
* The EAD is then discounted over the number of years (2024:2083) get the net present value for after incorporating risk premium.

function run\_sim\_risk(a::Action, sow::SOW, p::ModelParams, λ::Float64)  
 #| output: false  
  
 # first, we calculate the cost of elevating the house  
 construction\_cost = elevation\_cost(p.house, a.Δh\_ft)  
  
 # we don't need to recalculate the steps of the trapezoidal integral for each year  
 storm\_surges\_ft = range(  
 quantile(sow.surge\_dist, 0.0005); stop=quantile(sow.surge\_dist, 0.9995), length=130  
 )  
 eads = map(p.years) do year  
 # get the sea level for this year  
 slr\_ft = sow.slr(year)  
 # Compute EAD using risk premium concept  
 pdf\_values = pdf.(sow.surge\_dist, storm\_surges\_ft) # probability of each  
 depth\_ft\_gauge = storm\_surges\_ft .+ slr\_ft # flood at gauge  
 depth\_ft\_house = depth\_ft\_gauge .- (p.house.height\_above\_gauge\_ft + a.Δh\_ft) # flood @ house  
 damages\_frac = p.house.ddf.(depth\_ft\_house) ./ 100 # damage  
 mean\_damages = mean(damages\_frac)  
 std\_damages = std(damages\_frac)  
 ead = (mean\_damages + sow.λ \* std\_damages) \* p.house.value\_usd  
 end  
  
 years\_idx = p.years .- minimum(p.years)  
 discount\_fracs = (1 - sow.discount\_rate) .^ years\_idx  
 ead\_npv = sum(eads .\* discount\_fracs)  
 return -(ead\_npv + construction\_cost)  
end

run\_sim\_risk (generic function with 1 method)

## 3.3 Risk based objective function

* New objective function which incorporate new parameter λ is created.
* The new function is then passed to our optimization function

function objective\_function\_risk(Δh::Vector{Float64})  
 #| output: false  
 λ = rand(Normal(0.06, 0.0004))  
 a = Action(Δh[1])  
 npvs = [run\_sim\_risk(a, sow, p, λ) for sow in sows\_opt]  
 return -mean(npvs)  
end

objective\_function\_risk (generic function with 1 method)

# 4. Validation

we can use brute force. We can compare by plotting the risk-based objective function and the initial objective function for a range of elevations (from 0 to 14 ft) using all SOWs.

Figure 1. for risk-based, and non risk-based objective function

## 4.1 Calibration of the risk premium sampling

* Using Average market risk premium in the U.S. 2011-2023 Published by Statista Research Department, Jun 14, 2023; a normal distribution N(0.06,0.0004) were used for the sampling of the equity risk premium (Statista Research Department 2023) .
* The mean and the standard deviation for the distribution were calculated using the historical data.
* Quantile-Quantile (Q-Q) Plot were used to validate the calibration -see the appendix figure.

# 5. Results

## 5.1 Non risk-based NPV for all sow

Figure 2. Non risk-based NPV in M USD vs elevation in ft plot

## 5.2 Risk-based NPV for all sow

Figure 3. Risk-based NPV in M USD vs elevation in ft plot

## 5.3 Comparing risk-based and non risk-based results for all sow

Figure 4. Risk-based NPV and non risk-based in M USD vs elevation in ft plot

## 5.4 Impact of Adding Equity Risk Premium on Decision Support Tool:

* The NPV values range from -204.452M USD to -311.472M USD. [1][risl\_based]
* As elevation increases from 0.0 to 14.0 feet, the NPV generally becomes less negative, indicating a reduction in overall costs or losses as elevation increases.
* The NPV values range from -2338.18M USD to -899.982M USD. Similar to the non-risk analysis, as elevation increases, the NPV generally becomes less negative, suggesting a reduction in costs or losses as elevation increases.
* However, the NPV values are significantly more negative compared to the non-risk analysis, indicating higher costs or losses associated with incorporating the equity risk premium.

# 6. Conclusion

## 6.1 Discusion

* The enhanced decision-support tool could recommend elevation based on expected annual damages considering both financial and climate risk factors
* By accounting for equity risk premiums, climate risk assessments become more holistic.
* Incorporating an equity risk premium allows homeowners to assess the trade-offs between upfront costs (e.g., elevation construction) and long-term benefits (e.g., reduced flood risk).
* Owners making house elevation decisions need to be aware of the higher costs associated with assuming risk, which may influence their decision-making process.
* The tool provides a more realistic assessment of the costs and benefits, considering both the physical elevation costs and the financial risks associated with uncertain outcomes.
* The analysis highlights the need for integrated risk assessment frameworks that combine physical and financial risk considerations.
* Future studies could incorporate calibration of the equity risk premium using historical data in the financial equity markets.
* In conclusion adding the equity risk premium to the decision support tool for house elevation decisions enhances its ability to provide owners with a comprehensive understanding of the financial implications and risks associated with different elevation scenarios. This information enables owners to make more informed decisions that align with their risk tolerance and financial objectives.

# 7. references

Botzen, W. J. W., J. C. J. H. Aerts, and J. C. J. M. van den Bergh. 2013. “Willingness to Pay for Flood Insurance.” *Journal of Risk and Uncertainty* 46 (3): 253–76.

Investopedia. 2021. “Risk Premium.” <https://www.investopedia.com/terms/r/riskpremium.asp>.

Statista Research Department. 2023. “Average Market Risk Premium in the u.s.” <https://www.statista.com/statistics/664840/average-market-risk-premium-usa/>.

U.S. Army Corps of Engineers. 2017. “HAZUS Flood Loss Estimation Methodology.” Zenodo. <https://zenodo.org/records/10027236>.

Xian, S., N. Lin, and H. Kunreuther. 2017. “Optimal House Elevation and the Willingness to Pay for Flood Insurance and Mitigation.” *Natural Hazards Review* 18 (4): 04017005.

# 8. Appendix

Quantile-Quantile Plot during calibration