Research Trend in Modern Insurance Modeling

at Department of Mathematics and Statistics, Thammasat University

Pasin Marupanthorn, AMIMA

2023-01-29

0.1 Table of content

1 Lecturer Biography

1.1 Educations and Related Experainces

Pasin Marupanthorn, AMIMA

Educations

Ph.D. student **Actuarial Mathematics**, *Heriot-Watt University*

M.Sc. **Financial Engineering**, *WorldQuant University*

M.Sc. **Mathematical Modelling**, *University of Birmingham*

M.Sc. **Mathematics**, *Thammasat University*

B.Sc. **Applied Mathematics with Physics**, *Thammasat University*

Related Experiences

- **Founder**; Quantitative Finance and Insurance Laboratory
- **Teaching Assistance**; Machine Learning in Insurance A and B, Heriot-WAtt University, with Prof. Gareth W. Peters, 2021-2022
- **Teaching Assistance**; Life Insurance Mathematics A and B, Stochastic Modeling, and Time Series Analysis, 2020-2022, with Department of Actuarial Mathematics and Statistics, Heriot-Watt University
- **Quantitative Developer**;ResilentML, Australia, 2020 - Now
- **Financial Data Analyst**; University of Technology Sydney (UTS), Australia, 2021-2022

1.2 Research

- **Financial Mathematics**
  - Financial Data Science
  - Sustainable Finance
  - Algorithmic Trading and High Frequency Trading
  - Statistical Arbitrage
  - Portfolio Optimization
  - Econometrics
  - Stochastic Models in Finance
- **Actuarial Science**
  - Actuarial Data Science
  - Non-Life Insurance
  - Sustainable Insurance
  - Decentralized Insurance
  - Stochastic Models in Insurance
- **Statistical Learning**
  - Generative Models
  - Distributional Learning
  - Stochastic Optimization
  - Dependency Models
  - Unsupervised-Learning
  - Reinforcement Learning
  - Reproducing Kernel in Hilbert Space
  - Information Geometry
- **Others (Hobby)**
  - Management Mathematics
    - Meta-Heuristic Algorithm
    - Optimal Process Design
  - Mathematical Physics
    - Continuum Mechanics of Micro System
    - Algorithm Transforming for Quantum Computing

1.3 Contact Information

- Email: quantfilab@gmail.com (quantfilab@gmail.com)
- Page: oporkabbb.wixsite.com/math (oporkabbb.wixsite.com/math)
- Github: Quantitative Finance and Insurance Laboratory (https://github.com/QuantFILab)
- Facebook page: Quantitative Finance and Insurance Laboratory

2 How to Find the Emerging Topics in Insurance

2.1 Acturial Societies Research Page

2.1.1 SOA

- https://www.soa.org/research/topics/research-emerging-topics/ (https://www.soa.org/research/topics/research-emerging-topics/)
- https://www.soa.org/programs/strategic-research-program/ (https://www.soa.org/programs/strategic-research-program/)
- https://www.soa.org/research/trending-research/ (https://www.soa.org/research/trending-research/)

2.1.2 IFOA

- https://www.actuaries.org.uk/learn-and-develop/research-and-knowledge/actuarial-research-centre-arc/recent-research (https://www.actuaries.org.uk/learn-and-develop/research-and-knowledge/actuarial-research-centre-arc/recent-research)
- https://www.actuaries.org.uk/get-involved/volunteering-ifoa/volunteer-vacancies (https://www.actuaries.org.uk/get-involved/volunteering-ifoa/volunteer-vacancies)

2.2 Others

- Special Issue Topics of Actuarial Journals
  - Annals of Actuarial Science 2023 (https://www.cambridge.org/core/journals/annals-of-actuarial-science/announcements/call-for-papers/special-issue-of-aas-managing-climate-related-risks)
  - North American Actuarial Journal
  - Scandinavian Actuarial Journal
  - ASTIN Bulletin
  - European Actuarial Journal
  - British Actuarial Journal
  - Journal of Risk and Insurance
  - etc.
- Blogs
  - Medium
  - Insurely
  - etc.
- ChatGTP

3 Decenterized Insurance

3.1 Introduction

3.1.1 What is Decenterized Insurance?

- Similar to DiFi, it runs insurance process without central agent.
- Examples; Online Mutual Aid in China (2011), P2P Insurance in German (2010), and Takeful in Muslim communities
- It is becoming more efficient when cooperating with Blockchain technology.

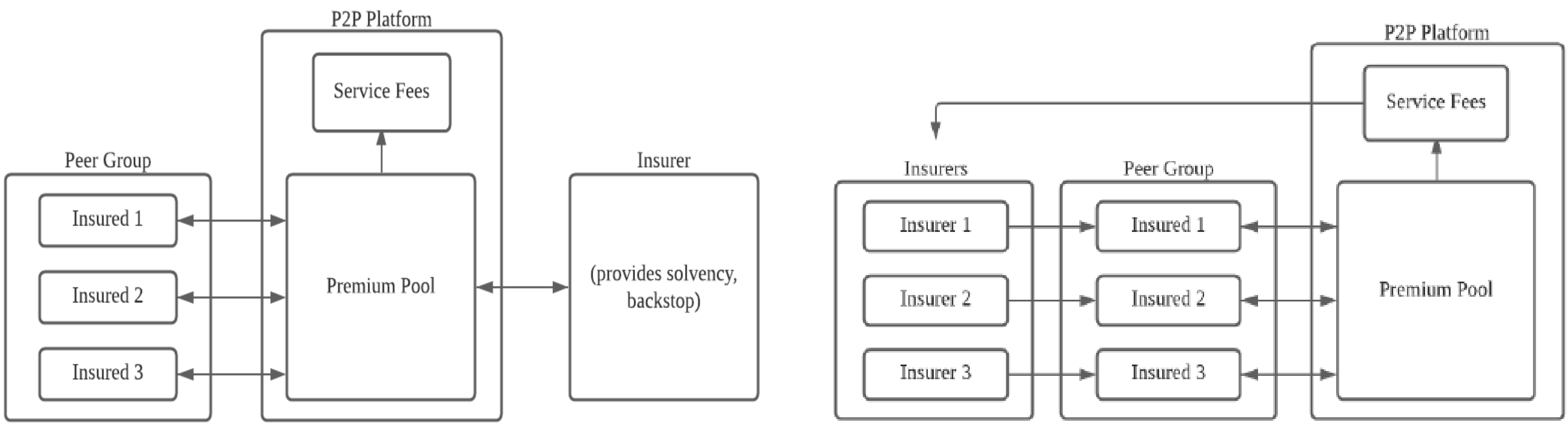


Figure form: Feng, R., Liu, M., & Zhang, N. (2022). A unified theory of decentralized insurance. Available at SSRN.

- InsurTech startups running Decentralized insurances;
  - Friendsurance (https://www.friendsurance.com/), Life P2P insurance
  - Bridge Mutual (https://bridgemutual.io/), DiFi P2P insurance
  - Nexus (https://nexusmutual.io/), DiFi P2P insurance
  - Carpool (https://brandinside.asia/carpool-peer-to-peer-insurance/), Car P2P insurance

3.1.2 Advantages

Similar to a general decentralized system; Fast, Low operating cost, Flexible

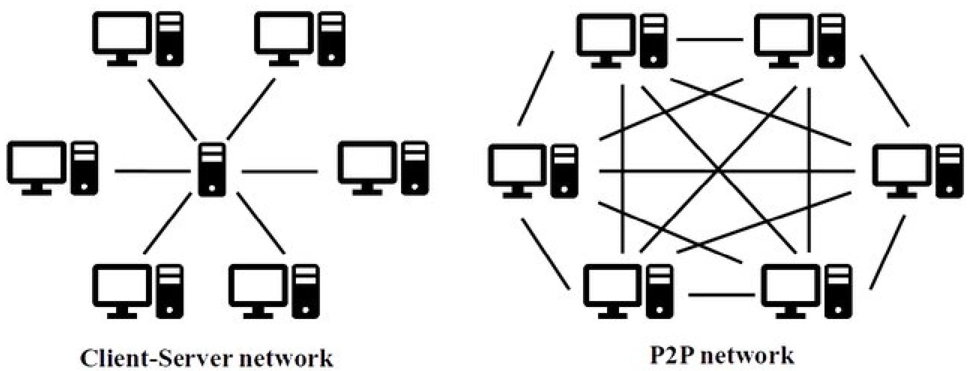
3.1.3 Disavdantage

Emerging technology risk and lack of regulation

3.2 Peer-to-Peer Insurance

3.2.1 P2P Network

- Traditional network had only a single or a few “hub(s)” and users are peers, whereas P2P network users are both hub and peer. Examples of P2P networks, BiTtorrent and uTorrent



Karthika, V., & Jaganathan, S. (2019). A quick synopsis of blockchain technology. International Journal of Blockchains and Cryptocurrencies, 1(1), 54-66.

3.2.2 Traditional Insurance

Let $(X_1, X_2, \ldots, X_n)$ be the independent and identically distributed random variables (iid), then

$$\frac{1}{n}\sum_{i=1}^{n} X_i \to \pi = \mathrm{E}(X).$$

- For homogeneous risk, this states holds.
- Be careful the conditions of the model when using in practice.

3.2.3 Risk-Sharing Rules

Let X_i be a risk from the policyholder i and Y_i be a risk migrated to the policyholder i, and $S = \sum_{i=1}^{n} X_i$ be a sum of the risks in the risk pool. The general risk sharing rule is a deterministic function of the random variables, $h(X) = (h_1(X), \ldots, h_n(X))$ such that

$$\sum_{i=1}^{n} h_i(X) = \sum_{i=1}^{n} X_i$$

where $h_i(X) = Y_i$ and $S = \sum_i X_i = \sum_i Y_i$.

Examples of Risk Sharing Rules

- *Quota-share risk-sharing* is a common rule can be seen regularly,

$$h_i^{Quota}(S) = \alpha_i S$$

  for $i \in \{1, \ldots, n\}$, where $\sum_{i=1}^{n} \alpha_i = 1$.

- *Uniform risk-sharing or All to claimants* - All members pay for the costs from claim

$$h_i^{Uni}(S) = \frac{S}{n}$$

- *Survivors to claimants risk-sharing* legitimate-claim members are asked to pay.

$$h_i^{Sur}(S) = \frac{S}{n - N}$$

where N is a total number of claims.

Examples of Risk Sharing Properties

Actuarial Fairness; The policyholder will not gain or loss from the risk sharing in average.

$$\mathcal{P}(Y_i) = \mathcal{P}(X_i),$$

where $\mathcal{P}$ is a premium principal, here $\mathcal{P}(X) = \mathrm{E}(X)$

3.2.4 What is Difference between P2P and Traditional Insruances Modeling?

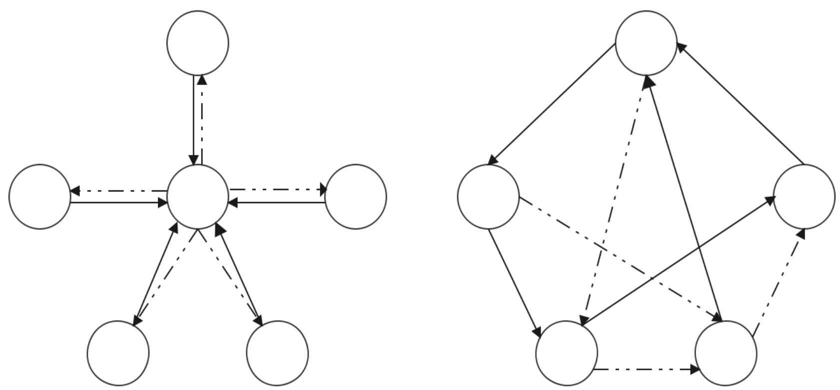


Figure form: Feng, R., Liu, M., & Zhang, N. (2022). A unified theory of decentralized insurance. Available at SSRN.

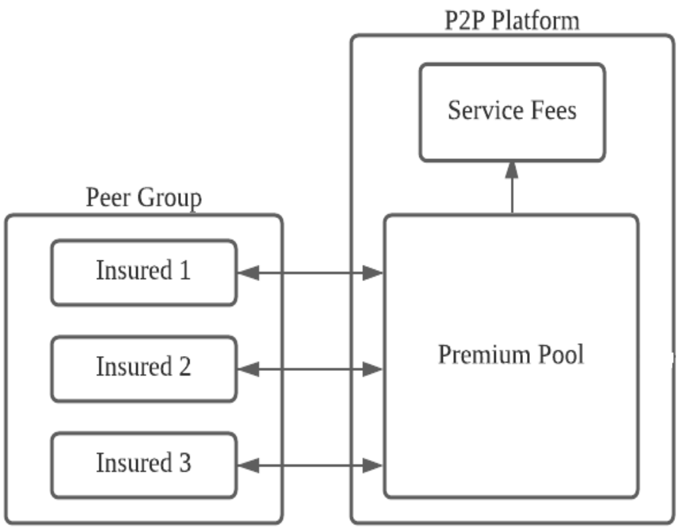
- **Traditional Insurance Risk Pool**

$$Y_i^{Trad} = h_i\left(\sum_{i=1}^{n} X_i\right)$$

- **P2P Insurance Risk Pool**

$$Y_i^{P2P} = h_i(X_1, \ldots, X_n)$$

3.2.5 Example: Group-covered P2P model with no excess-of-loss coverage and service charge



Three insureds pay the premium to the premium pool with assumption no excess-of-loss coverage.

- Using P2P system with the risk sharing-rule called, **Minimum variance Pareto optimal risk sharing-rule**, $Y = AX$ where

$$A = \frac{1}{n}ee^T + \mu^T\Sigma^{-1}\mu\left(I - \frac{1}{n}ee^T\right)\mu\mu^T\Sigma^{-1}$$

. Note that It satisfies actuarial fairness property.

- The claim distribution of the insureds is defined by, $X = (1000X_1, 1000X_2, 1000X_3)$ such that

$X_i \sim Bern(p = 0.001 * i)$ for $i = 1, 2, 3.$

Calculate premium each member must pay in the P2P insurance

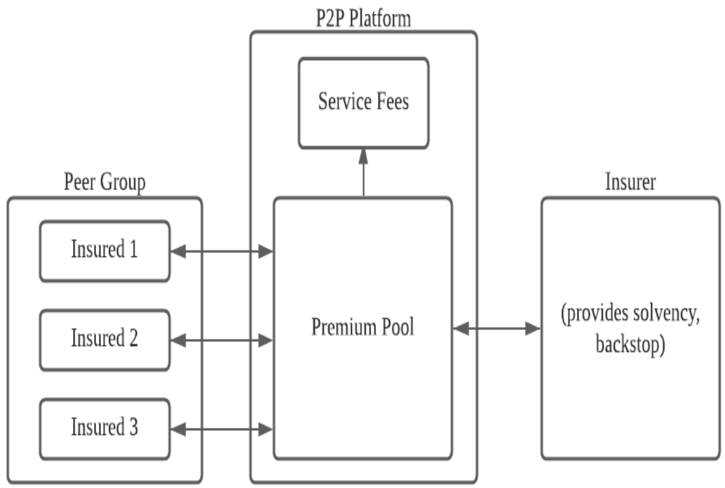
Sol

3.2.6 Example: Group-covered P2P model with no excess-of-loss coverage and service charge

Sol

$\mathrm{E}(Y_i) = 0.001 \times 1000 \times i$

3.2.7 Example: Real Group-covered P2P model



Let d be the cap of each insured, n be the number of the insureds in the network, θ be the service charge in percentage. Here nd is the pool capacity.

- The total premium pool is,

$$\Pi = (1 + \theta)\mathrm{E}[max(0, S - nd)]$$

- Each member will receive after round,

$$\frac{1}{n}\Pi + d - \frac{1}{n}max(0, nd - S)$$

- Using uniform risk-sharing rule and $Y = S/n$, each member required to pay,

$$g(Y) = \mathrm{E}[(max(0, Y - d)] + d - max(0, d - Y)$$

Feng, R., Liu, M., & Zhang, N. (2022). A unified theory of decentralized insurance. Available at SSRN.

4 Sustainable Insurance

4.1 Introduction

4.1.1 What is Sustainable Insurance?

- All activities in the insurance value chain, including interactions with stakeholders, are conducted in a responsible and forward-looking manner by recognizing, assessing, managing, and monitoring risks and opportunities related to environmental, social, and governance issues. The objective of sustainable insurance is to decrease risk, provide new solutions, enhance corporate performance, and contribute to environmental, social, and economic sustainability.
- **Principles for Sustainable Insurance (PSI)** serve as a global framework for the insurance industry to address environmental, social and governance risks and opportunities.
- **Environmental**- this sort of rating considers an organization’s emissions, water consumption, trash management, and other environmental considerations.
- **Social** - this type of score considers the employee relations, customer satisfaction, human rights record, and other social characteristics of an organization.
- **Governance** - this score considers board diversity, transparency, shareholder rights, and other governance considerations.

4.2 ESG Score Data

4.2.1 Thai Companies

- SET ESG data (https://www.set.or.th/app/online-data/esg)
- List of Thai companies and their Yahoo ticker

CSV Excel Search:

Symbol	Name
PTT.BK	PTT Public Company Limited
PTTEP.BK	PTT Exploration and Production Public Company Limited
GULF.BK	Gulf Energy Development Public Company Limited
CPALL.BK	CP ALL Public Company Limited
ADVANC.BK	Advanced Info Service Public Company Limited
BDMS.BK	Bangkok Dusit Medical Services Public Company Limited

Showing 1 to 6 of 860 entries Previous 1 2 3 4 5 … 144 Next

4.2.2 ESG data

Input Company Ticker

PTT.BK

submit

4.3 How insurance companies can help mitigate these risks through sustainable practices and policies

- Reinvest in sustainable (infrastructure) projects
- Offer sustainable support productions

4.4 Examples of Environmentally-Friendly Insurance Products and Services

- **Pay As You Drive (PAYD) from Allstate**; - Consumers can choose a flexible monthly car insurance rate, which varies based on miles driven.
- **LEED Certifications from Travelers**; Premium discounts are offered for homes that meet certain efficiency and sustainability standards.
- **Green Rebuild from Central Insurance Companies**; - Insurance coverage that replaces damages with an eco-friendly version
- **Green Behavior Discounts from DONEGAL**; - Consumers can receive premium discounts if they can prove that they purchased hybrid or electric vehicles
- **Green Building Restoration from CHUBB**; - In the event of a total loss, the policy will cover the cost of rebuilding as a green-certified building.

4.4.1 Examples in Thailand

- GPF Pension Fund, 2023 (https://www.gpf.or.th/thai2019/3Investment/main.php?page=7&menu=partinvest&lang=en)
- News, 2023 (https://www.prachachat.net/finance/news-1166769)
- News, 2023 (https://www.oic.or.th/th/consumer/news/releases/89358)

4.5 Emergng Topic: Climate Change Impact on Insurance

4.5.1 Climate Change

Insurers are also exposed to heightened financial risks due to climate change. More frequent and strong weather occurrences might increase claims and diminish the value of real estate investments.

4.5.2 How Climate Risk Affects Insurance

- Rising whether fluctuation and unpredictable; Increasing Claim Values and Frequency
  - Flight Travel Insurance
  - Sea Shipping Insurance
  - Agricultural Insurance
  - Natural Disaster Insurance
- Changing mortality and mobility rates
  - Life Insurance
  - Health Insurance

4.5.3 Climate Data Source

- SOA research (https://www.soa.org/resources/research-reports/2022/practical-guide-working-weather-datasets/)
- Thai Climate (https://tiwrm.hii.or.th/v3/weather_daily/tmd)
- Thai Water (https://www.thaiwater.net/)

4.6 Sustanable Insurance Challenge for Actuary

- Updating of mortality tables affected by climate-related problem
- Pricing of new-released sustainable insurance products
- Investigating sustainable reinsurance and reinvestment structures
- Observing dependencies and structure change in sustainability risks
- Modeling and forecasting for scenario analyses

4.7 Example: Cost of Imporving ESG of Pension Fund Portfolio

- Investments in blue-chip common and preferred stocks in the United States are a prominent asset class for pension funds. Managers traditionally prioritize dividends and growth. Let compare portfolio with PTTEP, BH, BANPU, KTB, MINT, BDMS, AOT, CRC, CPN, JMT, BBL, AWC, EGCO, CPALL, TOP, GULF, BEM, KBANK, BLA, and IVL. You can download ticker file here (https://github.com/QuantFILab/TU_Seminar_Modern_Trend_Insurance/blob/master/Data/ticker.csv).
- Let try Divfolio (https://quantfilab.shinyapps.io/divfolioserveri/).

4.8 Embedded API for Thai Climate Data

4.8.1 Climate by Stations

CSV Excel Search:

code	name_th	province	amphoe	tambon
432201	สุรินทร์	สุรินทร์	เมืองสุรินทร์	นอกเมือง
566202	กระบี่	กระบี่	เหนือคลอง	เหนือคลอง
552401	ฉวาง	นครศรีธรรมราช	ฉวาง	ฉวาง
432401	ท่าตูม	สุรินทร์	ท่าตูม	ท่าตูม
383201	มุกดาหาร	มุกดาหาร	เมืองมุกดาหาร	มุกดาหาร
551401	พระแสง สอท.	สุราษฎร์ธานี	พระแสง	อิปัน

Showing 1 to 6 of 73 entries

Previous 1 2 3 4 5 … 13 Next

Select Station Code

สุรินทร์

From:

2020-01-01

To:

2023-02-01

submit

Error: An error has occurred. Check your logs or contact the app author for clarification.

5 Introduction to Some Statistical Tools for Undergraduate Students

5.1 Linear Regression

5.1.1 Simple Linear Regression

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_N X_N + \varepsilon$$

- The model can be fitted to the data using least square method
- If ε is standard normal distributed, the model is reliable under stationary assumption.
- The coefficients β_i refer how much Y change when X_i change of one unit. The effect of the random independent variables to the dependent variable can be assessed by standardization.

5.1.1.1 Example 1: Regression on Euro Indices

```
data() #Finding biuld-in data set in R
EuStockMarkets
```

CSV Excel

Search:

DAX	SMI	CAC	FTSE
1628.75	1678.1	1772.8	2443.6
1613.63	1688.5	1750.5	2460.2
1606.51	1678.6	1718	2448.2
1621.04	1684.1	1708.1	2470.4
1618.16	1686.6	1723.1	2484.7
1610.61	1671.6	1714.3	2466.8

Showing 1 to 6 of 1,860 entries

Previous 1 2 3 4 5 … 310 Next

```r
# fit linear model
linear_model <- lm(FTSE ~ ., data=EuStockMarkets)

# view summary of linear model
summary(linear_model)
```

```
##
## Call:
## lm(formula = FTSE ~ ., data = EuStockMarkets)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -534.61  -76.61   12.18   84.13  386.73
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) 1988.54565   18.75930 106.003   <2e-16 ***
## DAX           -0.02123    0.02578  -0.823     0.41
## SMI            0.70758    0.01347  52.541   <2e-16 ***
## CAC           -0.34029    0.01988 -17.120   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 121.5 on 1856 degrees of freedom
## Multiple R-squared:  0.9845, Adjusted R-squared:  0.9845
## F-statistic: 3.941e+04 on 3 and 1856 DF,  p-value: < 2.2e-16
```

5.1.1.2 Example 2: Regression on Climite Data

```
##
## Call:
## lm(formula = t_dry ~ ., data = climate)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -1.3308 -0.3920 -0.1312  0.2697  5.4088
##
## Coefficients: (2 not defined because of singularities)
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)   33.795163   8.661744   3.902 0.000102 ***
## pres          -0.030556   0.008397  -3.639 0.000287 ***
## t_max         -0.006284   0.009997  -0.629 0.529748
## t_min          0.985146   0.011641  84.626  < 2e-16 ***
## t_max_24ch     0.011381   0.010744   1.059 0.289722
## t_min_24ch    -0.044165   0.014764  -2.991 0.002842 **
## rainfall_24hr        NA         NA      NA       NA
## rainfall_sum         NA         NA      NA       NA
## rel_hmd       -0.018981   0.002379  -7.978 3.87e-15 ***
## w_vel          0.028342   0.023369   1.213 0.225481
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.6483 on 1048 degrees of freedom
## Multiple R-squared:  0.9618, Adjusted R-squared:  0.9616
## F-statistic:  3770 on 7 and 1048 DF,  p-value: < 2.2e-16
```

5.2 Principal Components Analysis and Spectral Clustering

5.2.1 PCA

- Used for investigating the group of random variable by their variance contribution to the systems
- Maximum variance without group and Minimum variance within group

CSV Excel Search:

Date	432201	436401	564201	331201	431401	431201	564202	561201	379201	567201	380201
2017-12-31	18	18	25.2	18	18.5	19	24.2	22.3	19	26.3	20.7
2018-01-01	19.6	19.8	26	18	21	21.2	25.1	23.7	22.3	24.5	22.2
2018-01-02	20	19	26.4	20.3	20.1	21	25.5	24.3	21.6	24.6	22.7
2018-01-03	21.7	19.5	26.5	21.2	20	20.8	25	23.8	21	24.6	22.3
2018-01-04	25.5	23.1	26.2	21	23.1	23.6	26	24	23.2	23.5	23
2018-01-05	23.8	23.7	25.3	22.6	24.4	24.5	24.1	24.3	23.7	25	24

Showing 1 to 6 of 1,703 entries

Previous 1 2 3 4 5 … 284 Next

- Calculating covariance matrix
- Applying eigen decomposition to the covariance matrix

```
data_climate_new <- data_climate[,-1]
covmat <- cov(data_climate_new)
ei <- eigen(covmat)
eival <- ei$values/sum(ei$values)
eivec <- ei$vector
```

```
##  [1] 0.8244015043 0.0694380534 0.0181140937 0.0166418018 0.0097378349
##  [6] 0.0072590146 0.0057807561 0.0044928603 0.0043171192 0.0041267054
## [11] 0.0036332442 0.0032068772 0.0029939174 0.0028201636 0.0025954819
## [16] 0.0024366191 0.0020578587 0.0020099924 0.0017730448 0.0016577081
## [21] 0.0014935216 0.0014856263 0.0013665615 0.0012673934 0.0010638147
## [26] 0.0009567119 0.0009144723 0.0007835870 0.0006352187 0.0005384414
```

```
##  [1] 0.8244015 0.8938396 0.9119537 0.9285955 0.9383333 0.9455923 0.9513731
##  [8] 0.9558659 0.9601830 0.9643097 0.9679430 0.9711499 0.9741438 0.9769639
## [15] 0.9795594 0.9819960 0.9840539 0.9860639 0.9878369 0.9894947 0.9909882
## [22] 0.9924738 0.9938404 0.9951078 0.9961716 0.9971283 0.9980428 0.9988263
## [29] 0.9994616 1.0000000
```

```
##              [,1]         [,2]        [,3]         [,4]         [,5]
##  [1,] -0.21380768  0.231129038 -0.22604402 -0.140695659 -0.073376976
##  [2,] -0.22359301  0.177164259 -0.12845206 -0.144911005  0.156288876
##  [3,] -0.03030731  0.025925699  0.27179175 -0.271583120 -0.130743854
##  [4,] -0.26006545 -0.277776440 -0.06461661  0.077991098  0.003862156
##  [5,] -0.20683426  0.201056727 -0.04313931 -0.044885574  0.146428670
##  [6,] -0.20356267  0.209733084 -0.04599344 -0.035455222  0.095740581
##  [7,] -0.05878158 -0.066611837  0.22311644 -0.479924959 -0.141814466
##  [8,] -0.05716938 -0.037885418  0.15860543 -0.429003558 -0.105292019
##  [9,] -0.19974850  0.019308834  0.18713949  0.180775274 -0.045715357
## [10,] -0.03246779 -0.027474713  0.15907396 -0.236429002  0.037401980
## [11,] -0.18963808 -0.069542048  0.24183753  0.222234074 -0.095934265
## [12,] -0.16515839  0.156629114  0.06318349  0.003078230  0.304081312
## [13,] -0.24031371  0.179092791 -0.23964152 -0.068738075 -0.175167949
## [14,] -0.05512121 -0.038210378  0.21040003 -0.283800849  0.049745361
## [15,] -0.23690225  0.098095449 -0.24713876 -0.008513020 -0.288158222
## [16,] -0.21621379 -0.342168138 -0.06672857 -0.055093378  0.074301684
## [17,] -0.25609745 -0.216363447  0.08405775  0.151880024 -0.159427274
## [18,] -0.19948261 -0.007643339  0.11233013  0.175342685 -0.004617596
## [19,] -0.22200717  0.215074883 -0.27127736 -0.178824138 -0.216600421
## [20,] -0.19315788  0.192841165 -0.03247311  0.044133657 -0.017651247
## [21,] -0.18303579  0.132066091  0.26450892  0.198032816 -0.120174439
## [22,] -0.24293175 -0.385659602 -0.08446620 -0.047733320  0.082049897
```

5.2.2 Spectral Clustering

- Group of similarity
- Cutting eigenvectors of first d columns
- Applying K-mean for clustering the cut matrix

```
cut_loading <- eivec[,1:3] %>% `rownames<-`(colnames(data_climate_new))
km.res <- kmeans(cut_loading, 3, nstart = 25)
km.res$cluster
```

```
## 432201 436401 564201 331201 431401 431201 564202 561201 379201 567201 380201
##      3      3      1      2      3      3      1      1      1      1      1
## 440401 387401 532201 352201 327501 330201 379401 407501 403201 400201 329201
##      1      3      1      3      2      2      1      3      3      1      2
## 376201 568501 303201 517201 500202 426201 430401 430201
##      1      1      2      1      1      1      1      1
```