# Masterclass Analyzing risk in agriculture

*An overview of defining, measuring, and characterizing farm-level risk exposure*

March 20, 2024; AES Conference, Edinburgh, Scotland

Yann de Mey

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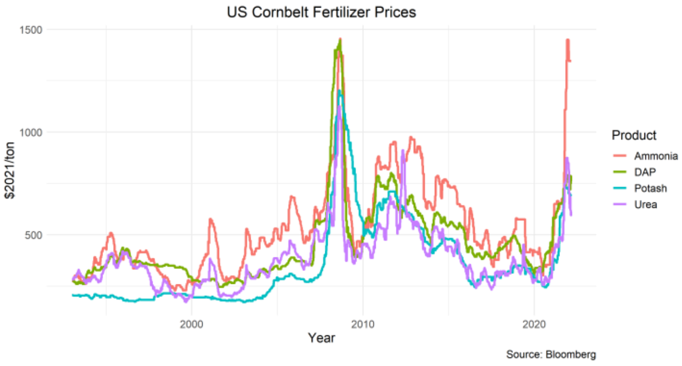
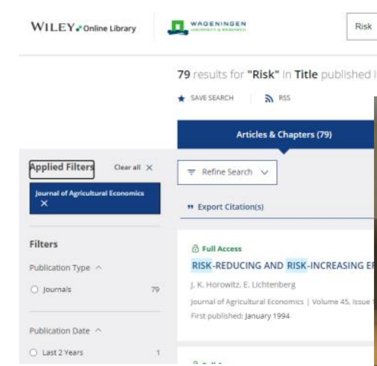
# Motivation



Source: Bloomberg



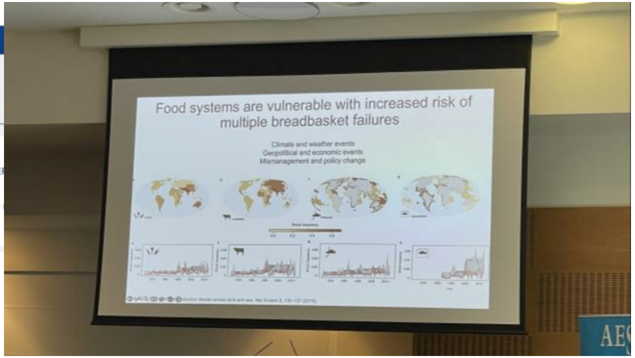
79 results for "Risk" in Title published in "Journal of Agricultural Economics"

RISK-REDUCING AND RISK-INCREASING EF

J. K. Horowitz, E. Lichtenberg

Journal of Agricultural Economics | Volume 45, Issue

First published: January 1994



Food systems are vulnerable with increased risk of multiple breadbasket failures

Climate and weather events
Geopolitical and economic events
Mismanagement and policy change

# Masterclass Overview

*An overview of defining, measuring, and characterizing farm-level risk exposure*

1. Defining Risk
2. Objective vs. Subjective Risk
3. Measuring Risk
4. Characterizing Farm-Level Risk Exposure

*Focus on presenting an overview, intuition (with many references)*

# 1. Defining Risk

“Risk is like love, we all know what it is, but we don’t know how to define it”

*Joseph Stiglitz*

# Definitions of Risk / Concepts

- Two main dimensions:
  - Probability (likelihood/chance/...)
  - Impact (outcomes/return/...)
- Most famous distinction made by Knight (1921) focusing on measurability

**Risk** **Uncertainty**

- However, this definition narrow and at odds with daily language
- More recently, we use knowledge about both dimensions for further classification

Knight, F. H. (1921). Risk, Uncertainty, and Profit. Boston: Hart, Schaffner & Marx.

# Definitions of Risk / Concepts

Knowledge about **Impact**

Knowledge about **Probabilities**

| | Not problematic | Problematic |
|---|---|---|
| Some basis | **RISK**<br>*Familiar systems*<br>*Controlled situations*<br>*Knowledge based* | **AMBIGUITY**<br>*Contested features*<br>*Disagreement*<br>*Insufficient knowledge* |
| No basis | **UNCERTAINTY**<br>*Complex systems*<br>*Open situations*<br>*Insufficient knowledge* | **IGNORANCE**<br>*Unexpected conditions*<br>*Surprises*<br>*Unknowns* |

# Definitions of Risk / Concepts

*1975 to 1977 United States Secretary of Defense Donald Rumsfeld*

| | Knowns | Unknowns |
|---|---|---|
| Known | Things we are aware of and understand | Things we are aware of but don't understand |
| Unknown | Things we understand but are not aware of |  |

Manning, L., Birchmore, I., & Morris, W. (2020). Swans and elephants: A typology to capture the challenges of food supply chain risk assessment. *Trends in Food Science & Technology*, *106*, 288-297.

# Definitions of Risk / Concepts

- Note that Risk should not be defined as expected consequences:

EV = Probability x Impact

- This is a risk metric (see part 3), not risk per se
- In fact, this is a risk metric that is informative in some cases but in most cases not. For example, different P and I combinations lead to same value:

$$1/4 \times 2 = 0.5 \quad \text{and} \quad 3/4 \times 2/3 = 0.5$$

- According to risk science, risk is defined as a triplet (Kaplan & Garrick, 1981):

< Scenario + Probability + Impact >

Kaplan, S., & Garrick, B. J. (1981). On the quantitative definition of risk. *Risk analysis*, *1*(1), 11-27.

# Formal Definitions of Risk

- *The possibility of something bad happening at some time in the future; a situation that could be dangerous or have a bad result*
- Hardaker et al. (2015): *Uncertainty that matters*
- Society for Risk Analysis (2020):
  - A future activity
  - In relation to the consequences and some reference values
  - Related to something that humans value
  - Focus is often on negative, undesirable consequences (always at least one outcome considered negative or undesirable)

Hardaker, J. B., Lien, G., Anderson, J. R., & Huirne, R. B. (2015). Coping with risk in agriculture: Applied decision analysis. Cabi.

# Formal Definitions of Risk

**Society for Risk Analysis Glossary**

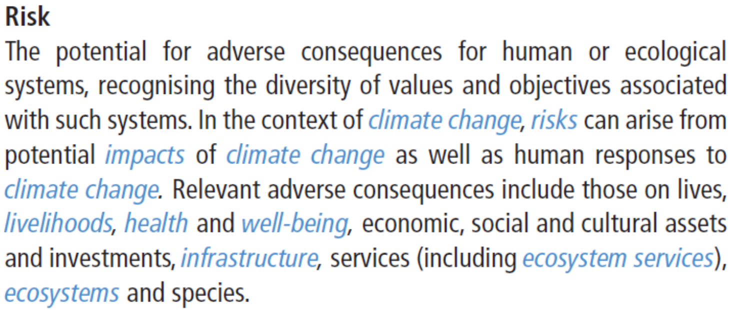
SRA

1. Risk is the possibility of an unfortunate occurrence
2. Risk is the potential for realization of unwanted, negative consequences of an event
3. Risk is exposure to a proposition (e.g., the occurrence of a loss) of which one is uncertain
4. Risk is the consequences of the activity and associated uncertainties
5. Risk is uncertainty about and severity of the consequences of an activity with respect to something that humans value
6. Risk is the occurrences of some specified consequences of the activity and associated uncertainties
7. Risk is the deviation from a reference value and associated uncertainties

Society for Risk Analysis Glossary: https://www.sra.org/wp-content/uploads/2020/04/SRA-Glossary-FINAL.pdf

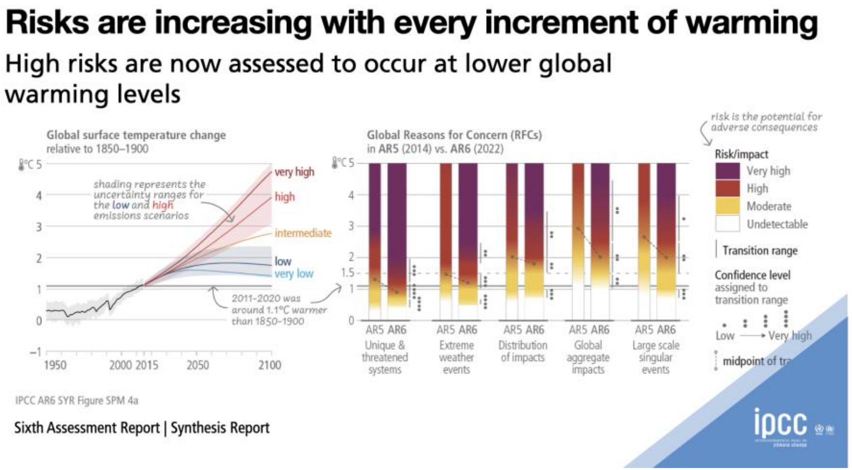
# Formal Definitions of Risk

- Even though various definitions exist, they agree/converge on:
  - Covering < Scenario + Probability + Impact >
  - Being distinct from risk measurement (which warrants diverse approaches)
- Our level of confidence is also a highly relevant aspect



**Risk**

The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of *climate change*, *risks* can arise from potential *impacts* of *climate change* as well as human responses to *climate change*. Relevant adverse consequences include those on lives, *livelihoods*, *health* and *well-being*, economic, social and cultural assets and investments, *infrastructure*, services (including *ecosystem services*), *ecosystems* and species.



**Risks are increasing with every increment of warming**

High risks are now assessed to occur at lower global warming levels

IPCC AR6 SYR Figure SPM 4a

Sixth Assessment Report | Synthesis Report

IPCC, 2023: *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.

# Intermezzo: Can we compare all risks?

Tweet by Kim Kardashian that earned "International Statistic of the Year" 2017

**Kim Kardashian West**
@KimKardashian

Statistics

Number of Americans killed annually by:

| | |
|---|---|
| Islamic jihadist immigrants[1]: | 2 |
| Far right-wing terrorists[1]: | 5 |
| All Islamic jihadist terrorists (including US citizens)[1]: | 9 |
| Armed toddlers[2]: | 21 |
| Lightning[3]: | 31 |
| Lawnmowers[4]: | 69 |
| Being hit by a bus[4]: | 264 |
| Falling out of bed[4]: | 737 |
| Being shot by another American[5]: | 11,737 |

[1] 10-year average of terrorist attacks "Deadly Attacks Since 9/11," New America, http://securitydata.newamerica.net/extremists/deadly-attacks.html

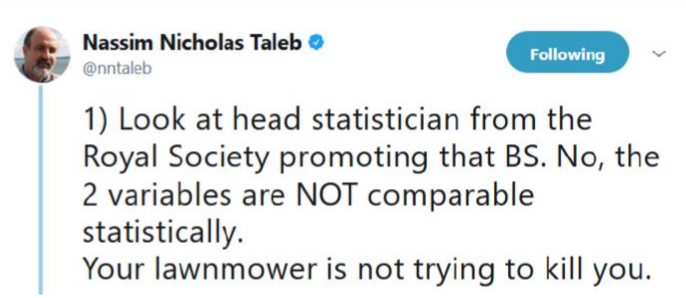
[2] www.snopes.com/toddlers-killed-americans-terrorists/

[3] 10-year average of deaths by lightning, NOAA, www.nws.noaa.gov/om/hazstats/resources/weather_fatalities.pdf

[4] 10-year average, Underlying Cause of Death 2014, CDC, http://wonder.cdc.gov/

[5] 10-year average 2005-2014, CDC, Injury Prevention & Control: Data & Statistics (WISQARS™) www.cdc.gov/injury/wisqars/fatal_injury_reports.html

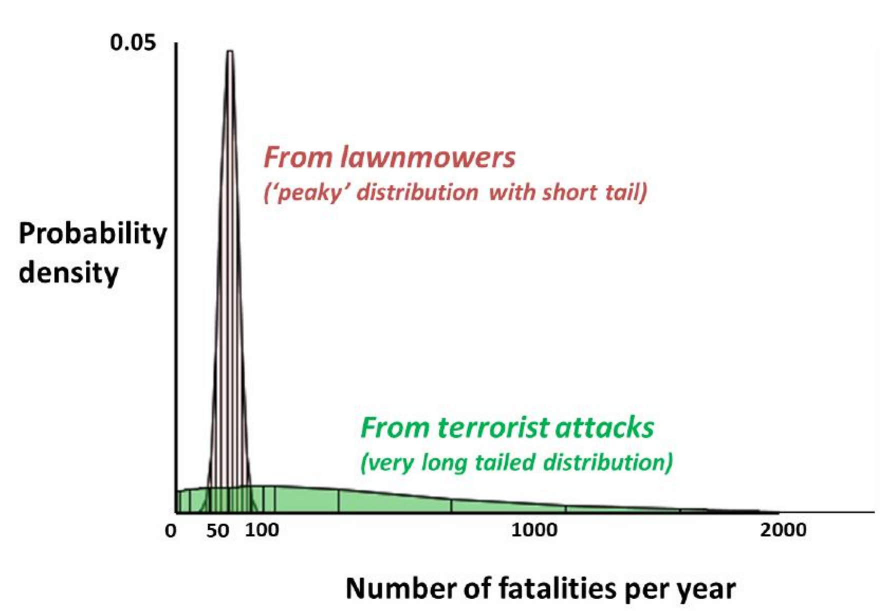
Tweet in response by disruptive thinker Nassim Taleb

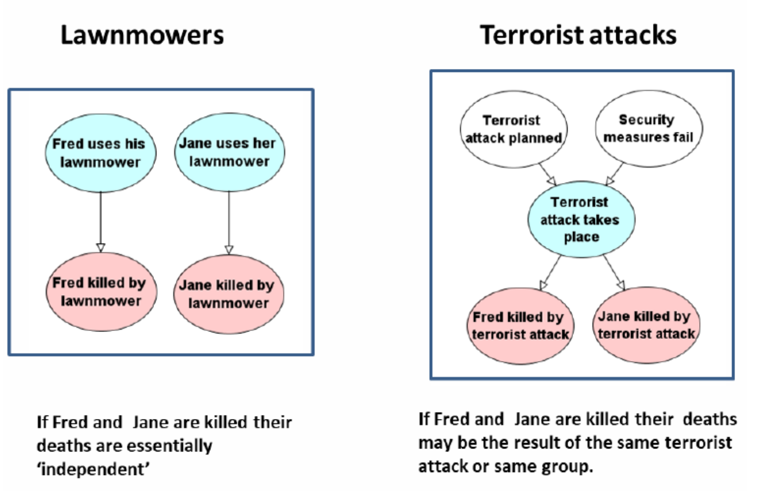


**Nassim Nicholas Taleb**
@nntaleb

1) Look at head statistician from the Royal Society promoting that BS. No, the 2 variables are NOT comparable statistically.
Your lawnmower is not trying to kill you.

# Intermezzo: Can we compare all risks?





If Fred and Jane are killed their deaths are essentially 'independent'

If Fred and Jane are killed their deaths may be the result of the same terrorist attack or same group.

Idiosyncratic risk vs correlated/systemic risk

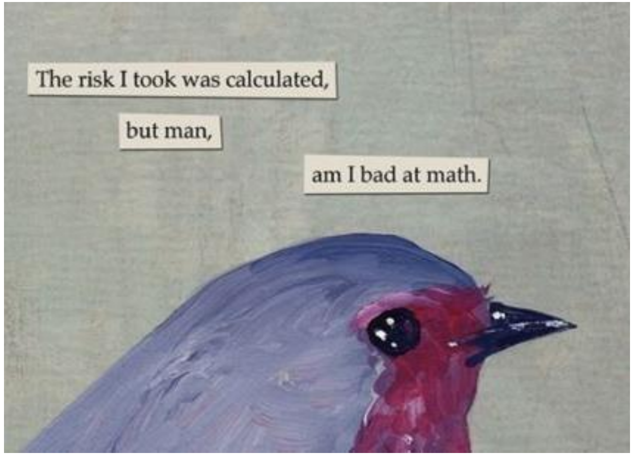
# Various Aspects of Risk Matter

- **Systematic**? Due to external forces or with repercussions at scale (e.g. earthquakes)
- **Systemic**? Leading to collapse of an entire system, with an important role for interlinkages (e.g. financial crises)
- **Catastrophic**? Unanticipated, crippling organizations and often leading to ruin (e.g. terrorist attack)
- **Idiosyncratic** (impacting a single entity, e.g. landslide) vs **covariate** (correlated between various entities, e.g. hailstorm)
- **Single shock** versus **repeated stressor** (time dimension)
- **Upside risk** (potential) versus **downside risk** (focus on negative)

*A lot of these concepts overlap or are used interchanged*
*Make sure to characterize your risk of interest well*

# 2. Objective vs. Subjective Risk

# Objective vs. Subjective Risk



**Objective Risk** (real risk)

vs.

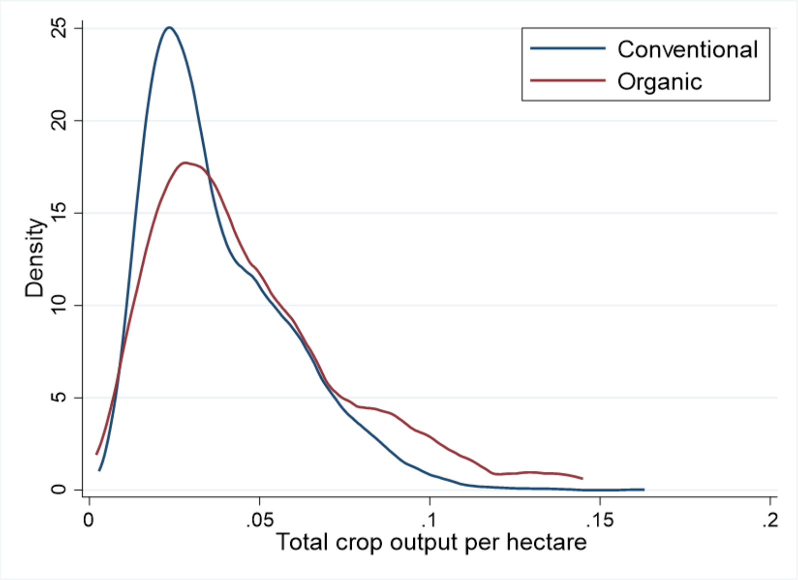
**Subjective Risk** (risk as-feelings)
(Loewenstein et al., 2001)

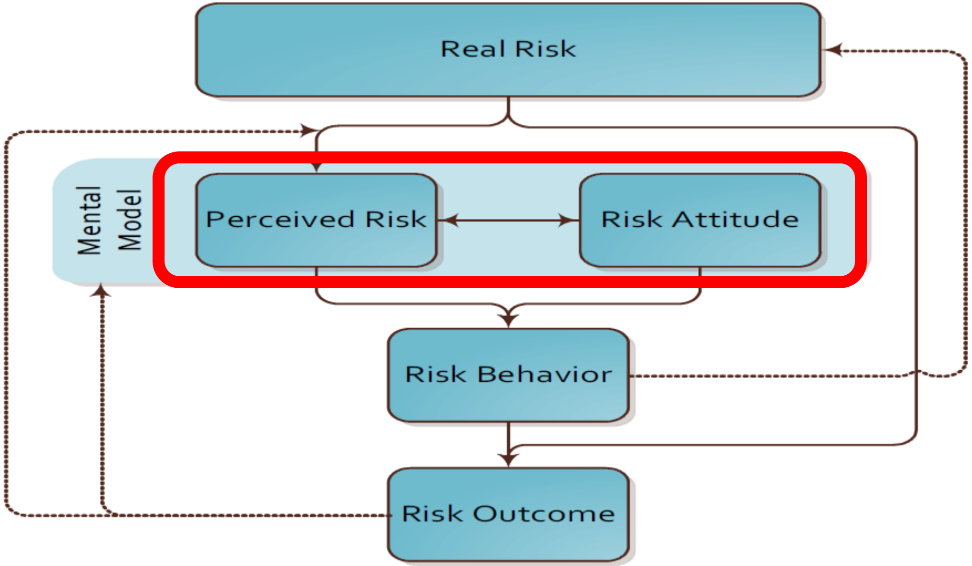
- Risk is always subjective, depends on your definitions
- We often treat risk as being objective, we have to, but be aware this introduces model risk
- Risk is inherently human, probability (theory) its language

Loewenstein, George F., Elke U. Weber, Christopher K. Hsee, and Ned Welch. "Risk as feelings." Psychological bulletin 127, no. 2 (2001): 267.

# Objective vs. Subjective Risk

## Risk Characterization vs. Decision Making Under Risk

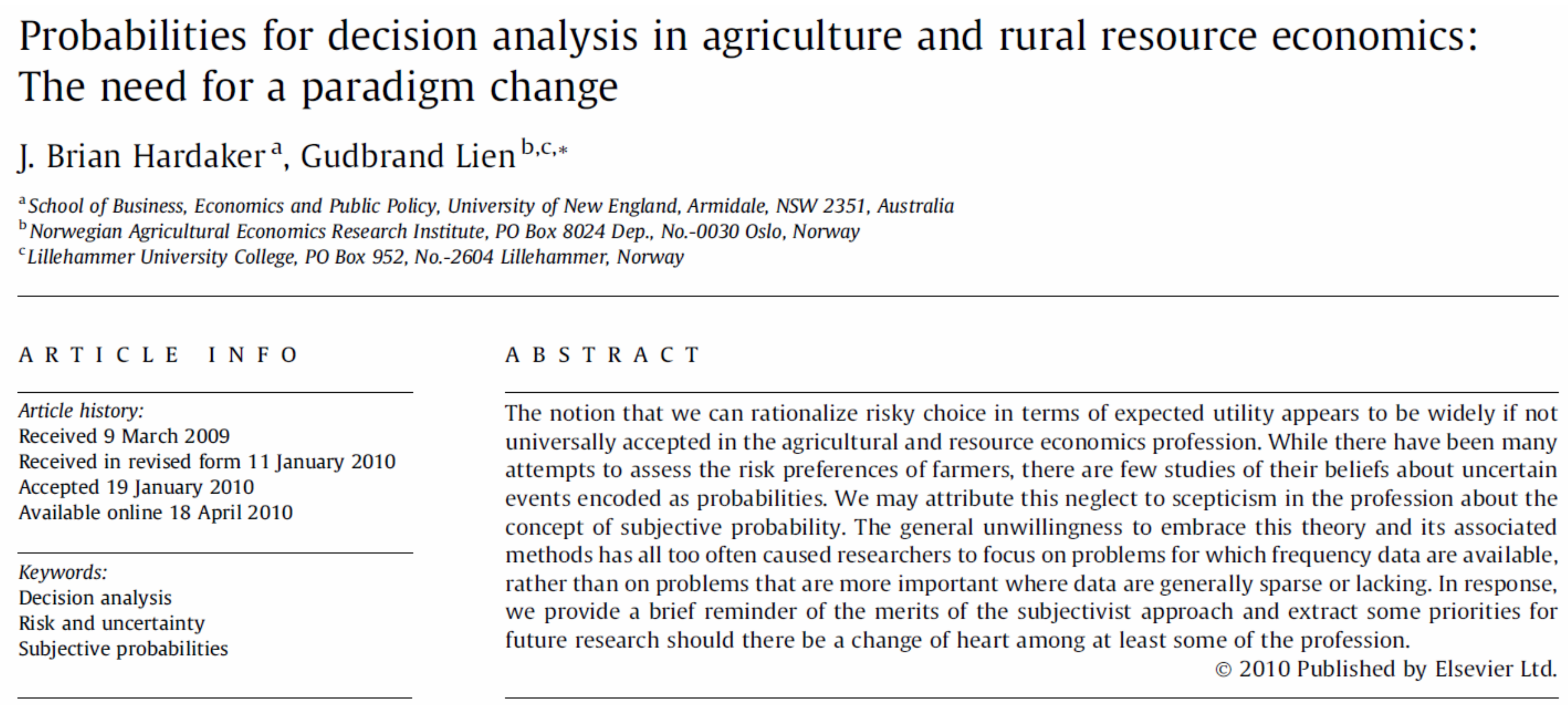




## Ex-Post / Understanding vs. Ex-ante / Prediction

van Winsen, F., de Mey, Y., Lauwers, L., Van Passel, S., Vancauteren, M., & Wauters, E. (2016). Determinants of risk behaviour: effects of perceived risks and risk attitude on farmer's adoption of risk management strategies. *Journal of Risk Research*, *19*(1), 56-78.

# Objective vs. Subjective Risk



## Probabilities for decision analysis in agriculture and rural resource economics: The need for a paradigm change

J. Brian Hardaker[a], Gudbrand Lien[b,c,*]

[a] *School of Business, Economics and Public Policy, University of New England, Armidale, NSW 2351, Australia*
[b] *Norwegian Agricultural Economics Research Institute, PO Box 8024 Dep., No.-0030 Oslo, Norway*
[c] *Lillehammer University College, PO Box 952, No.-2604 Lillehammer, Norway*

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ABSTRACT

The notion that we can rationalize risky choice in terms of expected utility appears to be widely if not universally accepted in the agricultural and resource economics profession. While there have been many attempts to assess the risk preferences of farmers, there are few studies of their beliefs about uncertain events encoded as probabilities. We may attribute this neglect to scepticism in the profession about the concept of subjective probability. The general unwillingness to embrace this theory and its associated methods has all too often caused researchers to focus on problems for which frequency data are available, rather than on problems that are more important where data are generally sparse or lacking. In response, we provide a brief reminder of the merits of the subjectivist approach and extract some priorities for future research should there be a change of heart among at least some of the profession.

Hardaker, J. B., & Lien, G. (2010). Probabilities for decision analysis in agriculture and rural resource economics: The need for a paradigm change. *Agricultural systems*, *103*(6), 345-350.

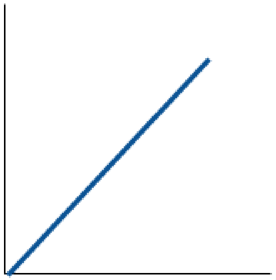
# Objective vs. Subjective Risk

- In essence: both perspectives matter depending on the application
- When modelling or approaching from “rational” or data-driven perspective we treat it as objective
- When used for decision making it always involves some level of subjectivity (see also Cerroni and Rippo, 2023)
- Note that at the core of the leading theories used to model economic decision making, assumptions are made regarding risk (perception) and risk preferences

Cerroni, S. and Rippo ,R. (2023) Subjective Probabilities and Farmers’ Decision-Making in Developing Countries, CABI, doi:10.1079/9781800622289.0003, (35–49).

# Objective vs. Subjective Risk

Expected Value

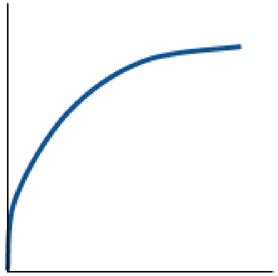


Outcome x

$EV = px$

Risk neutrality

Neoclassical Economics

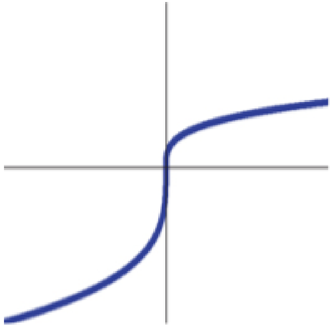


Utility u(x)

$EU = pu(x)$

Risk Aversion
Risk Neutrality
Risk Loving/Seeking

Prospect Theory

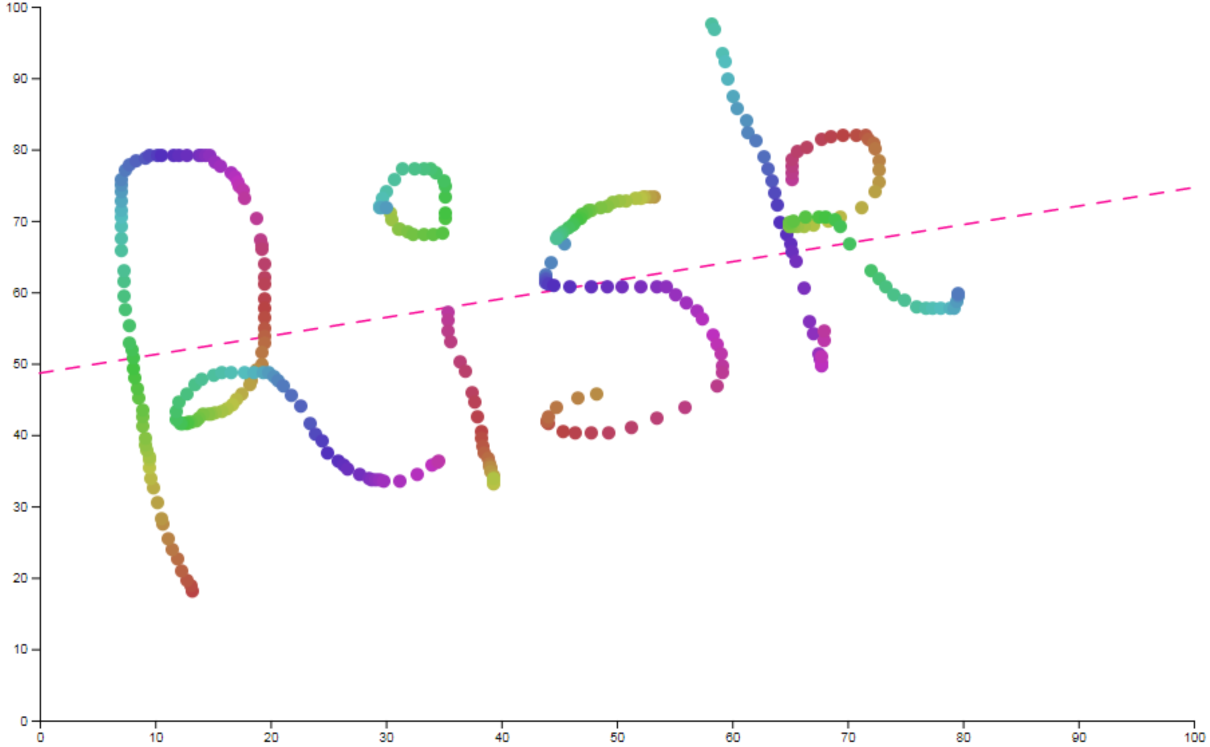


Value v(x)

$EP = pv(x)$

Risk Aversion
Loss Aversion
Probability Weighting

# 3. Measuring Risk



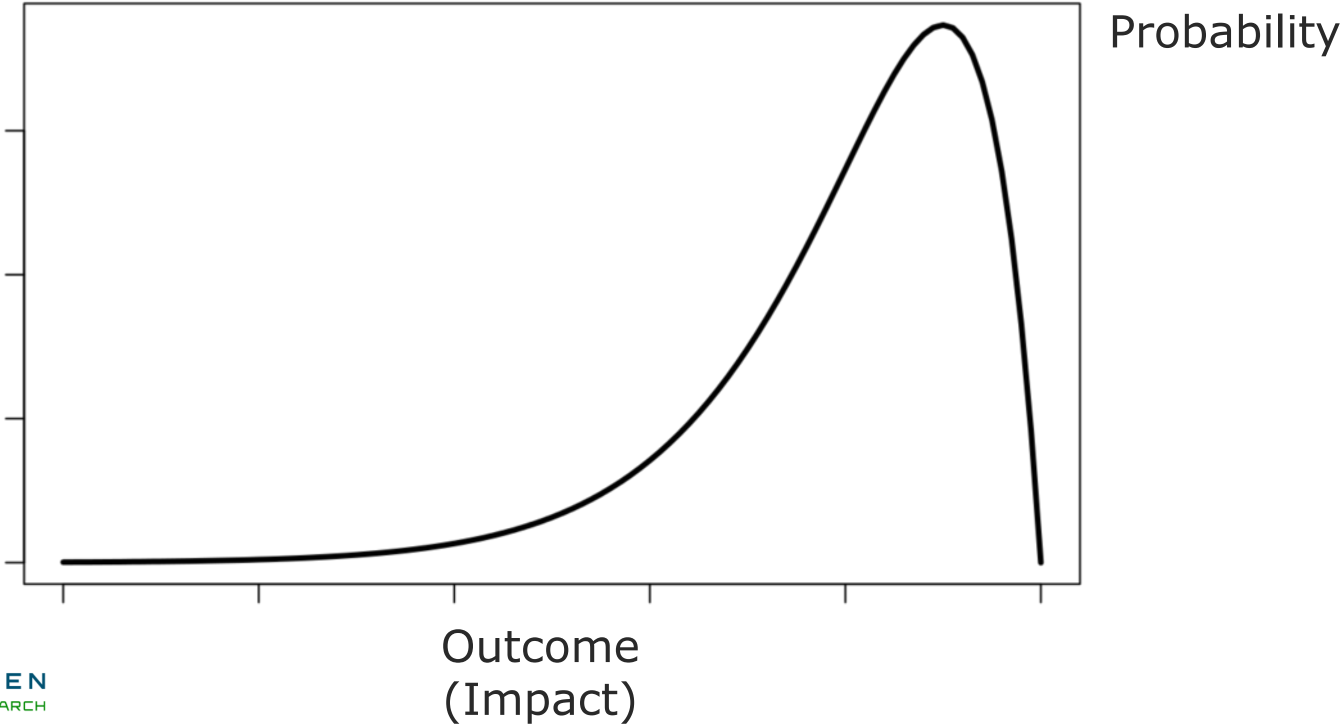
# From Risk Definition to Risk Measures

- Hardaker (2000) identifies 3 major views on risk that help classify different measures of risk:
  - I. Uncertainty of outcomes
  - II. Variability of outcomes
  - III. Chance of bad outcomes
- Although seemingly similar, these three views imply quite different ways of measuring risk
- When formally defined, they can be seen to be mutually inconsistent...

Hardaker, J.B. (2000) Some Issues in Dealing with Risk in Agriculture. Working Paper Series in Agricultural and Resource Economics No. 2000-3.

# From Risk Definition to Risk Measures

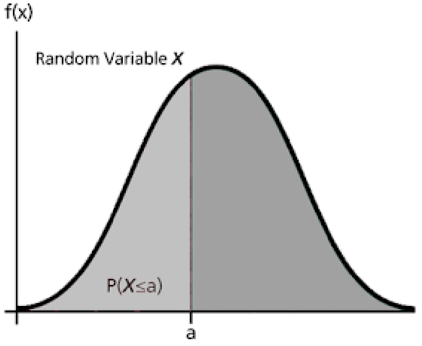
A starting/reference point is thinking in terms of distributions



# I. Uncertainty of Outcomes

- Probability density function (PDF)

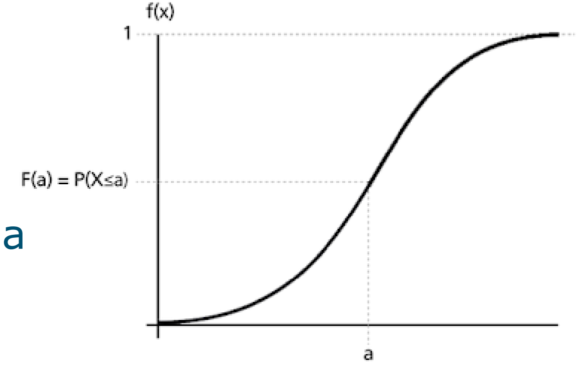
Probability that random variable *X* will take a value equal to a



*Can be evaluated/integrated over range:*

- Cumulative density function (CDF)

Probability that X will take a value less than or equal to a

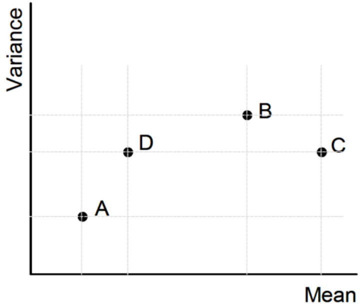


# II. Variability of Outcomes

- Ranges
    - Range of possible values: [Min – Max]
    - Percentiles of values: P01, P05 <> P99, P90
- Variability measures
    - Mean, Variance, SD

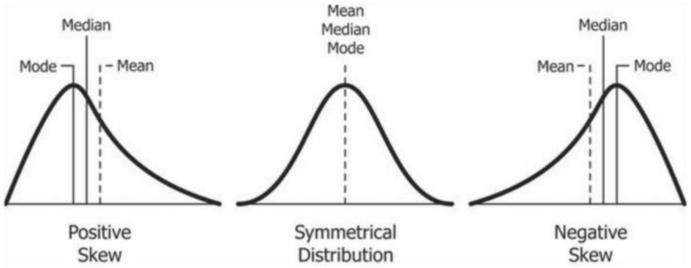
$$\bar{x} = \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right) \quad \mathrm{Var}(X) = \frac{1}{n}\sum_{i=1}^{n}(x_i - \mu)^2 \quad \sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

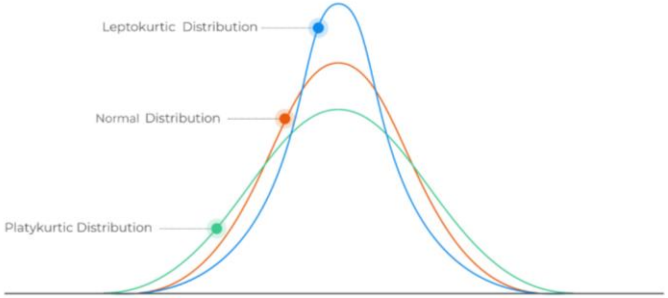
    - Coefficient of Variation (CV) = SD/Mean
    - Often used to depict volatility, symmetric measures



# II. Variability of Outcomes

- Skewness and Kurtosis (higher moments of distribution)



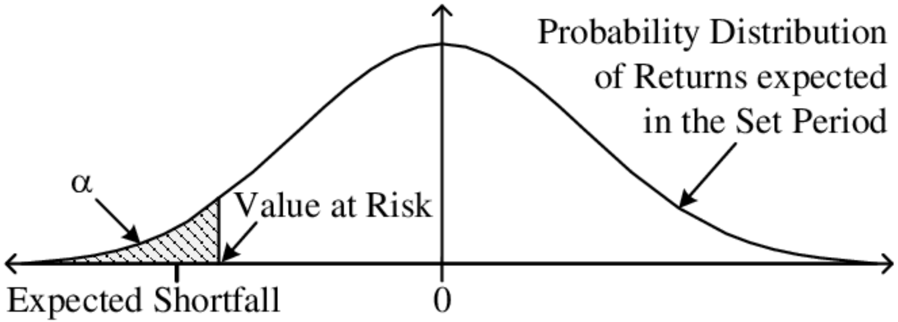


- Partial moments: Semi-variance, Semi-standard deviation (Downside risk)

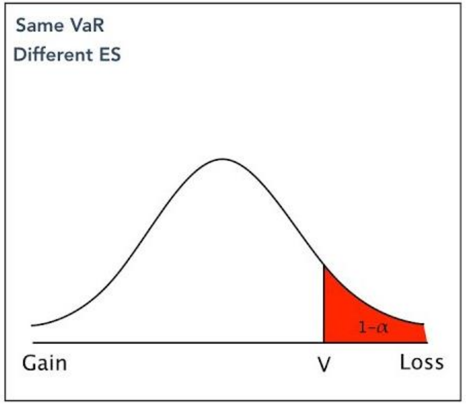
$$SV_{lower}(X) = \frac{1}{n-1}\sum[\,(X-\bar{X})^2 \cdot IF(X \leq \bar{X})\,]$$

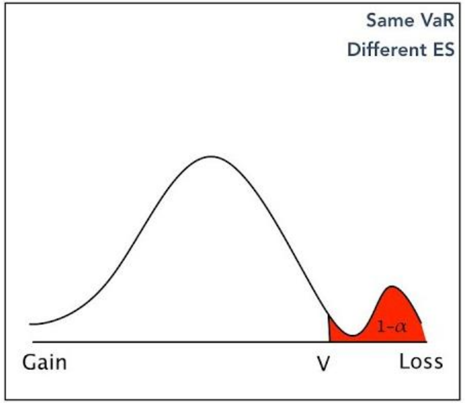
# III. Chance of Bad Outcomes

- $P(X < X^*)$ with X* = minimally acceptable outcome (0?)
- Value At Risk: $\text{VaR}_{\alpha\%}$ (threshold loss value)
- Expected Tail Loss (ETL) or Expected Shortfall (ES)



- Specify α% (threshold loss value) and reference period

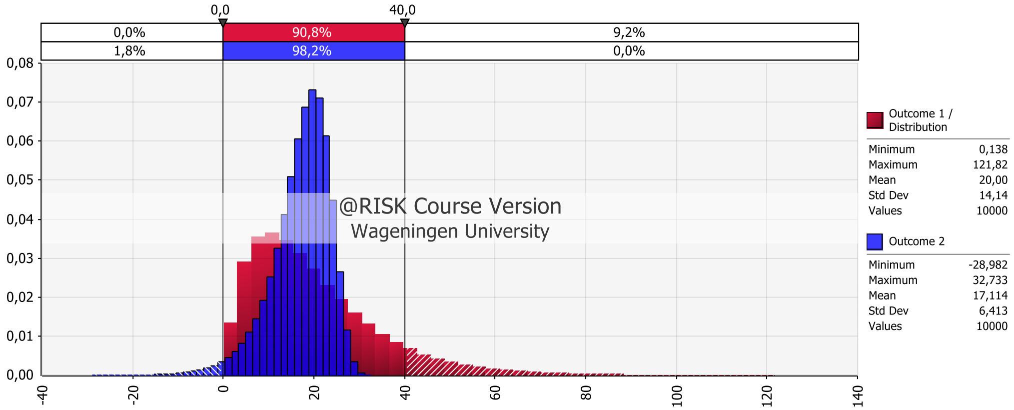


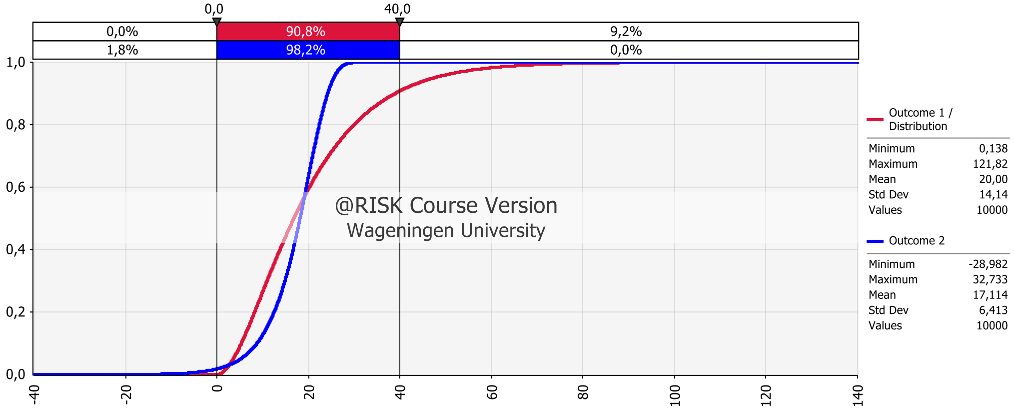


# How to Select a Risk Measure?

Which distribution is more risky?

Assume this is a positive outcome you care about (e.g. income)





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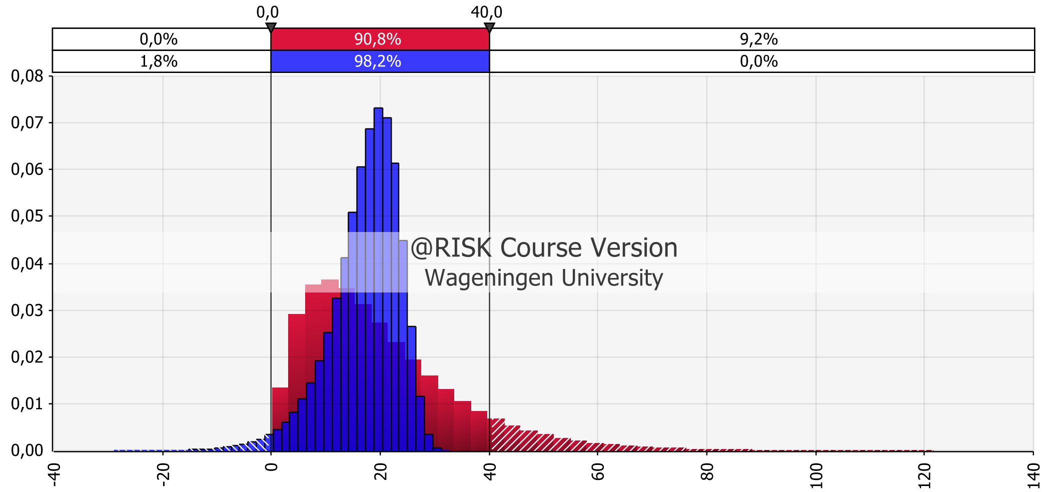
# How to Select a Risk Measure?

| | Min | Max | Mean | SD | CV | Skewness | Kurtosis | P<0 | P<10 | VaR$_{5\%}$ | ETL$_{5\%}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **RED** | 0.14 | 121.82 | 20.00 | 14.14 | 70.69% | 1.407 | 5.908 | 0.00% | 26.43% | 3.55 | 20.00 |
| **BLUE** | -28.98 | 32.73 | 17.11 | 6.41 | 37.47% | -1.137 | 5.363 | 1.82% | 12.66% | 5.14 | 17.11 |



# How to Select a Risk Measure?

- *"Aiming for consensus on the definition of risk based on risk metrics is not meaningful"* (Aven, 2023)
- Depending on your view on risk (always define it!)
- In line with your theory, for example
    - Portfolio analysis using mean-variance approach
    - Goal: company minimizing probability of making a loss
- Depending on its properties
    - Symmetric measure? (volatility matters)
    - Downside risk or not?
- Consider a combination of measures
- General risk measures, axiomatic view, convex/coherent risk measures

Aven, T. (2023). Is the definition of risk still contested?. *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability*, *237*(1), 3-3.

# Coherent Risk Measures

- Theory from financial economics/ mathematical finance
- Introduced by Artzner et al. (1999) *good luck reading that*
- Set of properties that matter for risk measures:
  - Normalization (The risk of nothing is zero)
  - Monotonicity (a security that always has higher return in all future states has less risk of loss)
  - Sub-additivity (diversification is risk reducing)
  - Positive homogeneity (if a portfolio doubles, the risk will also be doubled)
  - Translation invariance (if an amount is added to a portfolio, then the risk is reduced by that amount)
  - *(more have been developed)*

Artzner, Philippe, Freddy Delbaen, Jean-Marc Eber, and David Heath. "Coherent measures of risk." Mathematical finance 9, no. 3 (1999): 203-228.

# Coherent Risk Measures

- No single risk measure meets all of these properties!
- A risk measure captures only some of the characteristics of risk, every risk measure is incomplete.
- Any sensible risk measure needs to obey at least normalization, monotonicity and translation invariance
- Coherent risk measures also in addition meet sub-additivity, and positive homogeneity
- This underscores the importance of using diverse risk measures
- For examples
    - Variance is not coherent (not sub-additive), SD is

      $\mathrm{var}(X+Y) = \mathrm{var}(X) + \mathrm{var}(Y) + 2\rho(X,Y)\mathrm{sd}(X)\mathrm{sd}(Y)$ $\qquad$ $\mathrm{sd}(X+Y) \leq \mathrm{sd}(X) + \mathrm{sd}(Y)$
    - VaR is not a coherent (not sub-additive), ES is

# 4. Characterizing Farm-Level Risk Exposure

# How to approach this?

**Subjective vs Objective**

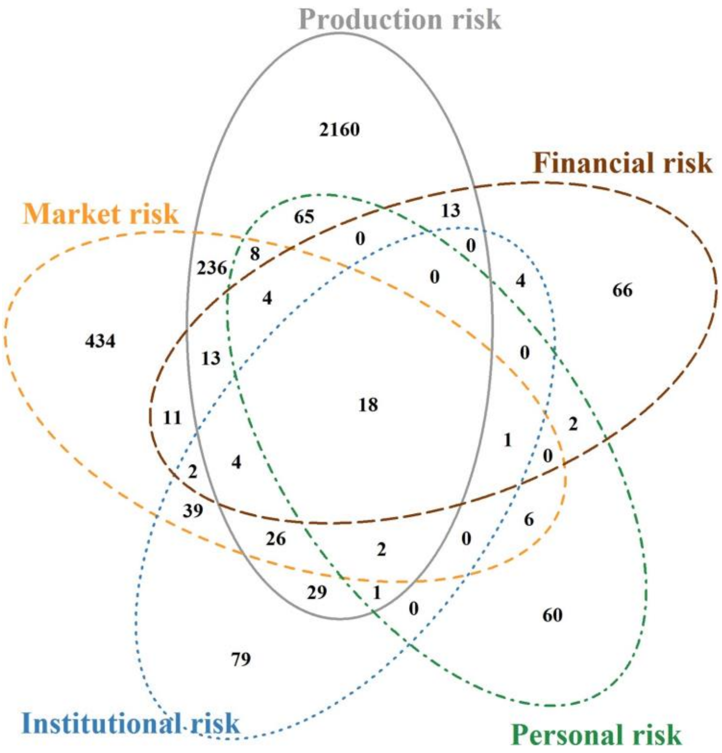
**Data availability/source**

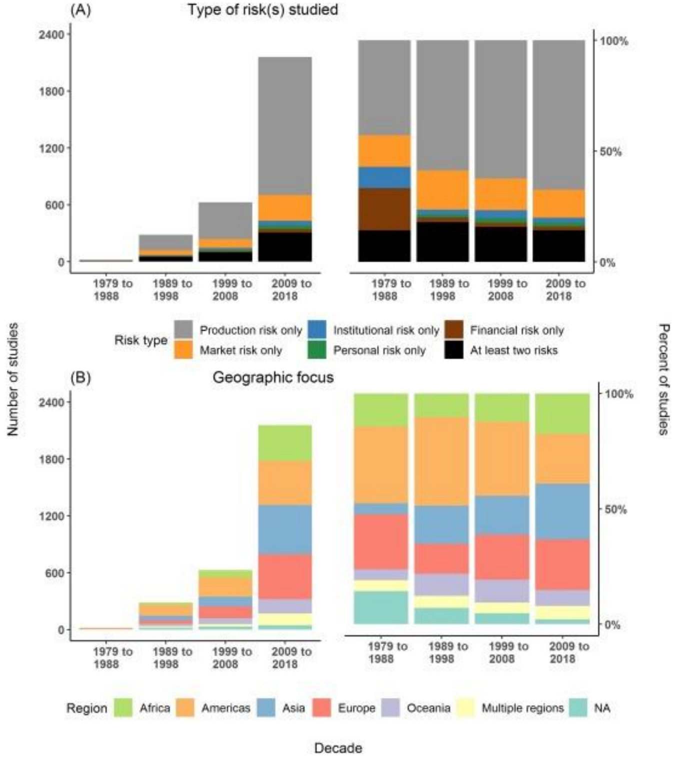
- Primary (survey) data vs. secondary data
- Sparse data <> abundant data <> too much data?

**Types of risk**

- Market, Production, Financial, Institutional and Personal (+more!)

# Different Types of Risk





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Komarek, A. M., De Pinto, A., & Smith, V. H. (2020). A review of types of risks in agriculture: What we know and what we need to know. *Agricultural Systems*, *178*, 102738.

# 3 Main Approaches

**I. Direct Elicitation**

**II. Simulation**

**III. Data-driven / Econometrics**

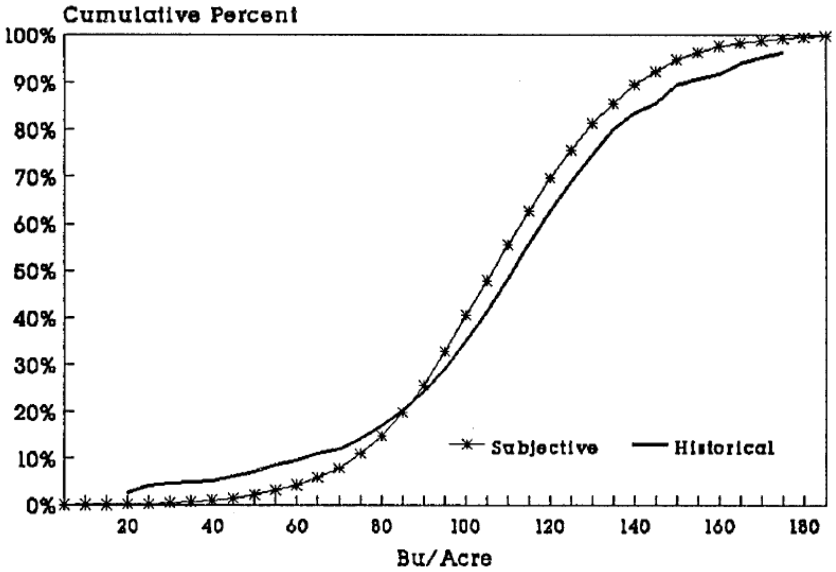
Subjective

Objective

Data availability

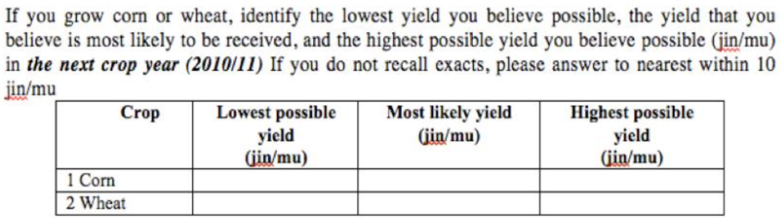
# I. Direct Elicitation

## Elicit with decision maker full CDF



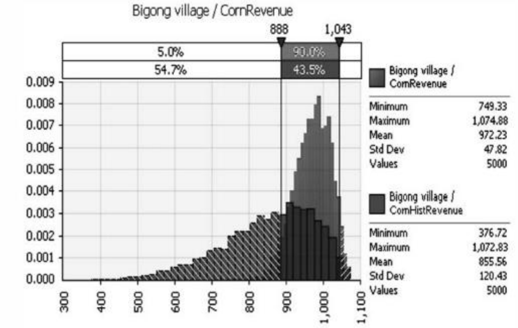
Pease, J. W. (1992). A comparison of subjective and historical crop yield probability distributions. Journal of Agricultural and Applied Economics, 24(2), 23-32.

## … Or parts of it to construct it



If you grow corn or wheat, identify the lowest yield you believe possible, the yield that you believe is most likely to be received, and the highest possible yield you believe possible (jin/mu) in *the next crop year (2010/11)* If you do not recall exacts, please answer to nearest within 10 jin/mu

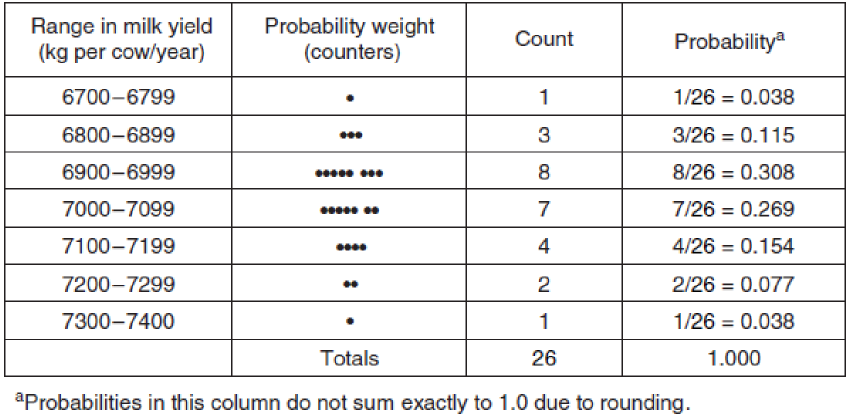
| **Crop** | **Lowest possible yield (jin/mu)** | **Most likely yield (jin/mu)** | **Highest possible yield (jin/mu)** |
|---|---|---|---|
| 1 Corn | | | |
| 2 Wheat | | | |



Turvey, C. G., Gao, X., Nie, R., Wang, L., & Kong, R. (2013). Subjective risks, objective risks and the crop insurance problem in rural China. The Geneva Papers on Risk and Insurance-Issues and Practice, 38(3), 612-633.

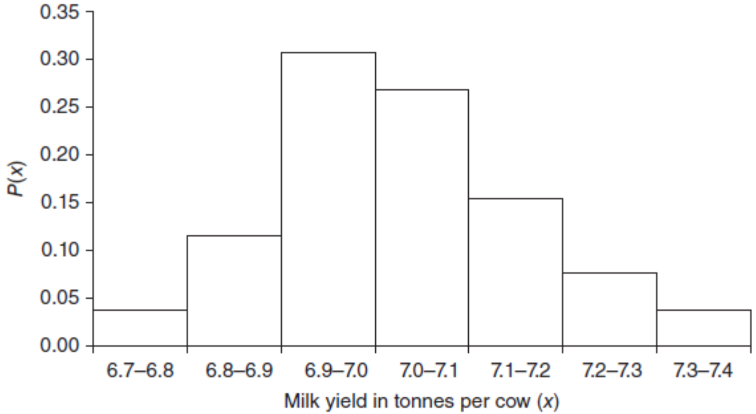
# I. Direct Elicitation

## Visual impact method (Hardaker et al. 2015)



| Range in milk yield (kg per cow/year) | Probability weight (counters) | Count | Probability[a] |
|---|---|---|---|
| 6700–6799 | • | 1 | 1/26 = 0.038 |
| 6800–6899 | ••• | 3 | 3/26 = 0.115 |
| 6900–6999 | ••••• ••• | 8 | 8/26 = 0.308 |
| 7000–7099 | ••••• •• | 7 | 7/26 = 0.269 |
| 7100–7199 | •••• | 4 | 4/26 = 0.154 |
| 7200–7299 | •• | 2 | 2/26 = 0.077 |
| 7300–7400 | • | 1 | 1/26 = 0.038 |
| | Totals | 26 | 1.000 |

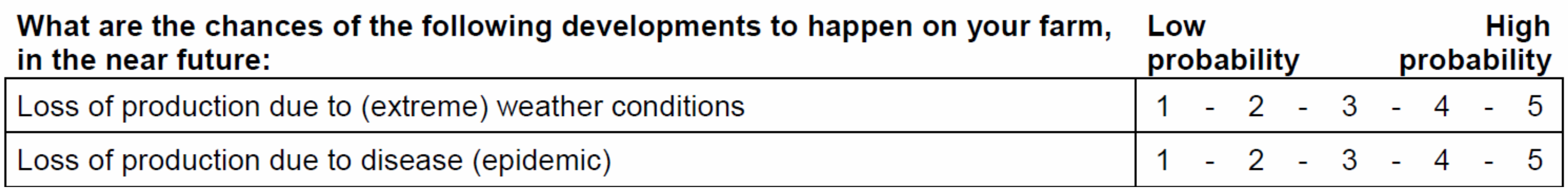
[a] Probabilities in this column do not sum exactly to 1.0 due to rounding.



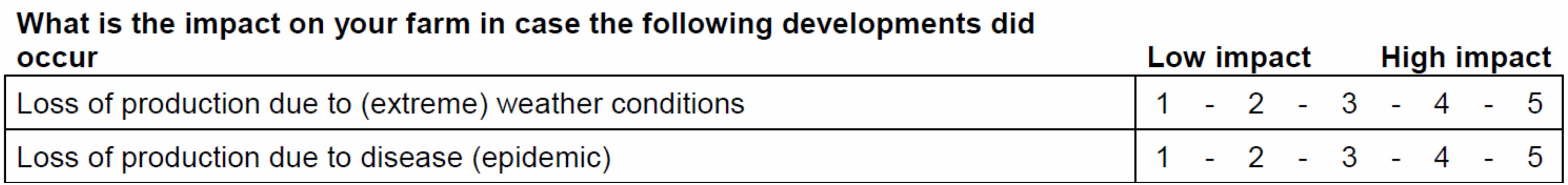
Hardaker, J. B., Lien, G., Anderson, J. R., & Huirne, R. B. (2015). Coping with risk in agriculture: Applied decision analysis. CABI

# I. Direct Elicitation

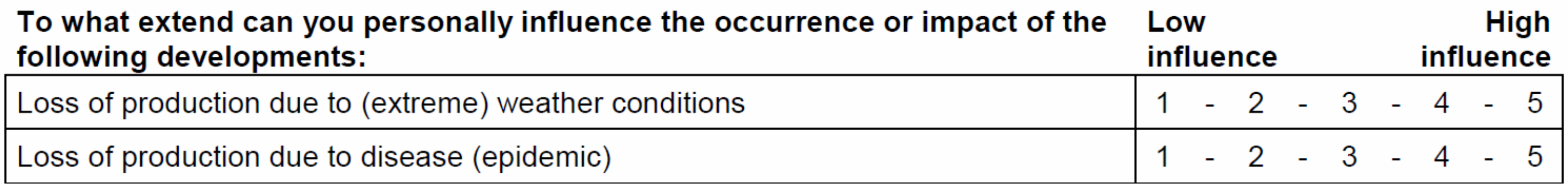
## Using Likert scales



| **What are the chances of the following developments to happen on your farm, in the near future:** | **Low probability** | | | | | | | | **High probability** |
|---|---|---|---|---|---|---|---|---|---|
| Loss of production due to (extreme) weather conditions | 1 | - | 2 | - | 3 | - | 4 | - | 5 |
| Loss of production due to disease (epidemic) | 1 | - | 2 | - | 3 | - | 4 | - | 5 |



| **What is the impact on your farm in case the following developments did occur** | **Low impact** | | | | | | | | **High impact** |
|---|---|---|---|---|---|---|---|---|---|
| Loss of production due to (extreme) weather conditions | 1 | - | 2 | - | 3 | - | 4 | - | 5 |
| Loss of production due to disease (epidemic) | 1 | - | 2 | - | 3 | - | 4 | - | 5 |

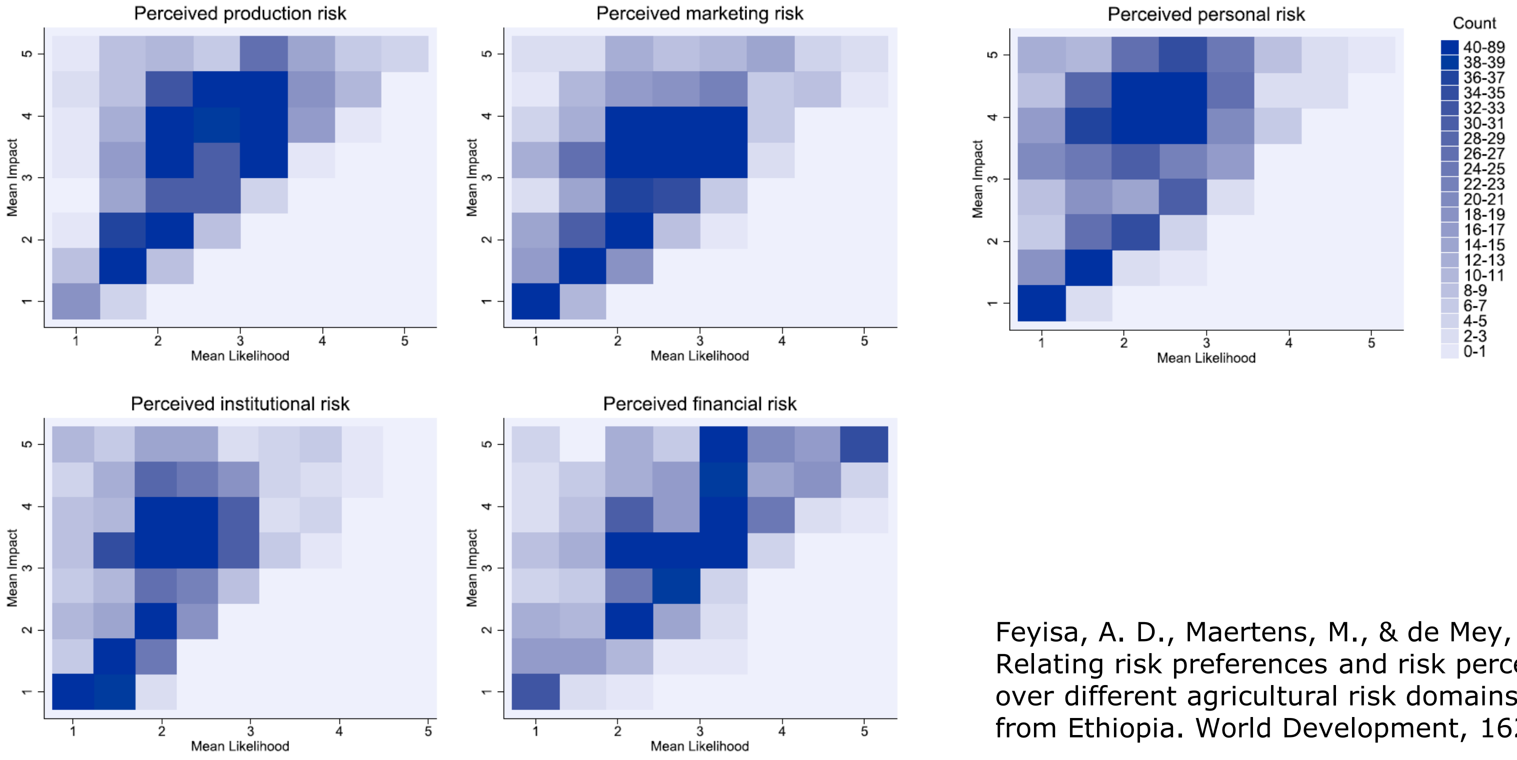


| **To what extend can you personally influence the occurrence or impact of the following developments:** | **Low influence** | | | | | | | | **High influence** |
|---|---|---|---|---|---|---|---|---|---|
| Loss of production due to (extreme) weather conditions | 1 | - | 2 | - | 3 | - | 4 | - | 5 |
| Loss of production due to disease (epidemic) | 1 | - | 2 | - | 3 | - | 4 | - | 5 |

Wauters, E., Van Winsen, F., de Mey, Y., & Lauwers, L. (2014). Risk perception, attitudes towards risk and risk management: evidence and implications. Agricultural Economics–Czech, 60(9), 389-405.

# I. Direct Elicitation

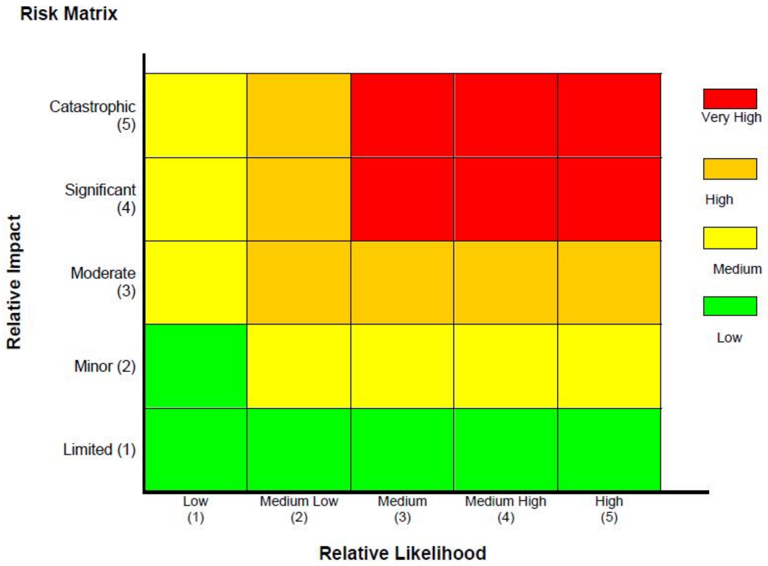
## Creating Heatmaps



Feyisa, A. D., Maertens, M., & de Mey, Y. (2023). Relating risk preferences and risk perceptions over different agricultural risk domains: Insights from Ethiopia. World Development, 162, 106137.

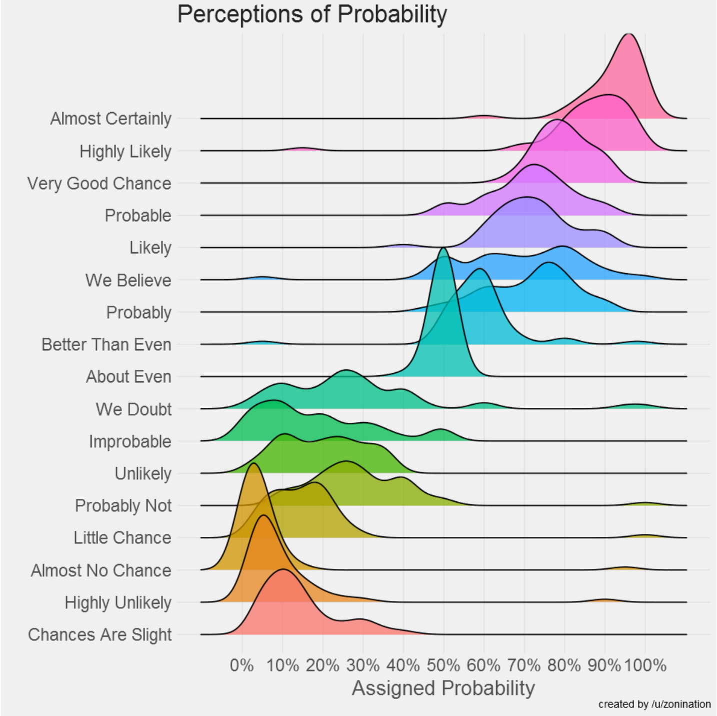
# I. Direct Elicitation

## One word of caution... about muddy waters



| | Low (1) | Medium Low (2) | Medium (3) | Medium High (4) | High (5) |
|---|---|---|---|---|---|
| Catastrophic (5) | 🟨 | 🟧 | 🟥 | 🟥 | 🟥 |
| Significant (4) | 🟨 | 🟧 | 🟥 | 🟥 | 🟥 |
| Moderate (3) | 🟨 | 🟧 | 🟧 | 🟧 | 🟧 |
| Minor (2) | 🟩 | 🟨 | 🟨 | 🟨 | 🟨 |
| Limited (1) | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 |

🟥 Very High
🟧 High
🟨 Medium
🟩 Low



created by /u/zonination

# II. Simulation

**General approach**

- Stylize your problem using equations
- Define your output, and inputs affecting it
- Impose distributions on the stochastic inputs
- Parametrize model using data + expert elicitation
- Using Monte Carlo simulation, simulate input distributions across *n* iterations (e.g. using R or @Risk in Excel)
- Obtain empirical distribution of output > risk measures

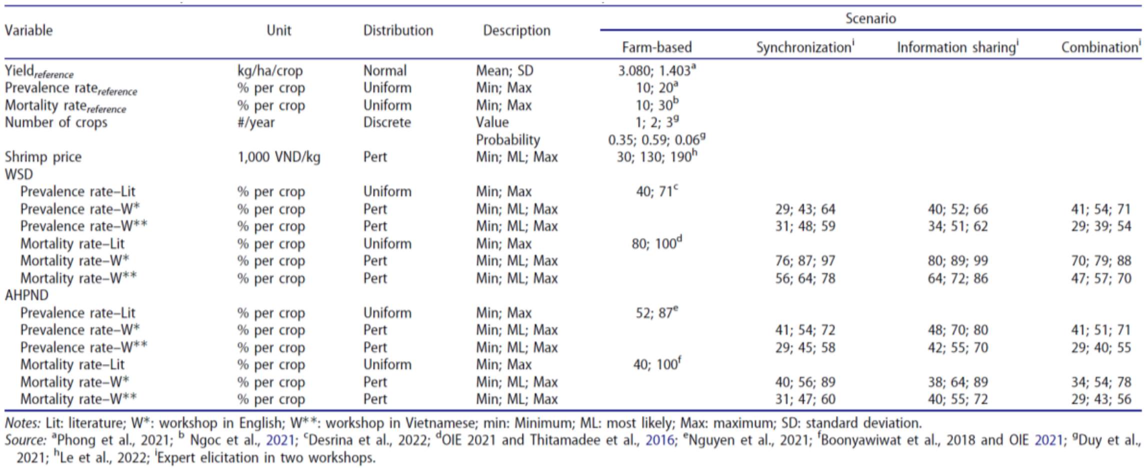
Lien, H. H., de Mey, Y., Nhan, D. K., Bush, S., & Meuwissen, M. P. (2024). Can cooperation reduce yield risks associated with infectious diseases in shrimp aquaculture in Vietnam?. *Aquaculture Economics & Management*, 1-21.

# II. Simulation

$$\text{Yield losses} = [\text{Yield}_{potential} \text{- } \text{Yield}_{disease}] \times \text{Price}.$$

$$\text{Yield}_{potential} = \frac{\text{Yield}_{reference}}{(1 - \text{Prevalence}_{reference}) \times (1 - \text{Mortality}_{reference})}.$$

$$\text{Yield}_{disease} = \text{Yield}_{potential} \times (1\text{- Prevalence}) \times (1\text{- Mortality})$$

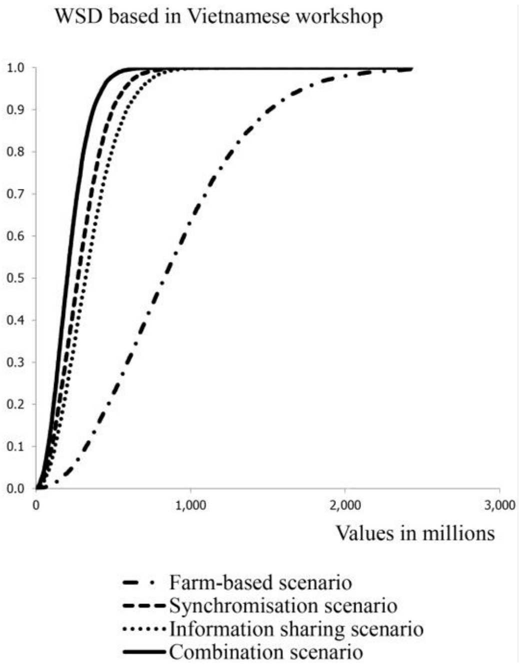


| Variable | Unit | Distribution | Description | Scenario | | | |
|---|---|---|---|---|---|---|---|
| | | | | Farm-based | Synchronization[i] | Information sharing[i] | Combination[i] |
| $\text{Yield}_{reference}$ | kg/ha/crop | Normal | Mean; SD | 3.080; 1.403[a] | | | |
| Prevalence $\text{rate}_{reference}$ | % per crop | Uniform | Min; Max | 10; 20[a] | | | |
| Mortality $\text{rate}_{reference}$ | % per crop | Uniform | Min; Max | 10; 30[b] | | | |
| Number of crops | #/year | Discrete | Value | 1; 2; 3[g] | | | |
| | | | Probability | 0.35; 0.59; 0.06[g] | | | |
| Shrimp price | 1,000 VND/kg | Pert | Min; ML; Max | 30; 130; 190[h] | | | |
| WSD | | | | | | | |
| Prevalence rate–Lit | % per crop | Uniform | Min; Max | 40; 71[c] | | | |
| Prevalence rate–W* | % per crop | Pert | Min; ML; Max | | 29; 43; 64 | 40; 52; 66 | 41; 54; 71 |
| Prevalence rate–W** | % per crop | Pert | Min; ML; Max | | 31; 48; 59 | 34; 51; 62 | 29; 39; 54 |
| Mortality rate–Lit | % per crop | Uniform | Min; Max | 80; 100[d] | | | |
| Mortality rate–W* | % per crop | Pert | Min; ML; Max | | 76; 87; 97 | 80; 89; 99 | 70; 79; 88 |
| Mortality rate–W** | % per crop | Pert | Min; ML; Max | | 56; 64; 78 | 64; 72; 86 | 47; 57; 70 |
| AHPND | | | | | | | |
| Prevalence rate–Lit | % per crop | Uniform | Min; Max | 52; 87[e] | | | |
| Prevalence rate–W* | % per crop | Pert | Min; ML; Max | | 41; 54; 72 | 48; 70; 80 | 41; 51; 71 |
| Prevalence rate–W** | % per crop | Pert | Min; ML; Max | | 29; 45; 58 | 42; 55; 70 | 29; 40; 55 |
| Mortality rate–Lit | % per crop | Uniform | Min; Max | 40; 100[f] | | | |
| Mortality rate–W* | % per crop | Pert | Min; ML; Max | | 40; 56; 89 | 38; 64; 89 | 34; 54; 78 |
| Mortality rate–W** | % per crop | Pert | Min; ML; Max | | 31; 47; 60 | 40; 55; 72 | 29; 43; 56 |

*Notes:* Lit: literature; W*: workshop in English; W**: workshop in Vietnamese; min: Minimum; ML: most likely; Max: maximum; SD: standard deviation.

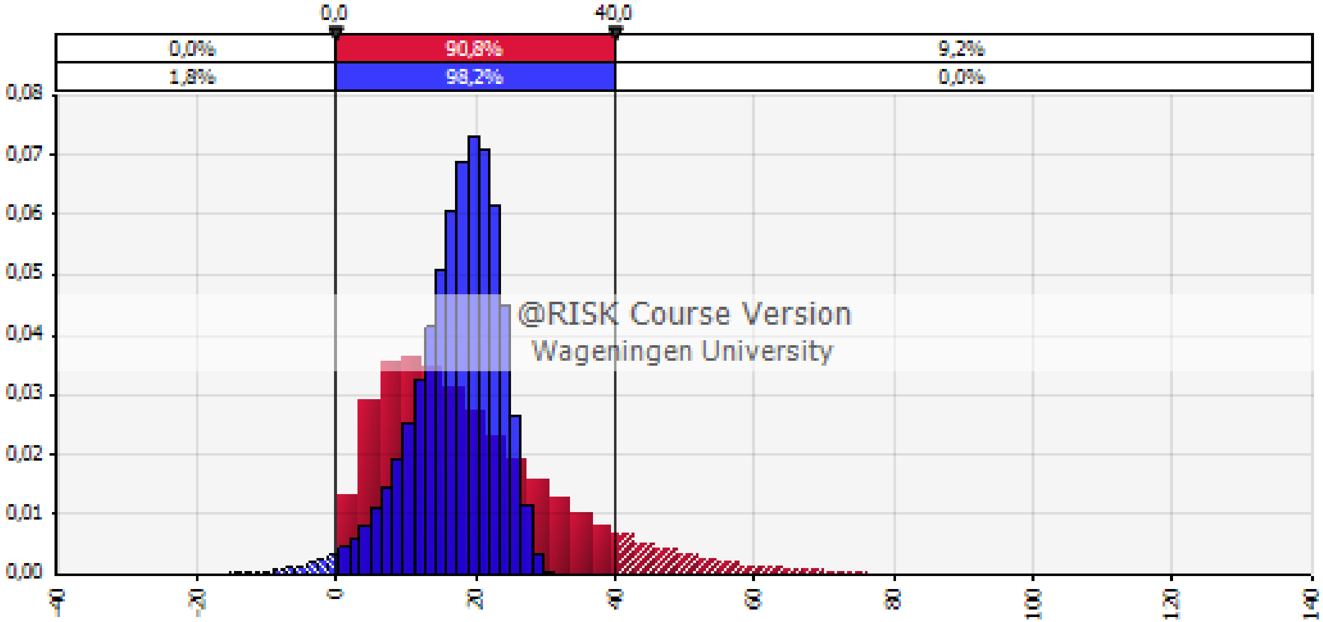
*Source:* [a]Phong et al., 2021; [b] Ngoc et al., 2021; [c]Desrina et al., 2022; [d]OIE 2021 and Thitamadee et al., 2016; [e]Nguyen et al., 2021; [f]Boonyawiwat et al., 2018 and OIE 2021; [g]Duy et al., 2021; [h]Le et al., 2022; [i]Expert elicitation in two workshops.

10.000 iterations



Lien, H. H., de Mey, Y., Nhan, D. K., Bush, S., & Meuwissen, M. P. (2024). Can cooperation reduce yield risks associated with infectious diseases in shrimp aquaculture in Vietnam?. *Aquaculture Economics & Management*, 1-21.

# II. Simulation



Blue = @RiskGamma(2;10)
Red = @RiskExtvalueMin(20;5)

# III. Data-driven / Econometrics

**In very general terms**

- You want to estimate the distribution of a “risky” variable *Y*
- Assuming you have a series of observations for *Y* (across *i* and *t*)
- Conditional versus unconditional approaches
    - Unconditional: curve-fitting exercise (ML based)
    - Conditional: understanding and capturing the DGP
- Parametric, Non-parametric, and Semi-parametric approaches
- Very diverse approaches depending on field/risk (e.g. time series econometrics for price / financial risk)

# III. Data-driven / Econometrics

- Impossible to summarize all approaches, so as an example, let’s focus on **production risk**
- We have 401 observations of rice producing farms in Senegal

| Variable | Explanation | Mean | Std. Dev. |
|---|---|---:|---:|
| **production** | Rice production in tonnes | 7.75 | 9.49 |
| **land** | Land cultivated in ha | 1.59 | 1.84 |
| **seed** | Seed used in kg | 204.51 | 245.48 |
| **labour** | Labour used in man x days | 87.73 | 55.49 |
| **fertilizer** | Fertiliser applied in kg | 540.23 | 661.49 |
| **irrgcost** | Total costs spent on irrigation in $10^3$ FCFA | 97529.10 | 112157.00 |
| **weed** | Total costs spent on weeding in $10^3$ FCFA | 49727.16 | 69124.87 |
| **bird** | Total time spent on bird scaring in man x days | 36.18 | 40.70 |

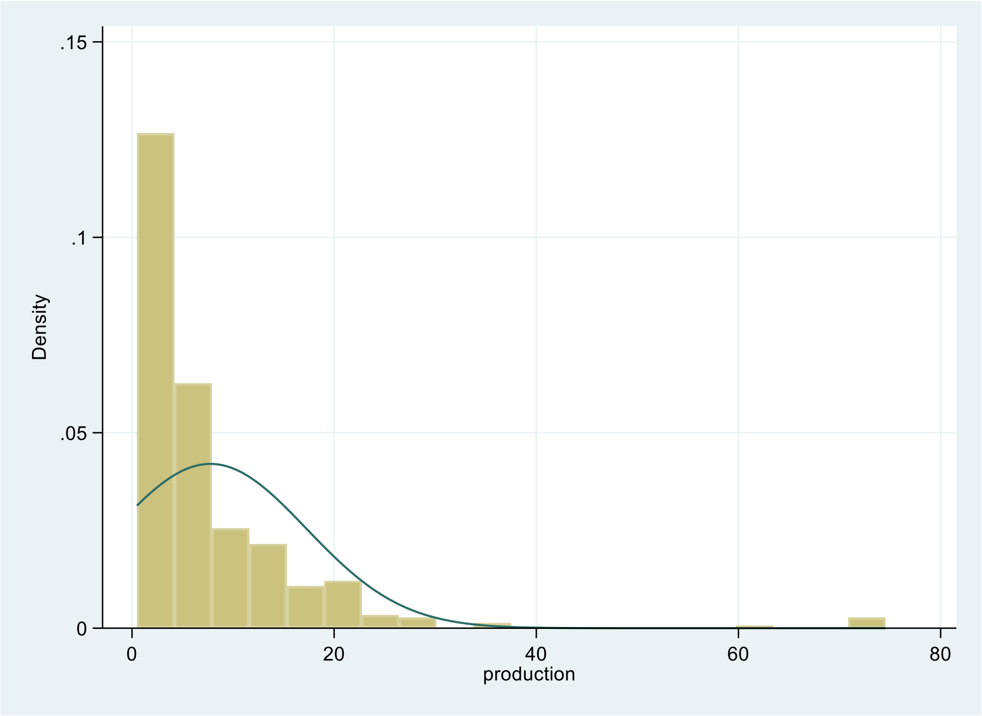
- I present Stata code and results in what follows

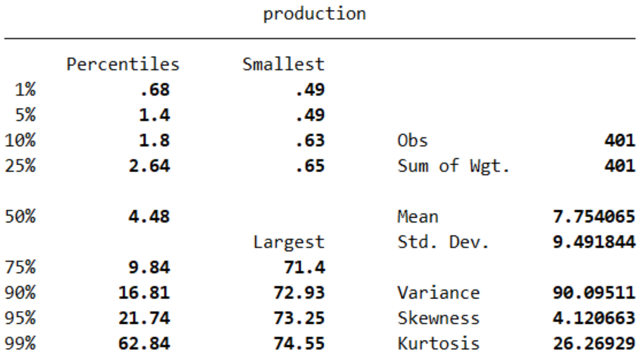
de Mey, Y., Demont, M., & Diagne, M. (2012). Estimating bird damage to rice in Africa: evidence from the Senegal River Valley. *Journal of Agricultural Economics*, *63*(1), 175-200.

# III. Data-driven / Econometrics

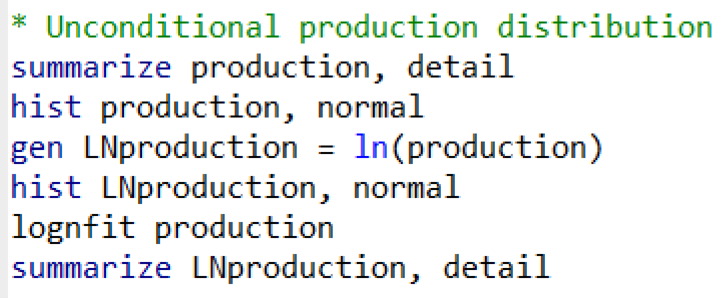
- Impossible to summarize all approaches, so as an example, let’s focus on **production risk**
- We have 401 observations of rice producing farms in Senegal
- We will:
  - First explore production risk unconditionally
  - Next consider influential factors, measuring conditional risk
  - Finally consider an econometric framework that allows conditional risk estimation and its determinants: stochastic production functions / moment-based approach

# Unconditional Production Risk



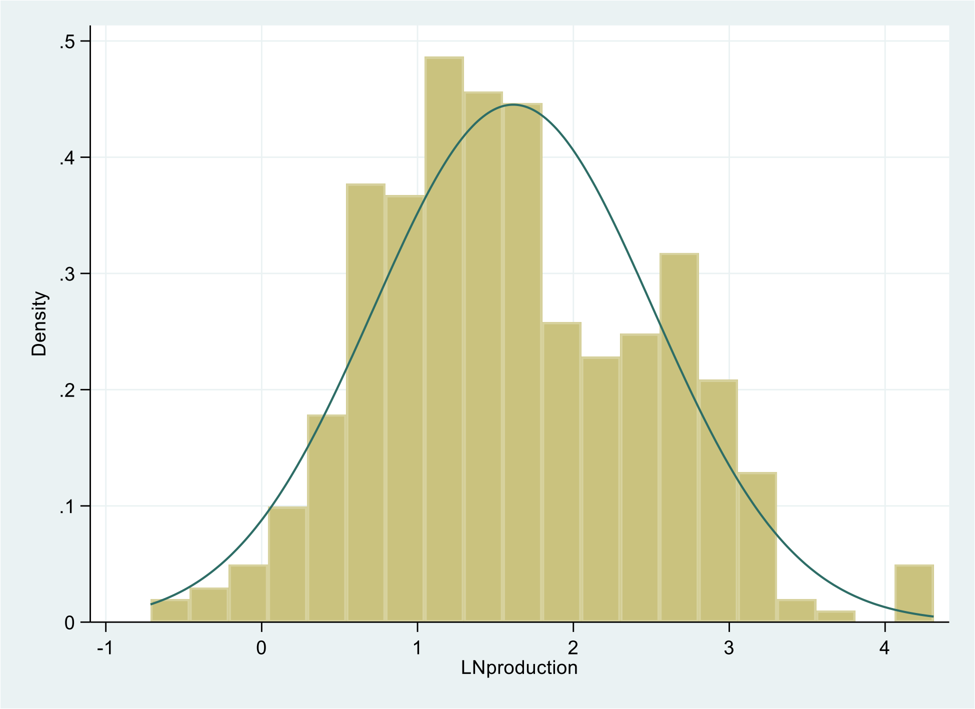


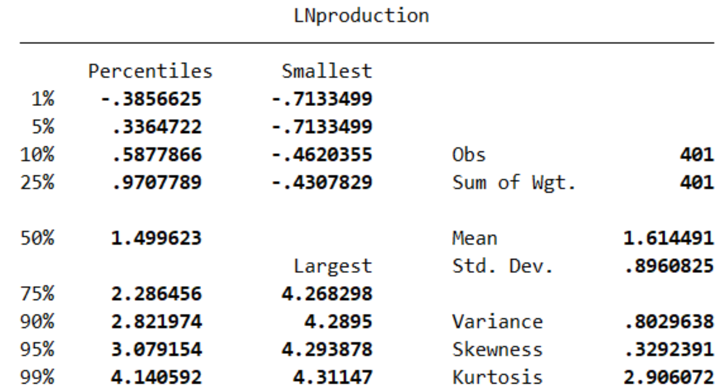
```
                         production
-------------------------------------------------------------
      Percentiles      Smallest
 1%          .68            .49
 5%          1.4            .49
10%          1.8            .63       Obs                 401
25%         2.64            .65       Sum of Wgt.         401

50%         4.48                      Mean           7.754065
                        Largest       Std. Dev.      9.491844
75%         9.84           71.4
90%        16.81          72.93       Variance       90.09511
95%        21.74          73.25       Skewness       4.120663
99%        62.84          74.55       Kurtosis       26.26929
```



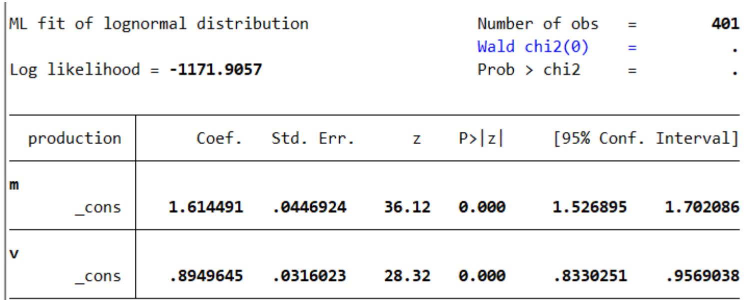
```
* Unconditional production distribution
summarize production, detail
hist production, normal
gen LNproduction = ln(production)
hist LNproduction, normal
lognfit production
summarize LNproduction, detail
```

# Unconditional Production Risk





```
                         LNproduction
-------------------------------------------------------------
      Percentiles      Smallest
 1%    -.3856625      -.7133499
 5%     .3364722      -.7133499
10%     .5877866      -.4620355       Obs                 401
25%     .9707789      -.4307829       Sum of Wgt.         401

50%     1.499623                      Mean           1.614491
                        Largest       Std. Dev.      .8960825
75%     2.286456       4.268298
90%     2.821974         4.2895       Variance       .8029638
95%     3.079154       4.293878       Skewness       .3292391
99%     4.140592        4.31147       Kurtosis       2.906072
```



```
ML fit of lognormal distribution                Number of obs   =        401
                                                Wald chi2(0)    =          .
Log likelihood = -1171.9057                     Prob > chi2     =          .

------------------------------------------------------------------------------
  production |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
m            |
       _cons |   1.614491   .0446924    36.12   0.000     1.526895    1.702086
-------------+----------------------------------------------------------------
v            |
       _cons |   .8949645   .0316023    28.32   0.000     .8330251    .9569038
------------------------------------------------------------------------------
```

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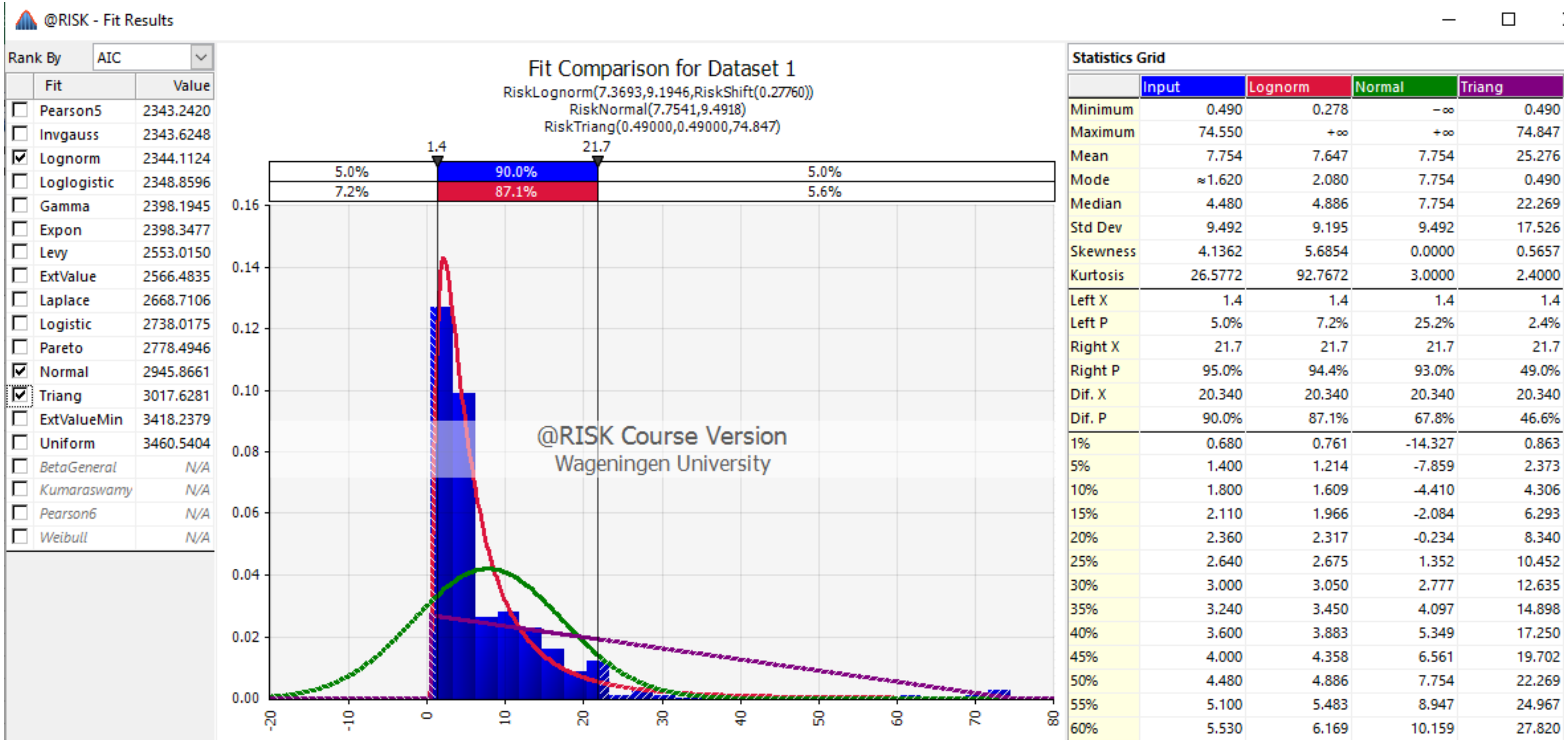
UNIVERSITY & RESEARCH

# Unconditional Production Risk



@RISK - Fit Results

Rank By: AIC

| | Fit | Value |
|---|---|---|
| ☐ | Pearson5 | 2343.2420 |
| ☐ | Invgauss | 2343.6248 |
| ☑ | Lognorm | 2344.1124 |
| ☐ | Loglogistic | 2348.8596 |
| ☐ | Gamma | 2398.1945 |
| ☐ | Expon | 2398.3477 |
| ☐ | Levy | 2553.0150 |
| ☐ | ExtValue | 2566.4835 |
| ☐ | Laplace | 2668.7106 |
| ☐ | Logistic | 2738.0175 |
| ☐ | Pareto | 2778.4946 |
| ☑ | Normal | 2945.8661 |
| ☑ | Triang | 3017.6281 |
| ☐ | ExtValueMin | 3418.2379 |
| ☐ | Uniform | 3460.5404 |
| ☐ | *BetaGeneral* | *N/A* |
| ☐ | *Kumaraswamy* | *N/A* |
| ☐ | *Pearson6* | *N/A* |
| ☐ | *Weibull* | *N/A* |

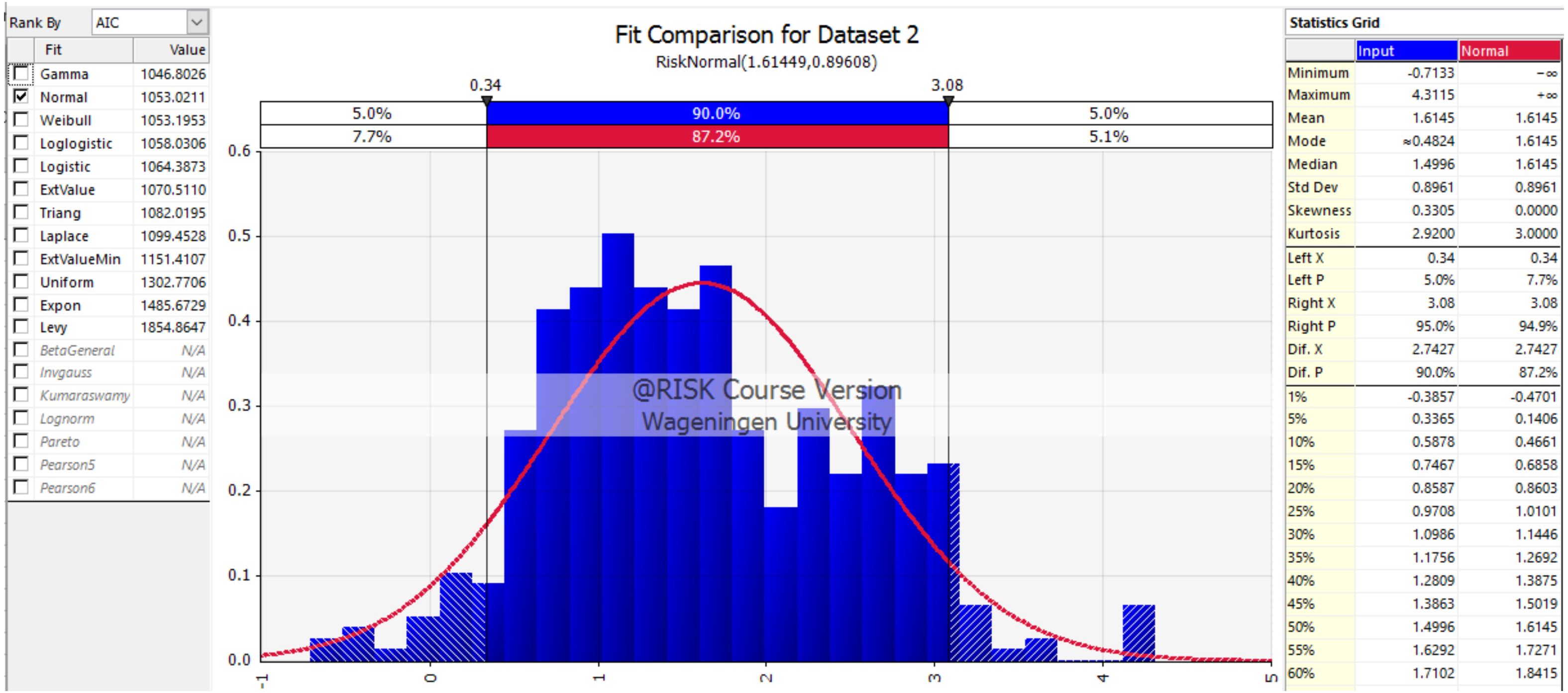
Fit Comparison for Dataset 1

RiskLognorm(7.3693,9.1946,RiskShift(0.27760))
RiskNormal(7.7541,9.4918)
RiskTriang(0.49000,0.49000,74.847)

Statistics Grid

| | Input | Lognorm | Normal | Triang |
|---|---|---|---|---|
| Minimum | 0.490 | 0.278 | −∞ | 0.490 |
| Maximum | 74.550 | +∞ | +∞ | 74.847 |
| Mean | 7.754 | 7.647 | 7.754 | 25.276 |
| Mode | ≈1.620 | 2.080 | 7.754 | 0.490 |
| Median | 4.480 | 4.886 | 7.754 | 22.269 |
| Std Dev | 9.492 | 9.195 | 9.492 | 17.526 |
| Skewness | 4.1362 | 5.6854 | 0.0000 | 0.5657 |
| Kurtosis | 26.5772 | 92.7672 | 3.0000 | 2.4000 |
| Left X | 1.4 | 1.4 | 1.4 | 1.4 |
| Left P | 5.0% | 7.2% | 25.2% | 2.4% |
| Right X | 21.7 | 21.7 | 21.7 | 21.7 |
| Right P | 95.0% | 94.4% | 93.0% | 49.0% |
| Dif. X | 20.340 | 20.340 | 20.340 | 20.340 |
| Dif. P | 90.0% | 87.1% | 67.8% | 46.6% |
| 1% | 0.680 | 0.761 | -14.327 | 0.863 |
| 5% | 1.400 | 1.214 | -7.859 | 2.373 |
| 10% | 1.800 | 1.609 | -4.410 | 4.306 |
| 15% | 2.110 | 1.966 | -2.084 | 6.293 |
| 20% | 2.360 | 2.317 | -0.234 | 8.340 |
| 25% | 2.640 | 2.675 | 1.352 | 10.452 |
| 30% | 3.000 | 3.050 | 2.777 | 12.635 |
| 35% | 3.240 | 3.450 | 4.097 | 14.898 |
| 40% | 3.600 | 3.883 | 5.349 | 17.250 |
| 45% | 4.000 | 4.358 | 6.561 | 19.702 |
| 50% | 4.480 | 4.886 | 7.754 | 22.269 |
| 55% | 5.100 | 5.483 | 8.947 | 24.967 |
| 60% | 5.530 | 6.169 | 10.159 | 27.820 |

# Unconditional Production Risk



Rank By: AIC

| | Fit | Value |
|---|---|---|
| ☐ | Gamma | 1046.8026 |
| ☑ | Normal | 1053.0211 |
| ☐ | Weibull | 1053.1953 |
| ☐ | Loglogistic | 1058.0306 |
| ☐ | Logistic | 1064.3873 |
| ☐ | ExtValue | 1070.5110 |
| ☐ | Triang | 1082.0195 |
| ☐ | Laplace | 1099.4528 |
| ☐ | ExtValueMin | 1151.4107 |
| ☐ | Uniform | 1302.7706 |
| ☐ | Expon | 1485.6729 |
| ☐ | Levy | 1854.8647 |
| ☐ | *BetaGeneral* | *N/A* |
| ☐ | *Invgauss* | *N/A* |
| ☐ | *Kumaraswamy* | *N/A* |
| ☐ | *Lognorm* | *N/A* |
| ☐ | *Pareto* | *N/A* |
| ☐ | *Pearson5* | *N/A* |
| ☐ | *Pearson6* | *N/A* |

Fit Comparison for Dataset 2

RiskNormal(1.61449,0.89608)

Statistics Grid

| | Input | Normal |
|---|---|---|
| Minimum | -0.7133 | −∞ |
| Maximum | 4.3115 | +∞ |
| Mean | 1.6145 | 1.6145 |
| Mode | ≈0.4824 | 1.6145 |
| Median | 1.4996 | 1.6145 |
| Std Dev | 0.8961 | 0.8961 |
| Skewness | 0.3305 | 0.0000 |
| Kurtosis | 2.9200 | 3.0000 |
| Left X | 0.34 | 0.34 |
| Left P | 5.0% | 7.7% |
| Right X | 3.08 | 3.08 |
| Right P | 95.0% | 94.9% |
| Dif. X | 2.7427 | 2.7427 |
| Dif. P | 90.0% | 87.2% |
| 1% | -0.3857 | -0.4701 |
| 5% | 0.3365 | 0.1406 |
| 10% | 0.5878 | 0.4661 |
| 15% | 0.7467 | 0.6858 |
| 20% | 0.8587 | 0.8603 |
| 25% | 0.9708 | 1.0101 |
| 30% | 1.0986 | 1.1446 |
| 35% | 1.1756 | 1.2692 |
| 40% | 1.2809 | 1.3875 |
| 45% | 1.3863 | 1.5019 |
| 50% | 1.4996 | 1.6145 |
| 55% | 1.6292 | 1.7271 |
| 60% | 1.7102 | 1.8415 |

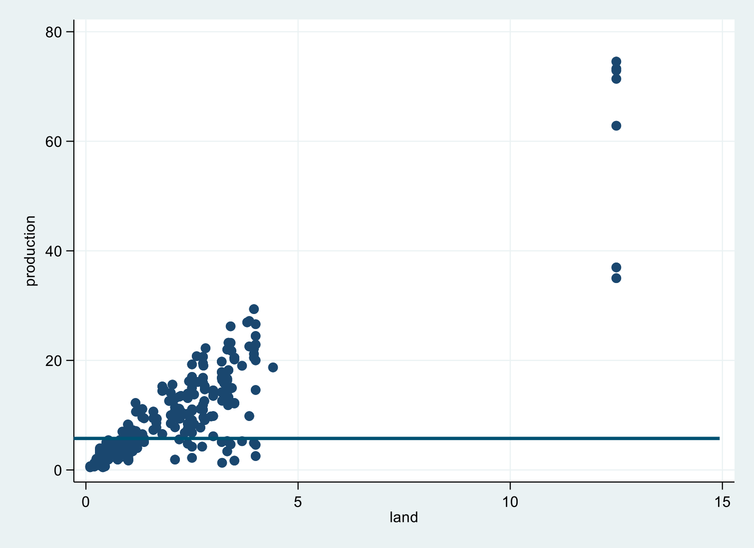
# Unconditional Production Risk

```
                         production
-------------------------------------------------------------
      Percentiles      Smallest
 1%          .68            .49
 5%          1.4            .49
10%          1.8            .63       Obs                 401
25%         2.64            .65       Sum of Wgt.         401

50%         4.48                      Mean           7.754065
                        Largest       Std. Dev.      9.491844
75%         9.84           71.4
90%        16.81          72.93       Variance       90.09511
95%        21.74          73.25       Skewness       4.120663
99%        62.84          74.55       Kurtosis       26.26929
```

$$E[(x-\mu_x)^r]$$

```
* Unconditional production distribution 2
scatter production land
regress production
predict r, res
gen r2 = r*r
sum r2
display r(mean)*r(N)/(r(N)-1)
```

```
. display r(mean)*r(N)/(r(N)-1)
90.095105
```



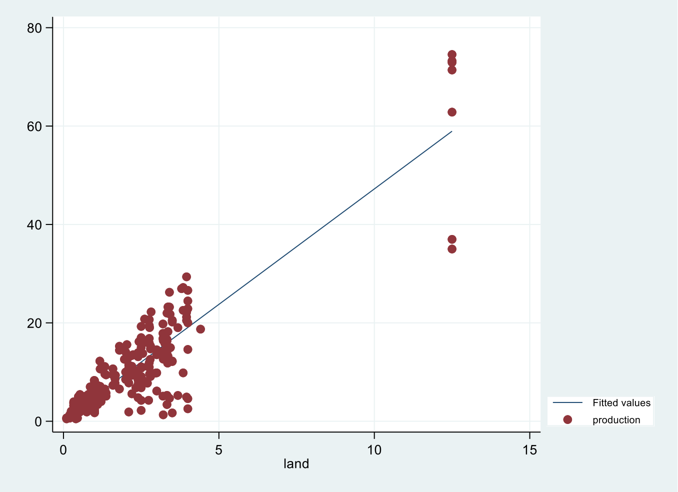
```
      Source |       SS           df       MS      Number of obs   =       401
-------------+----------------------------------   F(0, 400)       =      0.00
       Model |           0         0           .   Prob > F        =         .
    Residual |  36038.0425       400  90.0951063   R-squared       =    0.0000
-------------+----------------------------------   Adj R-squared   =    0.0000
       Total |  36038.0425       400  90.0951063   Root MSE        =    9.4918

------------------------------------------------------------------------------
  production |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |   7.754065   .4740001    16.36   0.000     6.822222    8.685907
------------------------------------------------------------------------------
```

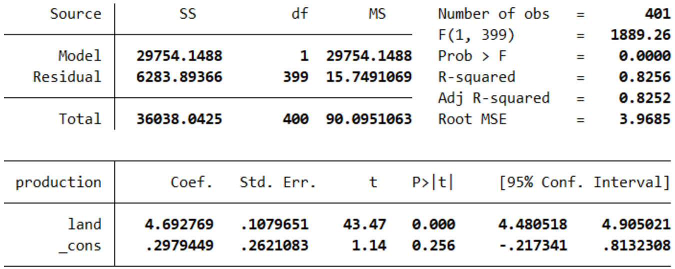
# Conditional Production Risk

```
* Conditional production distribution
graph twoway (lfit production land) (scatter production land)
regress production land
predict r_land, res
gen r2_land = r_land*r_land
sum r2_land
display r(mean)*r(N)/(r(N)-1)
```

```
90.095105
```

```
15.709734
```





```
      Source |       SS           df       MS      Number of obs   =       401
-------------+----------------------------------   F(1, 399)       =   1889.26
       Model |  29754.1488         1  29754.1488   Prob > F        =    0.0000
    Residual |  6283.89366       399  15.7491069   R-squared       =    0.8256
-------------+----------------------------------   Adj R-squared   =    0.8252
       Total |  36038.0425       400  90.0951063   Root MSE        =    3.9685

------------------------------------------------------------------------------
  production |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        land |   4.692769   .1079651    43.47   0.000     4.480518    4.905021
       _cons |   .2979449   .2621083     1.14   0.256     -.217341    .8132308
------------------------------------------------------------------------------
```

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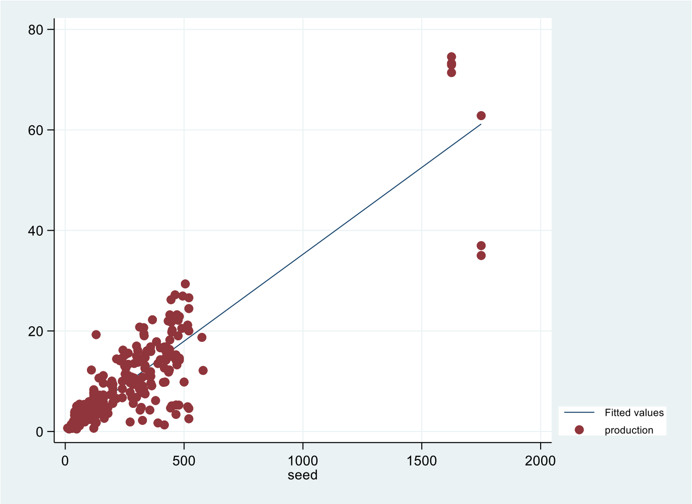
# Conditional Production Risk

```
* Conditional production distribution 2
regress production land seed
predict r_land_seed, res
gen r2_land_seed = r_land_seed*r_land_seed
sum r2_land_seed
display r(mean)*r(N)/(r(N)-1)
```

```
90.095105
```

```
15.709734
```

```
14.766064
```



```
      Source |       SS           df       MS      Number of obs   =       401
-------------+----------------------------------   F(2, 398)       =   1015.20
       Model |  30131.6167         2  15065.8083   Prob > F        =    0.0000
    Residual |  5906.42582       398  14.8402659   R-squared       =    0.8361
-------------+----------------------------------   Adj R-squared   =    0.8353
       Total |  36038.0425       400  90.0951063   Root MSE        =    3.8523

------------------------------------------------------------------------------
  production |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        land |   9.966935   1.051005     9.48   0.000     7.900721    12.03315
        seed |  -.0396852   .0078688    -5.04   0.000    -.0551549   -.0242156
       _cons |    .034107   .2597556     0.13   0.896    -.4765576    .5447715
------------------------------------------------------------------------------
```

# Conditional Production Risk

**Stochastic production function approach** (Just and Pope, 1978/79)

- $Y_{i,t} = g(t) + m(X_{i,t}) + \varepsilon_{i,t}\mathbf{h(i,t)}$
  - g(t) is a time trend (technological advance)
  - $m(X_t)$ captures the effects of influencing factors (inputs, weather, soil conditions, etc.)
  - $\varepsilon_t$ is an error term with zero mean and potential heteroskedasticity through variance h(i,t)

Just, R. E., R. D. Pope. 1978. Stochastic specification of production functions and economic implications. Journal of Econometrics 7 (1): 67-86.
Just, R. E., R. D. Pope. 1979. Production Function Estimation and Related Risk Considerations. American Journal of Agricultural Economics 61 (2): 276-284.

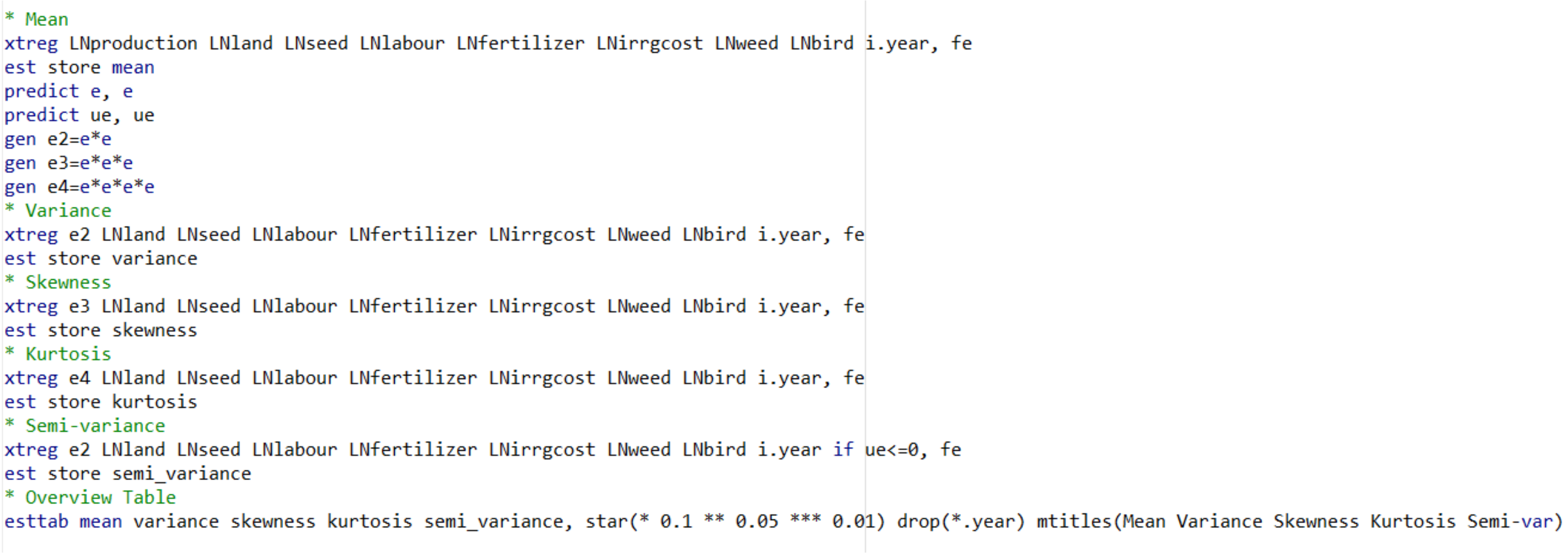
# Conditional Production Risk

**Stochastic production function approach** (Just and Pope, 1978/79)

- $Y_{i,t} = g(t) + m(X_{i,t}) + \varepsilon_{i,t}h(i,t)$
    - $h(i,t) = h(Z_{i,t})$
    - Where $Z_{i,t}$ is a vector of factors influencing variance. Typically contains the inputs: can be characterised as risk increasing, risk neutral or risk decreasing
- Extended to the higher moments by Antle (1983): impact on skewness, kurtosis, …
- Many more extensions such as focussing on downside risk by looking at semi-variance

Antle, J. M. 1983. Testing the Stochastic Structure of Production: A Flexible Moment-Based Approach. Journal of Business & Economic Statistics 1 (3): 192-201.

# Conditional Production Risk and Determinants



```
* Mean
xtreg LNproduction LNland LNseed LNlabour LNfertilizer LNirrgcost LNweed LNbird i.year, fe
est store mean
predict e, e
predict ue, ue
gen e2=e*e
gen e3=e*e*e
gen e4=e*e*e*e
* Variance
xtreg e2 LNland LNseed LNlabour LNfertilizer LNirrgcost LNweed LNbird i.year, fe
est store variance
* Skewness
xtreg e3 LNland LNseed LNlabour LNfertilizer LNirrgcost LNweed LNbird i.year, fe
est store skewness
* Kurtosis
xtreg e4 LNland LNseed LNlabour LNfertilizer LNirrgcost LNweed LNbird i.year, fe
est store kurtosis
* Semi-variance
xtreg e2 LNland LNseed LNlabour LNfertilizer LNirrgcost LNweed LNbird i.year if ue<=0, fe
est store semi_variance
* Overview Table
esttab mean variance skewness kurtosis semi_variance, star(* 0.1 ** 0.05 *** 0.01) drop(*.year) mtitles(Mean Variance Skewness Kurtosis Semi-var)
```

# Conditional Production Risk and Determinants

```
------------------------------------------------------------------------------------
                      (1)             (2)             (3)             (4)             (5)
                     Mean        Variance        Skewness        Kurtosis        Semi-var
------------------------------------------------------------------------------------
LNland              0.862***      -0.0513          0.0116        -0.00190          -0.193
                   (4.18)         (-0.53)          (0.09)         (-0.01)         (-1.01)

LNseed             -0.299*          0.120          -0.106           0.109          0.296*
                  (-1.95)          (1.64)         (-1.05)          (0.91)          (1.86)

LNlabour            0.129***      -0.0395*         0.0706**       -0.0882**        -0.110**
                   (2.64)         (-1.71)          (2.20)         (-2.33)         (-2.26)

LNfertilizer        0.150**       -0.0236          0.0285         -0.0412          -0.101
                   (1.99)         (-0.66)          (0.57)         (-0.71)         (-1.22)

LNirrgcost          0.110        -0.00144          0.0174        -0.00726           0.113
                   (0.83)         (-0.02)          (0.20)         (-0.07)          (0.95)

LNweed             0.0502*       -0.00877        -0.00599         0.00656         0.00484
                   (1.81)         (-0.67)         (-0.33)          (0.30)          (0.08)

LNbird            -0.0213         0.00168        -0.00260        0.000992         -0.0107
                  (-1.23)          (0.21)         (-0.23)          (0.07)         (-0.54)

_cons              0.0486          -0.123         -0.0699          0.0976          -1.630
                   (0.03)         (-0.15)         (-0.06)          (0.07)         (-1.08)
------------------------------------------------------------------------------------
N                     401             401             401             401             180
------------------------------------------------------------------------------------
t statistics in parentheses
* p<0.1, ** p<0.05, *** p<0.01
```

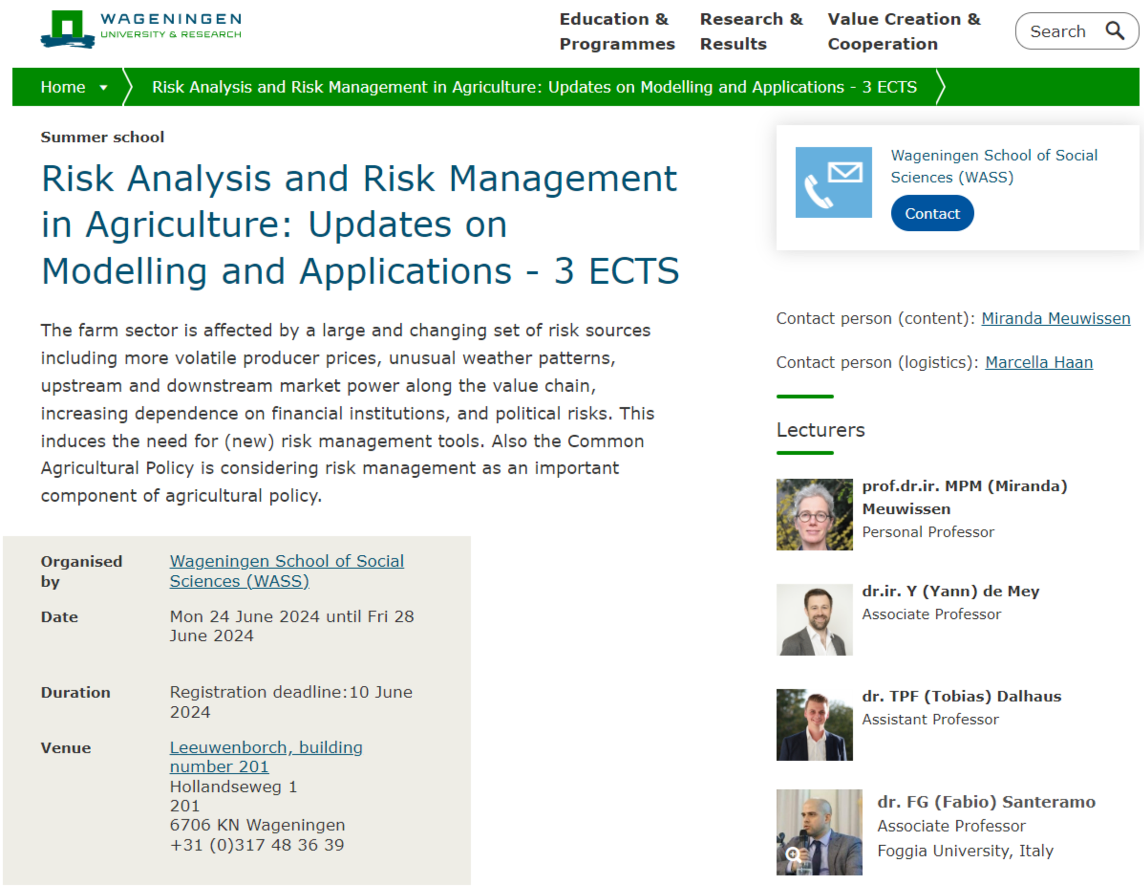
# Key/Take Home Messages I

- There are various (often confounded) risk-related concepts that all rely on probability and impact.
- Our knowledge on these dimensions matters and leads to risk, uncertainty, ambiguity, and ignorance.
- Risk usually has a distinct set of features, explore and explain these in your context.
- Various definitions of risk exist, be explicit in your paper.
- Risk is inherently subjective, and that is fine.
- An objective versus subjective view/approach depends on the application.

# Key/Take Home Messages II

- Among the diverse set of risk measures (and related concepts), all are incomplete. So choose wisely or combine measures.
- Align your risk measure with your view on / definition of risk having your decision maker or research subject in mind.
- Different risk measure = different level of risk.
- Consider looking at multiple risks jointly, rather than single sources
- Various approaches exist to characterizing farm-level risk exposure, typically your research question and data availability/reliability will guide your choice.
- We discussed direct elicitation vs. simulation vs. econometrics

# Summer School @WUR, 24-28 June 2024



**Summer school**

## Risk Analysis and Risk Management in Agriculture: Updates on Modelling and Applications - 3 ECTS

The farm sector is affected by a large and changing set of risk sources including more volatile producer prices, unusual weather patterns, upstream and downstream market power along the value chain, increasing dependence on financial institutions, and political risks. This induces the need for (new) risk management tools. Also the Common Agricultural Policy is considering risk management as an important component of agricultural policy.

| | |
|---|---|
| **Organised by** | Wageningen School of Social Sciences (WASS) |
| **Date** | Mon 24 June 2024 until Fri 28 June 2024 |
| **Duration** | Registration deadline:10 June 2024 |
| **Venue** | Leeuwenborch, building number 201<br>Hollandseweg 1<br>201<br>6706 KN Wageningen<br>+31 (0)317 48 36 39 |

Wageningen School of Social Sciences (WASS)

Contact person (content): Miranda Meuwissen

Contact person (logistics): Marcella Haan

### Lecturers

**prof.dr.ir. MPM (Miranda) Meuwissen**
Personal Professor

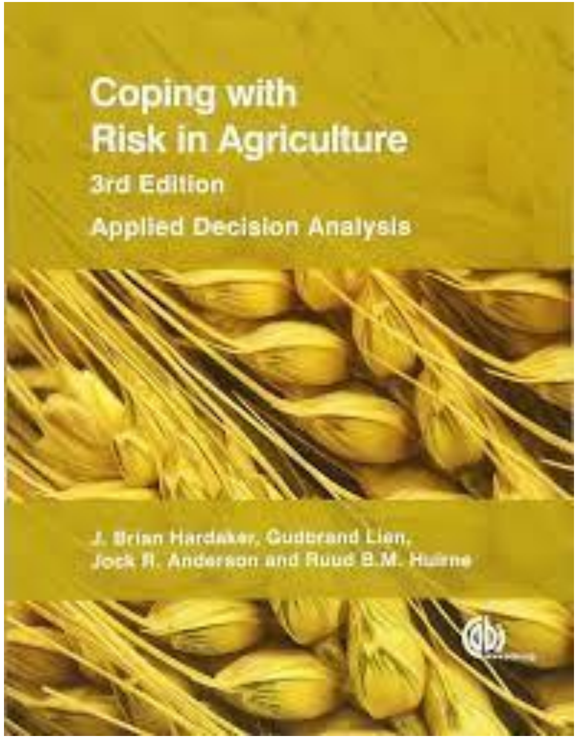
**dr.ir. Y (Yann) de Mey**
Associate Professor

**dr. TPF (Tobias) Dalhaus**
Assistant Professor

**dr. FG (Fabio) Santeramo**
Associate Professor
Foggia University, Italy

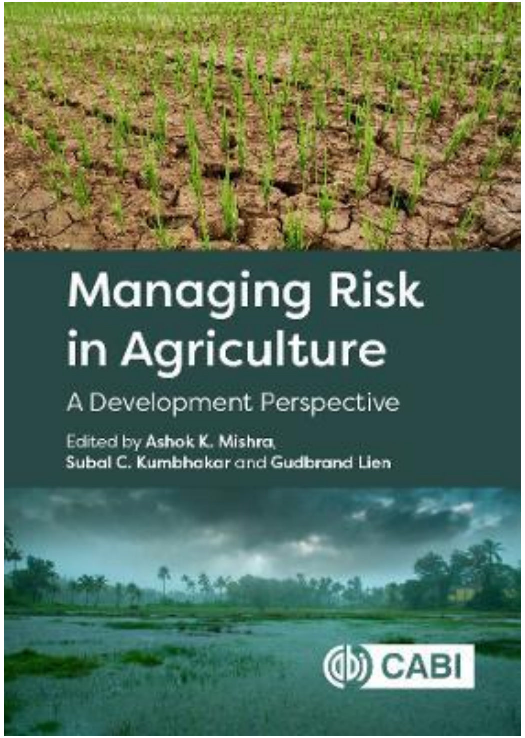
https://www.wur.nl/en/activity/risk-analysis-and-risk-management-in-agriculture-updates-on-modelling-and-applications-3-ects.htm

# Some References – Risk in Agriculture



Coping with
Risk in Agriculture
3rd Edition
Applied Decision Analysis

J. Brian Hardaker, Gudbrand Lien,
Jock R. Anderson and Ruud B.M. Huirne



Managing Risk
in Agriculture
A Development Perspective

Edited by Ashok K. Mishra,
Subal C. Kumbhakar and Gudbrand Lien

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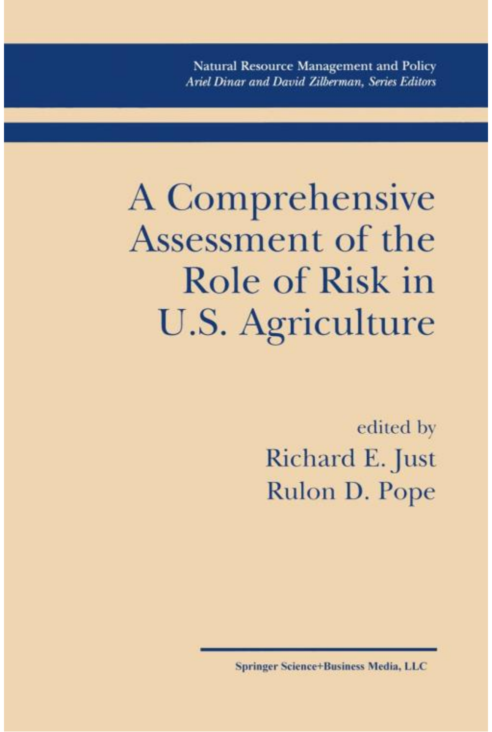


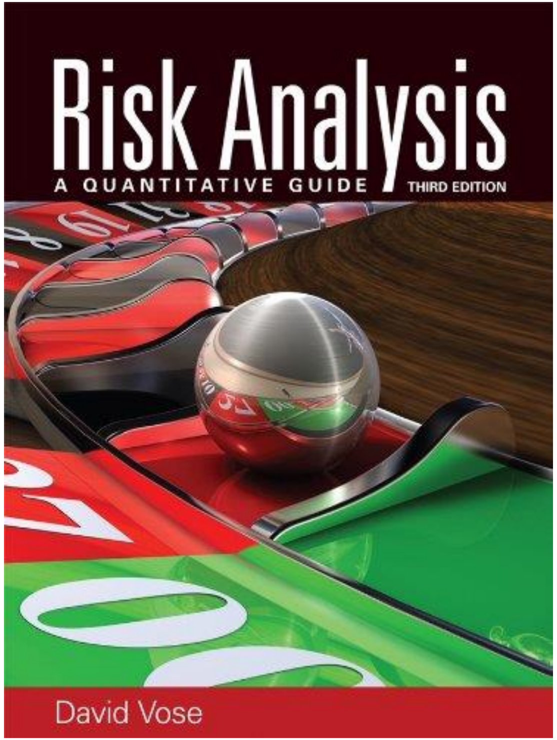
Natural Resource Management and Policy
*Ariel Dinar and David Zilberman, Series Editors*

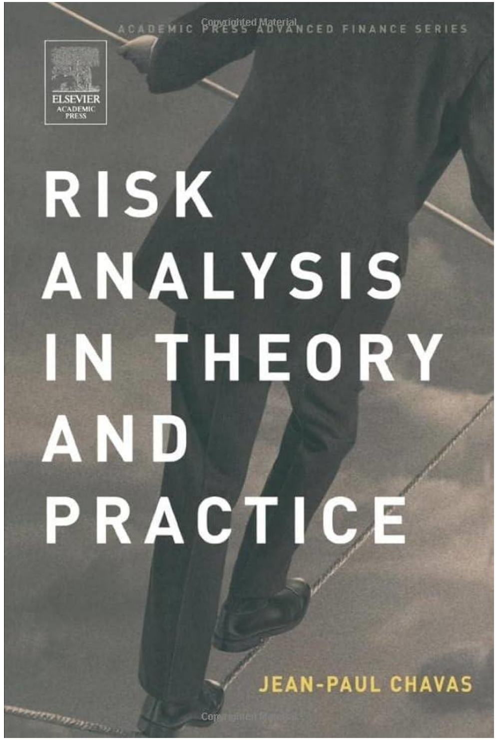
A Comprehensive
Assessment of the
Role of Risk in
U.S. Agriculture

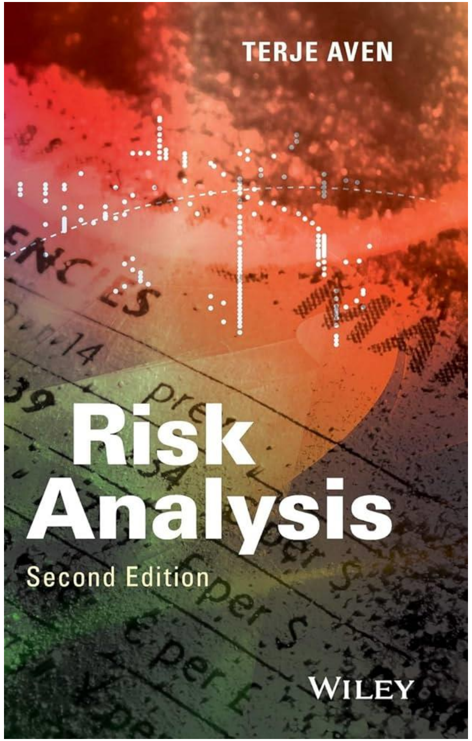
edited by
Richard E. Just
Rulon D. Pope

Springer Science+Business Media, LLC

# Some References – Risk Analysis in General







# Thanks! Questions?

yann.demey@wur.nl

**Yann de Mey**
@YanndeMey

Associate Professor @WURbec interested in digitalization of agricultural risk analysis | @AgEconMeet | 🇧🇪 living in 🇳🇱 | Feminist

https://www.linkedin.com/in/yanndemey