

Andreas Krause

Risk aversion

Dislike of risk

Dislike of risk

- ▶ Individuals prefer, *ceteris paribus*, **higher outcomes** to lower outcomes

Dislike of risk

- ▶ Individuals prefer, *ceteris paribus*, higher outcomes to lower outcomes
- ▶ Individuals prefer, *ceteris paribus*, **lower risks** to higher risks

Dislike of risk

- ▶ Individuals prefer, *ceteris paribus*, higher outcomes to lower outcomes
- ▶ Individuals prefer, *ceteris paribus*, lower risks to higher risks
- ▶ The attitude towards risk is commonly referred to as **risk aversion**

Dislike of risk

- ▶ Individuals prefer, *ceteris paribus*, higher outcomes to lower outcomes
- ▶ Individuals prefer, *ceteris paribus*, lower risks to higher risks
- ▶ The attitude towards risk is commonly referred to as risk aversion
- ▶ More formally, we define

Dislike of risk

- ▶ Individuals prefer, *ceteris paribus*, higher outcomes to lower outcomes
- ▶ Individuals prefer, *ceteris paribus*, lower risks to higher risks
- ▶ The attitude towards risk is commonly referred to as risk aversion
- ▶ More formally, we define
*Individuals are **risk averse** if they always prefer to receive a fixed payment to a random payment of equal expected value.*

(B. Dumas and B. Allaz, Financial Securities: Market Equilibrium and Pricing Methods, Cengage Learning, London 1996)

Measuring risk and risk aversion

Measuring risk and risk aversion

- ▶ The most common risk measure in finance is the **variance** of outcomes

Measuring risk and risk aversion

- ▶ The most common risk measure in finance is the variance of outcomes
- ▶ Variance is a measure of how much outcomes deviate from the expected value
- ▶ $\text{Var}[V] = E[(V - E[V])^2]$

Measuring risk and risk aversion

- ▶ The most common risk measure in finance is the variance of outcomes
- ▶ Variance is a measure of how much outcomes deviate from the expected value
- ▶ $\text{Var}[V] = \text{E} \left[(V - \text{E}[V])^2 \right]$
- ▶ Risk aversion is more difficult to measure as it will depend on the utility function of individuals

Measuring risk and risk aversion

- ▶ The most common risk measure in finance is the variance of outcomes
- ▶ Variance is a measure of how much outcomes deviate from the expected value
- ▶ $\text{Var}[V] = \text{E} \left[(V - \text{E}[V])^2 \right]$
- ▶ Risk aversion is more difficult to measure as it will depend on the utility function of individuals

Risk premium

Risk premium

- ▶ Using the definition of risk aversion, we see can compare the **expected utility of risky outcomes** and the **utility non-risky outcomes**

- ▶ $E[U(V)] \quad U(E[V])$

Risk premium

- ▶ Using the definition of risk aversion, we see can compare the **expected utility of risky outcomes** and the **utility non-risky outcomes**
- ▶ The utility of the risky outcomes, should be **less** than that of a non-risky-outcome with the same expected value
- ▶ $E[U(V)] \leq U(E[V])$

Risk premium

- ▶ Using the definition of risk aversion, we see can compare the **expected utility of risky outcomes** and the **utility non-risky outcomes**
- ▶ The utility of the risky outcomes, should be less than that of a non-risky-outcome with the same expected value
- ▶ The amount to be deducted from the safe outcome to obtain the same utility as the risky outcome is the **risk premium**
- ▶ $E[U(V)] = U(E[V] - \Pi)$

Risk premium

- ▶ Using the definition of risk aversion, we see can compare the expected utility of risky outcomes and the utility non-risky outcomes
- ▶ The utility of the risky outcomes, should be less than that of a non-risky-outcome with the same expected value
- ▶ The amount to be deducted from the safe outcome to obtain the same utility as the risky outcome is the risk premium
- ▶ $E[U(V)] = U(E[V] - \Pi)$

Approximating the risky outcome

Approximating the risky outcome

- ▶ We use a **quadratic approximation** of the expected utility of the individual facing risky outcomes

Approximating the risky outcome

- ▶ We use a quadratic approximation of the expected utility of the individual facing risky outcomes
- ▶ We use the **expected value** as a starting point
- ▶ $E[U(V)] = E[U(E[V])]$

Approximating the risky outcome

- ▶ We use a quadratic approximation of the expected utility of the individual facing risky outcomes
- ▶ We use the **expected value** as a starting point, then make a **linear adjustment**

- ▶
$$E[U(V)] = E \left[U(E[V]) + \frac{\partial U(E[V])}{\partial V} (V - E[V]) \right]$$

Approximating the risky outcome

- ▶ We use a quadratic approximation of the expected utility of the individual facing risky outcomes
- ▶ We use the **expected value** as a starting point, then make a **linear adjustment**, and a **quadratic adjustment**
- ▶
$$E[U(V)] = E\left[U(E[V]) + \frac{\partial U(E[V])}{\partial V}(V - E[V]) + \frac{1}{2} \frac{\partial^2 U(E[V])}{\partial V^2} (V - E[V])^2\right]$$

Approximating the risky outcome

- ▶ We use a quadratic approximation of the expected utility of the individual facing risky outcomes
- ▶ We use the **expected value** as a starting point, then make a **linear adjustment**, and a **quadratic adjustment**

- ▶
$$\begin{aligned} E[U(V)] &= E\left[U(E[V]) + \frac{\partial U(E[V])}{\partial V}(V - E[V]) + \frac{1}{2} \frac{\partial^2 U(E[V])}{\partial V^2} (V - E[V])^2\right] \\ &= U(E[V]) + \frac{1}{2} \frac{\partial^2 U(E[V])}{\partial V^2} \text{Var}[V] \end{aligned}$$

Approximating the risky outcome

- ▶ We use a quadratic approximation of the expected utility of the individual facing risky outcomes
- ▶ We use the expected value as a starting point, then make a linear adjustment, and a quadratic adjustment

- ▶
$$\begin{aligned} E[U(V)] &= E \left[U(E[V]) + \frac{\partial U(E[V])}{\partial V} (V - E[V]) + \frac{1}{2} \frac{\partial^2 U(E[V])}{\partial V^2} (V - E[V])^2 \right] \\ &= U(E[V]) + \frac{1}{2} \frac{\partial^2 U(E[V])}{\partial V^2} \text{Var}[V] \end{aligned}$$

Approximating the safe outcome

Approximating the safe outcome

- ▶ We use a **linear approximation** of the expected utility of the individual facing a safe outcome

Approximating the safe outcome

- ▶ We use a linear approximation of the expected utility of the individual facing a safe outcome
- ▶ We use the **expected value** as a starting point
- ▶ $U(E[V] - \Pi) = U(E[V])$

Approximating the safe outcome

- ▶ We use a linear approximation of the expected utility of the individual facing a safe outcome
- ▶ We use the **expected value** as a starting point and then make a **linear adjustment**
- ▶ $U(\mathbb{E}[V] - \Pi) = U(\mathbb{E}[V]) + \frac{\partial U(\mathbb{E}[V])}{\partial V} \Pi$

Approximating the safe outcome

- ▶ We use a linear approximation of the expected utility of the individual facing a safe outcome
- ▶ We use the expected value as a starting point and then make a linear adjustment
- ▶ $U(\mathbf{E}[V] - \Pi) = U(\mathbf{E}[V]) + \frac{\partial U(\mathbf{E}[V])}{\partial V} \Pi$
- ▶ Setting this equal to the approximation of the risky outcome gives

$$\Pi = \frac{1}{2} \left(-\frac{\frac{\partial^2 U(\mathbf{E}[V])}{\partial V^2}}{\frac{\partial U(\mathbf{E}[V])}{\partial V}} \right) \text{Var} [V]$$

Approximating the safe outcome

- ▶ We use a linear approximation of the expected utility of the individual facing a safe outcome
- ▶ We use the expected value as a starting point and then make a linear adjustment
- ▶ $U(\mathbf{E}[V] - \Pi) = U(\mathbf{E}[V]) + \frac{\partial U(\mathbf{E}[V])}{\partial V} \Pi$
- ▶ Setting this equal to the approximation of the risky outcome gives

$$\Pi = \frac{1}{2} \left(-\frac{\frac{\partial^2 U(\mathbf{E}[V])}{\partial V^2}}{\frac{\partial U(\mathbf{E}[V])}{\partial V}} \right) \text{Var} [V]$$

- ▶ The **risk premium** is increasing in the risk and the risk aversion

Approximating the safe outcome

- ▶ We use a linear approximation of the expected utility of the individual facing a safe outcome
- ▶ We use the expected value as a starting point and then make a linear adjustment
- ▶ $U(\mathbf{E}[V] - \Pi) = U(\mathbf{E}[V]) + \frac{\partial U(\mathbf{E}[V])}{\partial V} \Pi$
- ▶ Setting this equal to the approximation of the risky outcome gives

$$\Pi = \frac{1}{2} \left(-\frac{\frac{\partial^2 U(\mathbf{E}[V])}{\partial V^2}}{\frac{\partial U(\mathbf{E}[V])}{\partial V}} \right) \text{Var} [V]$$

- ▶ The risk premium is increasing in the risk and the risk aversion

Arrow-Pratt measure of risk aversion

Arrow-Pratt measure of risk aversion

- ▶ We define $z = -\frac{\frac{\partial^2 U(E[V])}{\partial V^2}}{\frac{\partial U(E[V])}{\partial V}}$ as the **Arrow-Pratt measure of absolute risk aversion**

Arrow-Pratt measure of risk aversion

- ▶ We define $z = -\frac{\partial^2 U(E[V])}{\partial V^2}$ as the Arrow-Pratt measure of absolute risk aversion
- ▶ The more risk averse an individual is, the higher the risk premium: $\Pi = \frac{1}{2}z\text{Var}[V]$

Arrow-Pratt measure of risk aversion

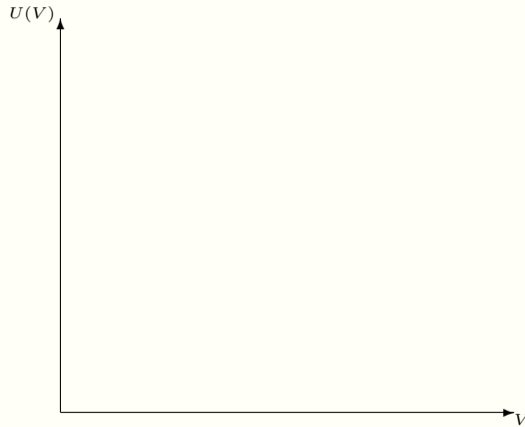
- ▶ We define $z = -\frac{\partial^2 U(E[V])}{\partial V^2}$ as the Arrow-Pratt measure of absolute risk aversion
- ▶ The more risk averse an individual is, the higher the risk premium: $\Pi = \frac{1}{2}z\text{Var}[V]$
- ▶ The second derivative of the utility function reflects the **curvature** of the utility function

Arrow-Pratt measure of risk aversion

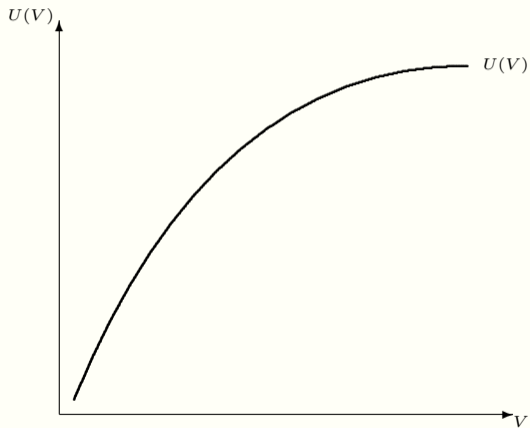
- ▶ We define $z = -\frac{\partial^2 U(E[V])}{\partial V^2}$ as the Arrow-Pratt measure of absolute risk aversion
- ▶ The more risk averse an individual is, the higher the risk premium: $\Pi = \frac{1}{2}z\text{Var}[V]$
- ▶ The second derivative of the utility function reflects the curvature of the utility function

Risk premium with two outcomes

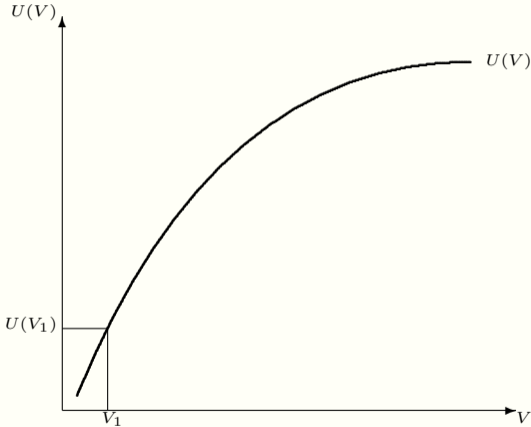
Risk premium with two outcomes



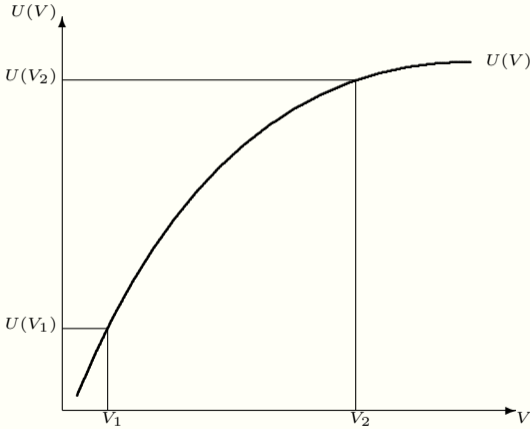
Risk premium with two outcomes



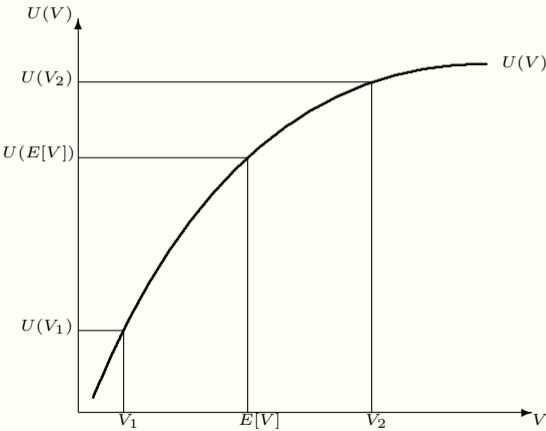
Risk premium with two outcomes



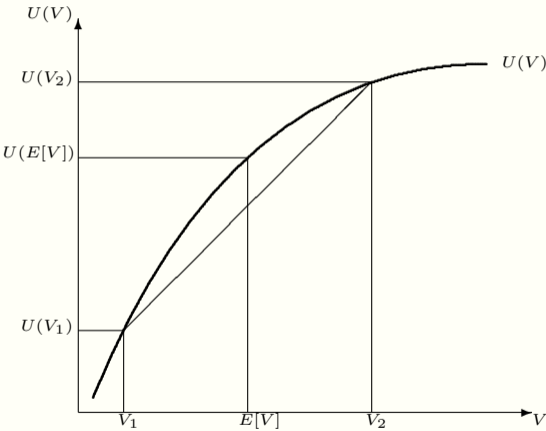
Risk premium with two outcomes



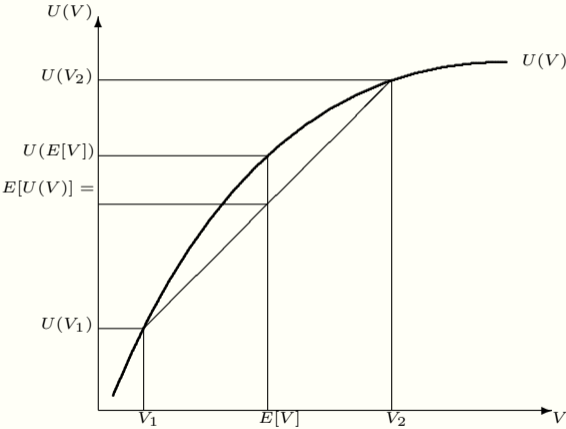
Risk premium with two outcomes



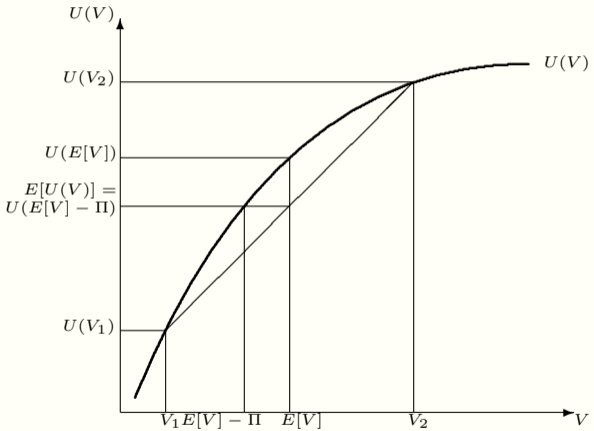
Risk premium with two outcomes



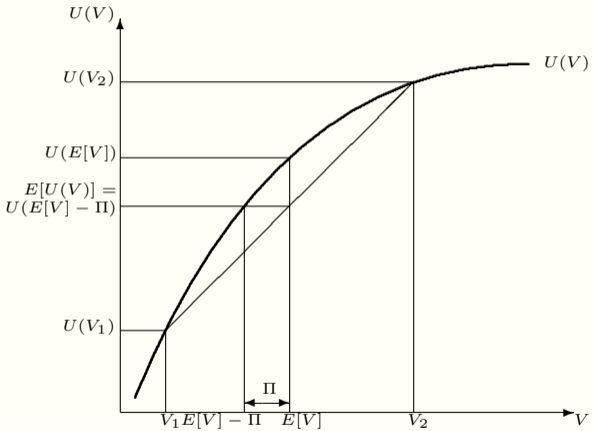
Risk premium with two outcomes



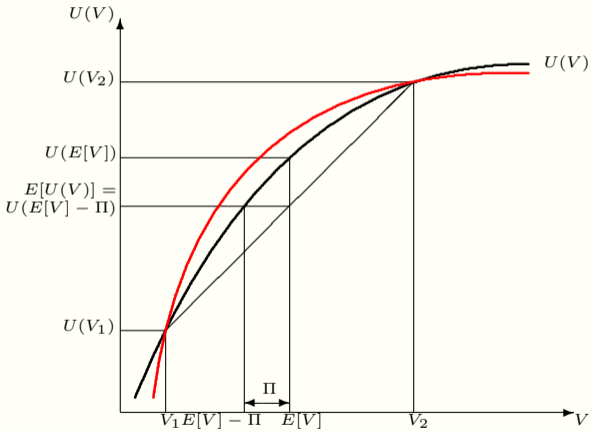
Risk premium with two outcomes



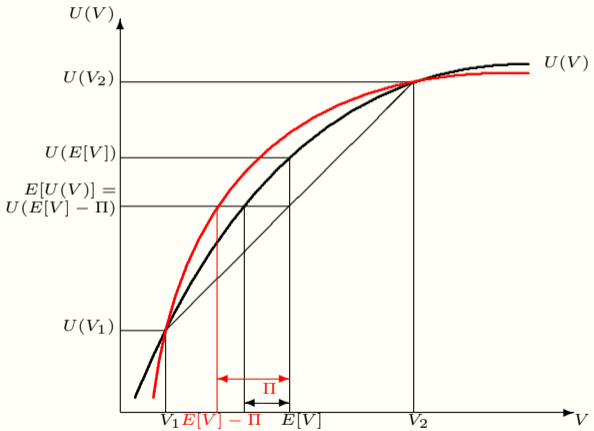
Risk premium with two outcomes



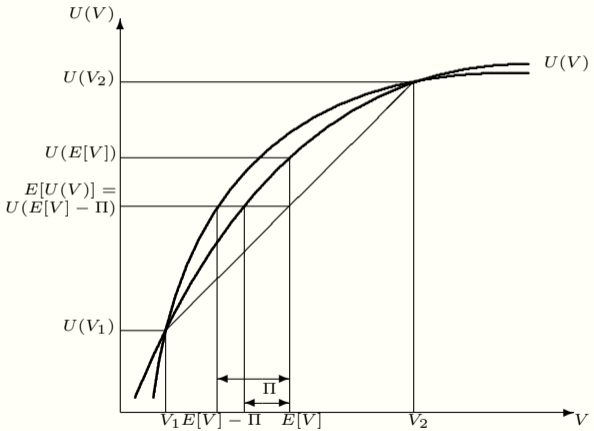
Risk premium with two outcomes



Risk premium with two outcomes



Risk premium with two outcomes



Approximating expected utility

Approximating expected utility

- ▶ We have the expected utility given as $E[U(V)] = U(E[V] - \Pi)$

Approximating expected utility

- ▶ We have the expected utility given as $E[U(V)] = U(E[V] - \Pi)$
- ▶ The risk premium was $\Pi = \frac{1}{2}z\text{Var}[V]$

Approximating expected utility

- ▶ We have the expected utility given as $E[U(V)] = U(E[V] - \Pi)$
 - ▶ The risk premium was $\Pi = \frac{1}{2}z\text{Var}[V]$
- $\Rightarrow E[U(V)] = U(E[V] - \frac{1}{2}z\text{Var}[V])$

Approximating expected utility

- ▶ We have the expected utility given as $E[U(V)] = U(E[V] - \Pi)$
- ▶ The risk premium was $\Pi = \frac{1}{2}z\text{Var}[V]$
- ⇒ $E[U(V)] = U(E[V] - \frac{1}{2}z\text{Var}[V])$
- ▶ As marginal utility is positive, we can often maximize expected utility by maximizing only the argument $E[V] - \frac{1}{2}z\text{Var}[V]$

Approximating expected utility

- ▶ We have the expected utility given as $E[U(V)] = U(E[V] - \Pi)$
- ▶ The risk premium was $\Pi = \frac{1}{2}z\text{Var}[V]$
- ⇒ $E[U(V)] = U(E[V] - \frac{1}{2}z\text{Var}[V])$
- ▶ As marginal utility is positive, we can often maximize expected utility by maximizing only the argument $E[V] - \frac{1}{2}z\text{Var}[V]$
- ▶ We can maximize expected utility **without** knowing the utility function

Approximating expected utility

- ▶ We have the expected utility given as $E[U(V)] = U(E[V] - \Pi)$
- ▶ The risk premium was $\Pi = \frac{1}{2}z\text{Var}[V]$
- ⇒ $E[U(V)] = U(E[V] - \frac{1}{2}z\text{Var}[V])$
- ▶ As marginal utility is positive, we can often maximize expected utility by maximizing only the argument $E[V] - \frac{1}{2}z\text{Var}[V]$
- ▶ We can maximize expected utility without knowing the utility function, we only require the **risk aversion**

Approximating expected utility

- ▶ We have the expected utility given as $E[U(V)] = U(E[V] - \Pi)$
- ▶ The risk premium was $\Pi = \frac{1}{2}z\text{Var}[V]$
- ⇒ $E[U(V)] = U(E[V] - \frac{1}{2}z\text{Var}[V])$
- ▶ As marginal utility is positive, we can often maximize expected utility by maximizing only the argument $E[V] - \frac{1}{2}z\text{Var}[V]$
- ▶ We can maximize expected utility without knowing the utility function, we only require the risk aversion

Summary

Summary

- ▶ Risk aversion measures the **attitude** towards risk

Summary

- ▶ Risk aversion measures the attitude towards risk
- ▶ Risk aversion will be dependent on the **preferences** of individuals

Summary

- ▶ Risk aversion measures the attitude towards risk
- ▶ Risk aversion will be dependent on the preferences of individuals
- ▶ **Risk** itself can be measured objectively through the variance

Summary

- ▶ Risk aversion measures the attitude towards risk
- ▶ Risk aversion will be dependent on the preferences of individuals
- ▶ Risk itself can be measured objectively through the variance



Copyright © by Andreas Krause

Picture credits:

Cover: Premier regard, Public domain, via Wikimedia Commons, [https://commons.wikimedia.org/wiki/File:DALL-E_-_Financial_markets_\(1\).jpg](https://commons.wikimedia.org/wiki/File:DALL-E_-_Financial_markets_(1).jpg)

Back: Rhododendrites, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons, [https://upload.wikimedia.org/wikipedia/commons/0/04/Manhattan_at_night_south_of_Rockefeller_Center_panorama_\(11263p\).jpg](https://upload.wikimedia.org/wikipedia/commons/0/04/Manhattan_at_night_south_of_Rockefeller_Center_panorama_(11263p).jpg)

Andreas Krause
Department of Economics
University of Bath
Claverton Down
Bath BA2 7AY
United Kingdom

E-mail: mnsak@bath.ac.uk