

EE432 Monetary Theory and Policy



Lecture 2 Understanding Risk
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Outline

- Risk Defining and Measuring
- Source of risk and risk reducing

Chapter 5

Understanding Risk

Risk Defining and Measuring

Defining Risk

- Risk is “*the possibility of loss.*”
- For outcomes of financial and economic decisions

Risk is a measure of **uncertainty** about the **future payoff** to an investment, **assessed over some time horizon and relative to a benchmark.**

Defining Risk

1. Risk is a ***measure*** that *can be quantified*.
 - The ***riskier*** the investment, the ***less desirable*** and the ***lower the price***.
2. Risk arises from ***uncertainty about the future***.
 - We do not know ***which of many possible outcomes will follow in the future***.
3. Risk has to do with the ***future payoff of an investment***.
 - We must imagine all the **possible payoffs** and the **likelihood** of each.

Defining Risk

4. *Definition of risk refers to an **investment** or group of investments.*
 - Investment described very broadly.
5. **Risk must be assessed over some *time horizon*.**
 - In general, risk over *shorter periods* is *lower*.
6. **Risk must be measured *relative to some benchmark* - not in isolation.**
 - A good **benchmark** is the *performance of a group of experienced investment advisors* or money managers.

Measuring Risk

- In determining *expected inflation* or *expected return*, we need to understand **expected value**.
 - The investments return out of *all possible values*.

Possibilities, Probabilities, and Expected Value

- **Probability theory** states that considering uncertainty requires:
 - Listing *all* the ***possible outcomes***.
 - Figuring out the ***chance of each one occurring***.
- **Probability** is a ***measure of the likelihood*** that an ***event will occur***.
 - It is always **between zero and one**.
 - Can also be *stated as frequencies*.

Possibilities, Probabilities, and Expected Value

- We can construct a table of all **outcomes** and **probabilities** for an *event*, like tossing a fair coin.

Table 5.1

A Simple Example: All Possible Outcomes of a Single Coin Toss

Possibilities	Probability	Outcome
#1	$\frac{1}{2}$	Heads
#2	$\frac{1}{2}$	Tails

Possibilities, Probabilities, and Expected Value

- If constructed correctly, *the values in the **probabilities** column will sum to one.*
- Assume instead we have an **investment** that *can rise or fall* in value.
 - \$1,000 stock which can *rise to \$1,400 or fall to \$700*.
 - The amount you could get back is the **investment's payoff**.
 - We can construct a similar table and determine the investment's **expected value** - *the average or most likely outcome*.

Possibilities, Probabilities, and Expected Value

Table 5.2

Investing \$1,000: Case 1

Possibilities	Probability	Payoff	Payoff × Probability
#1	$\frac{1}{2}$	\$ 700	\$350
#2	$\frac{1}{2}$	\$1,400	\$700
Expected value = Sum of (Probability × Payoff) = \$1,050			

- **Expected value** is the *mean* - the sum of their probabilities multiplied by their payoffs.

$$\text{Expected Value} = 1/2(\$700) + 1/2(\$1,400) = \$1,050$$

Possibilities, Probabilities, and Expected Value

Now, suppose there are more possible factors (events), which could affect the outcomes.

The payoffs from investment in \$1,000 now vary as following outcomes

1. *Rise in value to \$2,000, with probability of 0.1*
2. *Rise in value to \$1,400, with probability of 0.4*
3. *Fall in value to \$700, with probability of 0.4*
4. *Fall in value to \$100, with probability of 0.1*

Possibilities, Probabilities, and Expected Value

Table 5.3

Investing \$1,000: Case 2

Possibilities	Probability	Payoff	Payoff × Probability
#1	0.1	\$ 100	\$ 10
#2	0.4	\$ 700	\$280
#3	0.4	\$1,400	\$560
#4	0.1	\$2,000	\$200

Expected value = Sum of (Probability × Payoff) = \$1,050

Expected Value =

$$0.1 \times (\$100) + 0.4 \times (\$700) + 0.4 \times (\$1,400) + 0.1 \times (\$2,000) = \$1,050$$

Possibilities, Probabilities, and Expected Value

- Using percentages allows ***comparison of returns*** regardless of the size of initial investment.
 - The **expected return** in *both cases* is \$50 on a \$1,000 investment, or *5 percent*.
- Are the two investments the same?
 - No - the ***second investment*** *has a wider range of payoffs*, causing by **more volatilities**
- **Variability** equals **risk**.

Measures of Risk

- It seems intuitive that the wider the range of *outcomes*, the greater the risk.
- A **risk free asset** is an investment whose *future value is known with certainty and whose return is the risk free rate of return.*
 - The **payoff** you receive is guaranteed and *not varied*
- **Measuring the spread** allows us to **measure the risk.**

Variance and Standard Deviation

The variance is the *average of the squared deviations of the possible outcomes* from their *expected value*, weighted by their *probabilities*.

1. Compute **expected value**.
2. **Subtract expected value** from each of the **possible payoffs** and **square the result**.
3. **Multiply** each result *times* the **probability**.
4. **Add up** the results.

Variance and Standard Deviation

Refer to previous example

Investing \$1,000: Case 1

Table 5.2

Investing \$1,000: Case 1

Possibilities	Probability	Payoff	Payoff × Probability
#1	$\frac{1}{2}$	\$ 700	\$350
#2	$\frac{1}{2}$	\$1,400	\$700
Expected value = Sum of (Probability × Payoff) = \$1,050			

Variance and Standard Deviation

1. Compute the **expected value**:

$$(\$1400 \times \frac{1}{2}) + (\$700 \times \frac{1}{2}) = \$1,050.$$

2. **Subtract** this **from each of the possible payoffs** and then **square** the results:

$$\$1,400 - \$1,050 = (\$350)^2 = 122,500 \text{ (dollars)}^2 \text{ and}$$

$$\$700 - \$1,050 = (-\$350)^2 = 122,500 \text{ (dollars)}^2$$

3. **Multiply each result** *times* its **probability**, and **add up the results**:

$$\frac{1}{2} [122,500(\text{dollars})^2] + \frac{1}{2} [122,500(\text{dollars})^2] = 122,500(\text{dollars})^2$$

4. The **Standard deviation** is the ***square root of the variance***:

$$= \sqrt{\text{Variance}} = \sqrt{122,500 \text{ dollars}^2} = \$350$$

Variance and Standard Deviation

Refer to another example

Investing \$1,000: Case 2 (more volatility)

Table 5.3

Investing \$1,000: Case 2

Possibilities	Probability	Payoff	Payoff × Probability
#1	0.1	\$ 100	\$ 10
#2	0.4	\$ 700	\$280
#3	0.4	\$1,400	\$560
#4	0.1	\$2,000	\$200
Expected value = Sum of (Probability × Payoff) = \$1,050			

Variance and Standard Deviation

1. Compute the **expected value**:

$$0.1 \times (\$100) + 0.4 \times (\$700) + 0.4 \times (\$1,400) + 0.1 \times (\$2,000) = \$1,050$$

2. **Subtract** this **from each of the possible payoffs** and then **square** the results:

$$\$100 - \$1,050 = (-\$950)^2 = 902,500(\text{dollars})^2$$

$$\$700 - \$1,050 = (-\$350)^2 = 122,500(\text{dollars})^2$$

$$\$1,400 - \$1,050 = (\$350)^2 = 122,500(\text{dollars})^2$$

$$\$2,000 - \$1,050 = (\$950)^2 = 902,500(\text{dollars})^2$$

3. **Multiply each result** *times* its **probability**, and **add up the results**:

$$0.1 \times (\$902,500) + 0.4 \times (\$122,500) + 0.4 \times (\$122,500) + 0.1 \times (\$902,500) = \$278,500$$

4. The **Standard deviation** is the **square root of the variance**:

$$\text{Standard deviation} = \sqrt{\text{variance}} = \sqrt{278,500} = 528$$

Variance and Standard Deviation

- **Standard deviation** is the *(positive) square root of the variance*

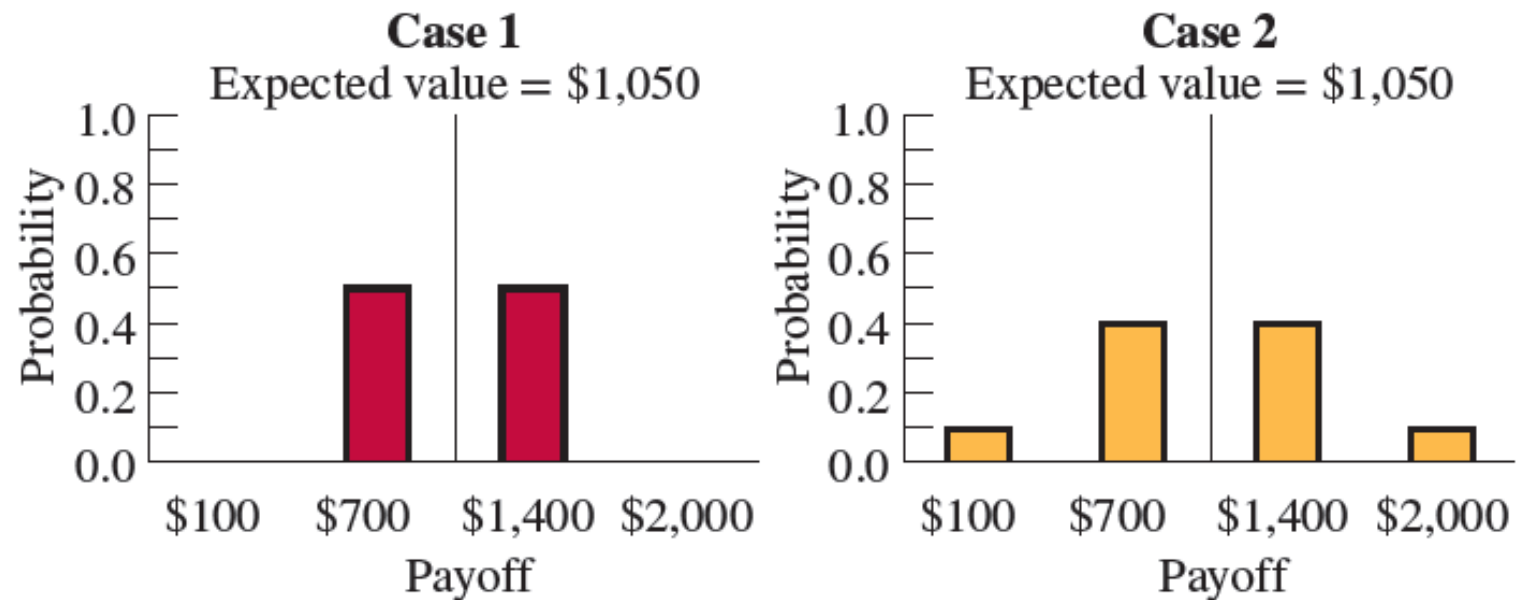
$$\text{standard deviation} = \sqrt{\text{Variance}}$$

- The **standard deviation** is more useful because it deals in *normal units*, not squared units (like dollars-squared).
- We can **calculate standard deviation** into a **percentage of the initial investment**.
- We can *compare other investments* to this one.
- *Given a choice between two investments with equal expected payoffs*, most will **choose the one with the lower standard deviation**.
 - *The greater the standard deviation, the higher the risk.*

Variance and Standard Deviation

Figure 5.1

Investing \$1,000



- We can see **Case 2 is more spread out** - *higher standard deviation* - therefore it carries **more risk**.

Value at Risk

- Sometimes we are *less concerned with spread* than with the **worst possible outcome**
 - Example: We don't want a bank to fail
- **Value at Risk (VaR)**: The **worst possible loss** over a *specific horizon* at a *given probability*.

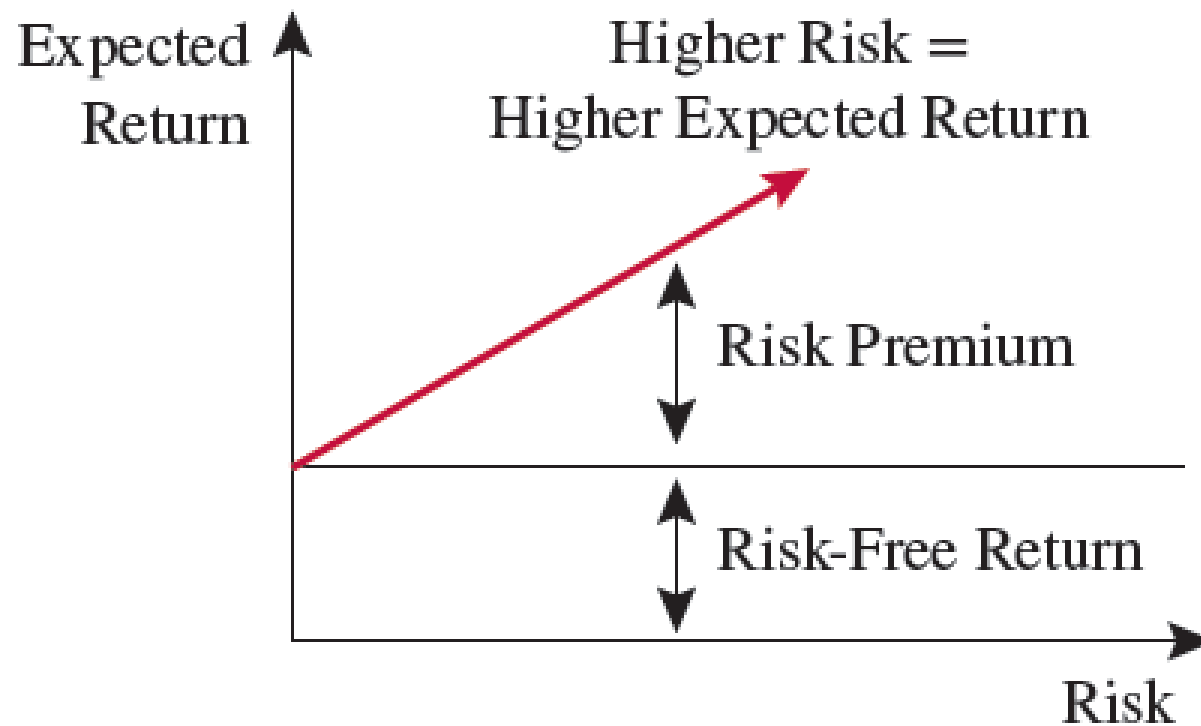
Value at Risk

- For a *mortgage*, the **worst-case scenario** means you ***cannot afford your mortgage*** and will ***lose you home***.
 - *Expected value and standard deviation do not really **tell** you the **risk** you face, in this case.*
- **VaR** answers the question: ***how much will I lose*** if the *worst possible scenario* occurs?
 - *Sometimes this is the most important question.*

Risk Aversion, the Risk Premium, and the Risk-Return Tradeoff

- Most people do not like **risk** and will **pay to avoid** it because most of us are **risk averse**.
 - *Insurance* is a good example of this.
- A **risk averse** investor will always *prefer an investment with a certain return* to one with the same expected return but *any amount of uncertainty*.
- Therefore, the *riskier an investment*, the **higher the risk premium**.
 - The **compensation** investors **required to hold the risky asset**.

Risk Aversion, the Risk Premium, and the Risk-Return Tradeoff



Source of Risk and Risk Reducing

Sources of Risk: Idiosyncratic and Systematic Risk

All **risks** can be classified into two groups:

1. Those *affecting a small number of people* but no one else:

Idiosyncratic or *unique risks*

2. Those *affecting everyone*:

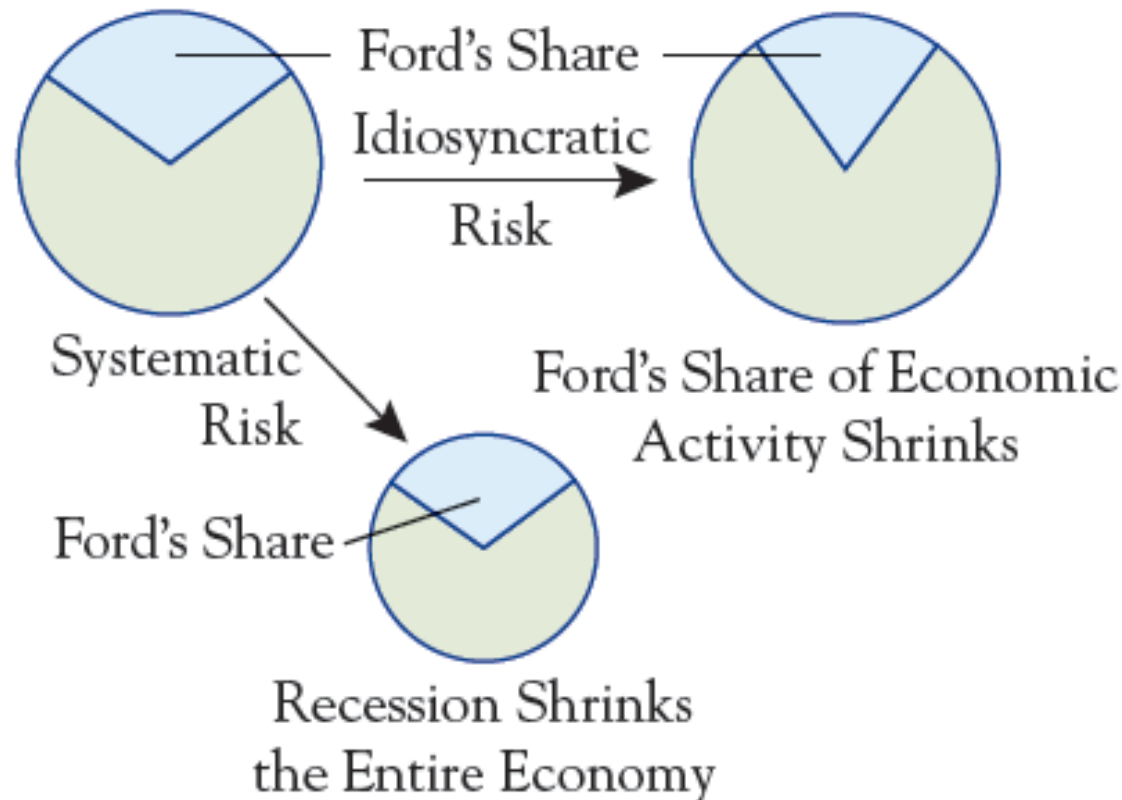
Systematic or *economy-wide risks*

Sources of Risk: Idiosyncratic and Systematic Risk

Idiosyncratic risks can be classified into two types:

1. A **risk** is **bad for one sector** of the economy but good for another.
 - A rise in oil prices is **bad for car industry** but **good for the energy industry**.
2. **Unique risks** **specific to one person or company** and no one else.

Sources of Risk: Idiosyncratic and Systematic Risk



Reducing Risk through Diversification

- Some people take on so much risk that a **single big loss** can wipe them out.
 - Traders call this “**blowing up.**”
- Risk can be *reduced through* **diversification**, the principle of **holding more than one risk** at a time.
 - This **reduces the idiosyncratic risk** an investor bears.
- One can ***hedge*** risks or ***spread*** them among many investments.

Hedging Risk

- **Hedging** is the strategy of *reducing idiosyncratic risk* by *making two investments with opposing risks*.
- Let's compare three strategies for investing \$100:
 - Invest \$100 in GE – *an alternative energy producer*
 - Invest \$100 in Texaco – *a carbon-based fuel producer*
 - And “hedging”; invest half in each company – *splitting investment between two stocks with different payoff patterns to eliminate risk*

Hedging Risk

Table 5.6

Results of Possible Investment Strategies: Hedging Risk

Initial Investment = \$100

Investment Strategy	Expected Payoff	Standard Deviation
GE only	\$110	\$10
Texaco only	\$110	\$10
$\frac{1}{2}$ and $\frac{1}{2}$	\$110	\$0

- In the last row:
- We invest \$50 in each stock to ensure our payoff, which called “**Hedging**” to *eliminate risk entirely*.
- ***Hedging*** is a position undertaken by an investor that would eliminate the risk of an existing position, which needs **a perfectly negative correlation**

Single Stock Investment

In this case, we may **invest in each stock**; GE or TEXACO individually

Another way, we can also **invest in a bundle of both stocks** as a **portfolio**

Case1: Invest in GE

Assuming that,
when the oil price decrease, investor will receive \$120

	Probability	Payoff	Payoff x Probability
Oil price increase	0.5	\$100	\$50
Oil price decrease	0.5	\$120	\$60

$$\text{Expected Value} = 0.5(\$100) + 0.5(\$120) = \$110$$

Single Stock Investment

Case1: Invest in GE

1. Compute the **expected value**:

$$0.5(\$100) + 0.5(\$120) = \$110$$

2. **Subtract** this **from each of the possible payoffs** and then **square** the results:

$$\$100 - \$110 = (-\$10)^2 = 100 \text{ (dollars)}^2 \text{ and}$$

$$\$120 - \$110 = (\$10)^2 = 100 \text{ (dollars)}^2$$

3. **Multiply each result** *times* its **probability**, and **add up the results**:

$$0.5 [100 \text{ (dollars)}^2] + 0.5 [100 \text{ (dollars)}^2] = 100 \text{ (dollars)}^2$$

4. The **Standard deviation** is the **square root of the variance**:

$$\text{Standard deviation} = \sqrt{\text{variance}} = \sqrt{100} = 10$$

Single Stock Investment

Case2: Invest in TEXACO

Assuming that,
when the oil price increase, investor will receive \$120

	Probability	Payoff	Payoff x Probability
Oil price increase	0.5	\$120	\$60
Oil price decrease	0.5	\$100	\$50

$$\text{Expected Value} = 0.5(\$120) + 0.5(\$100) = \$110$$

Single Stock Investment

Case2: Invest in TEXACO

1. Compute the **expected value**:

$$0.5(\$120) + 0.5(\$100) = \$110$$

2. **Subtract** this **from each of the possible payoffs** and then **square** the results:

$$\$120 - \$110 = (\$10)^2 = 100 \text{ (dollars)}^2 \text{ and}$$

$$\$100 - \$110 = (-\$10)^2 = 100 \text{ (dollars)}^2$$

3. **Multiply each result** *times* its **probability**, and **add up the results**:

$$0.5 [100 \text{ (dollars)}^2] + 0.5 [100 \text{ (dollars)}^2] = 100 \text{ (dollars)}^2$$

4. The **Standard deviation** is the **square root of the variance**:

$$\text{Standard deviation} = \sqrt{\text{variance}} = \sqrt{100} = 10$$

Portfolio Investment: Hedging

Now, let we **invest half in GE** and **another half in TEXACO** as a **portfolio** with the following probability

And the **payoff is half** as big *as compared to single stock*

	Probability	GE	TEXACO	Payoff
Oil price increase	0.5	\$50	\$60	\$110
Oil price decrease	0.5	\$60	\$50	\$110

$$\text{Expected Value} = 0.5(\$110) + 0.5(\$110) = \$110$$

Portfolio Investment: Hedging

1. Compute the **expected value**:

$$0.5(\$110) + 0.5(\$110) = \$110$$

2. **Subtract** this **from each of the possible payoffs** and then **square** the results:

$$\$110 - \$110 = (\$0)^2 = 0 \text{ (dollars)}^2 \text{ and}$$

$$\$110 - \$110 = (\$0)^2 = 0 \text{ (dollars)}^2$$

3. **Multiply each result** *times* its **probability**, and **add up the results**:

$$\frac{1}{2} [0 \text{ (dollars)}^2] + \frac{1}{2} [0 \text{ (dollars)}^2] = 0 \text{ (dollars)}^2$$

4. The **Standard deviation** is the ***square root of the variance***:

$$\text{Standard deviation} = \sqrt{\text{variance}} = \sqrt{0} = 0$$

Spreading Risk

- You can't always hedge as *investments don't always move in a predictable fashion.*
- The *alternative* is to **spread risk** around.
 - Find investments *whose payoffs are unrelated.*
 - ***Unrelated diversification** occurs when a firm lacks any similarities with other firms, implying **no linear correlation or random***
- We need to look at ***the probabilities and associated payoffs of different investments.***

Spreading Risk

- Let's again compare three strategies for investing \$100:
 - Invest \$100 in GE.
 - Invest \$100 in Microsoft.
 - Invest half in each company – *there will be 4 possible outcomes*

Table 5.7

Payoffs from Investing \$50 in Each of Two Stocks

Initial Investment = \$100

Possibilities	GE	Microsoft	Total Payoff	Probability
#1	\$60	\$60	\$120	$\frac{1}{4}$
#2	\$60	\$50	\$110	$\frac{1}{4}$
#3	\$50	\$60	\$110	$\frac{1}{4}$
#4	\$50	\$50	\$100	$\frac{1}{4}$

Single Stock Investment

Again, we may **invest in each stock**; GE or Microsoft (MS) individually

Or we **invest in both stocks** as a **portfolio**

For **Case1: Invest in GE** and **Case2: Invest in Microsoft (MS)**,
The *expected value, standard deviation and variance* for investing in **GE** are the ***same as we have seen before***.

Assuming that, the **payoffs** of these stocks are **independent** and **unrelated**. In the ***good time, investor will receive \$120***

Case 2: Invest in MS	Probability	Payoff	Payoff x Probability
Good time for MS	0.5	\$120	\$60
Otherwise	0.5	\$100	\$50

$$\text{Expected Value} = 0.5(\$100) + 0.5(\$120) = \$110$$

Single Stock Investment

Case2: Invest in Microsoft (MS)

1. Compute the **expected value**:

$$0.5(\$100) + 0.5(\$120) = \$110$$

2. **Subtract** this from each of the possible payoffs and then **square** the results:

$$\$120 - \$110 = (\$10)^2 = 100 \text{ (dollars)}^2 \text{ and}$$

$$\$100 - \$110 = (-\$10)^2 = 100 \text{ (dollars)}^2$$

3. **Multiply each result** *times* its **probability**, and **add up the results**:

$$0.5 [100 \text{ (dollars)}^2] + 0.5 [100 \text{ (dollars)}^2] = 100 \text{ (dollars)}^2$$

4. The **Standard deviation** is the **square root of the variance**:

$$\text{Standard deviation} = \sqrt{\text{variance}} = \sqrt{100} = 10$$

(For Case 1: Invest in GE, the results are similar to the previous example)

Portfolio Investment: Spreading

Besides, we also **invest half in GE** and **another half in Microsoft (MS)** as a **portfolio** with the following probability

And the **payoff is half** as big *as compared to single stock*

The ***possible outcomes would be two for each stock*** (Good time vs Otherwise).

Then, **there would be a combination of four possible outcomes.**

	Probability	GE	MS	Payoff
#1	0.25	\$60	\$60	\$120
#2	0.25	\$60	\$50	\$110
#3	0.25	\$50	\$60	\$110
#4	0.25	\$50	\$50	\$100

$$\text{Expected Value} = 0.25(\$120) + 0.25(\$110) + 0.25(\$110) + 0.25(\$100) = \$110$$

Portfolio Investment: Spreading

1. Compute the **expected value**:

$$0.25(\$120) + 0.25(\$110) + 0.25(\$110) + 0.25(\$100) = \$110$$

2. **Subtract** this **from each of the possible payoffs** and then **square** the results:

$$\$120 - \$110 = (\$0)^2 = 100 \text{ (dollars)}^2$$

$$\$110 - \$110 = (\$0)^2 = 0 \text{ (dollars)}^2$$

$$\$110 - \$110 = (\$0)^2 = 0 \text{ (dollars)}^2 \text{ and}$$

$$\$100 - \$110 = (-\$10)^2 = 100 \text{ (dollars)}^2$$

3. **Multiply each result** *times* its **probability**, and **add up the results**:

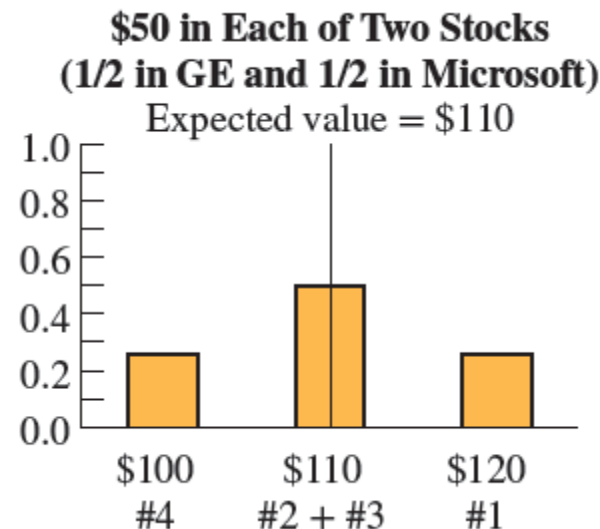
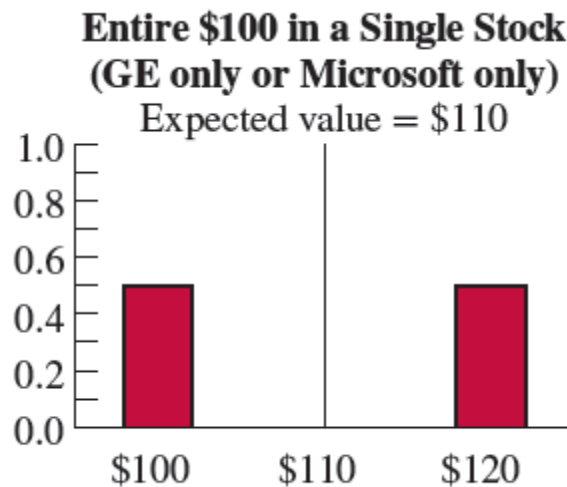
$$0.25 [100 \text{ (dollars)}^2] + 0.25[0 \text{ (dollars)}^2] + 0.25[0 \text{ (dollars)}^2] \\ + 0.25 [100 \text{ (dollars)}^2] = 50 \text{ (dollars)}^2$$

4. The **Standard deviation** is the ***square root of the variance***:

$$\text{Standard deviation} = \sqrt{\text{variance}} = \sqrt{50} = 7.1$$

Spreading Risk

- We can see the distribution of outcomes from the possible investment strategies.
- This figure clearly shows **spreading risk- (*diversifying*) lowers the spread of outcome and *lowers the risk (standard deviation)*.**



Spreading Risk

- The **more independent sources of risk** you hold in your portfolio, the **lower your overall risk**.
 - *Never put all eggs in one basket*
- As we add more and more independent sources of risk, the ***standard deviation becomes negligible***.
- **Diversification** through the ***spreading of risk*** is the ***basis for the insurance business***.

End of lecture