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 <u>not</u> 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 **<u>risk</u> 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 <u>outcomes</u>***.
  - **Figuring out** the ***<u>chance</u> 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*.

Expected Value = 1/2($700) + 1/2($1,400) = $1,050

Possibilities, Probabilities, and Expected Value

Now, suppose there are <u>more possible factors (events)</u>, 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 × ($100) + 0.4 × ($700) + 0.4 × ($1,400) +0.1 × ($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 x ½) + (\$700 x ½) = \$1,050.

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

   \$1,400 – \$1,050 = (\$350)^2 = 122,500 (dollars)^2 and

   \$700 – \$1,050 = (–\$350)^2 =122,500 (dollars)^2

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

   ½ [122,500(dollars)^2] + ½ [122,500(dollars)^2] =122,500(dollars)^2

4. The **Standard deviation** is the ***<u>square root of the variance</u>***:

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

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 × ($100) + 0.4 × ($700) + 0.4× ($1,400) +0.1× ($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(dollars)^2

   $700 – $1,050 = (–$350)^2 =122,500(dollars)^2

   $1,400 – $1,050 = ($350)^2 =122,500(dollars)^2

   $2,000 – $1,050 = ($950)^2 =902,500(dollars)^2

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

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

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

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

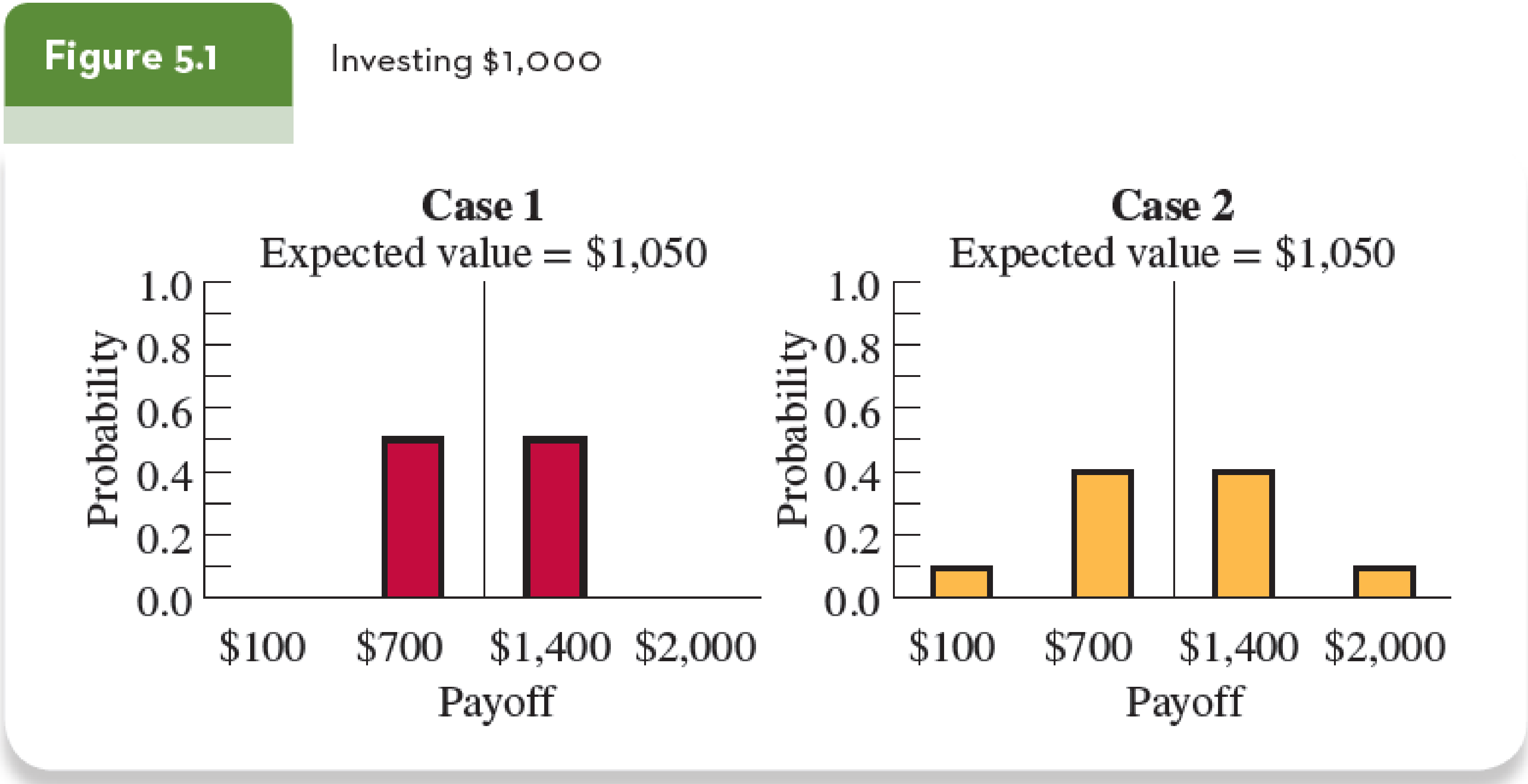
Variance and Standard Deviation

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

  standard deviation = $\sqrt{Variance}$

- 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 investmen**t.
- 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 <u>lower standard deviation</u>**.
  - The *greater the standard deviation*, the *higher the risk*.

Variance and Standard Deviation



• We can see **Case 2 is <u>more spread out</u>** - *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***.

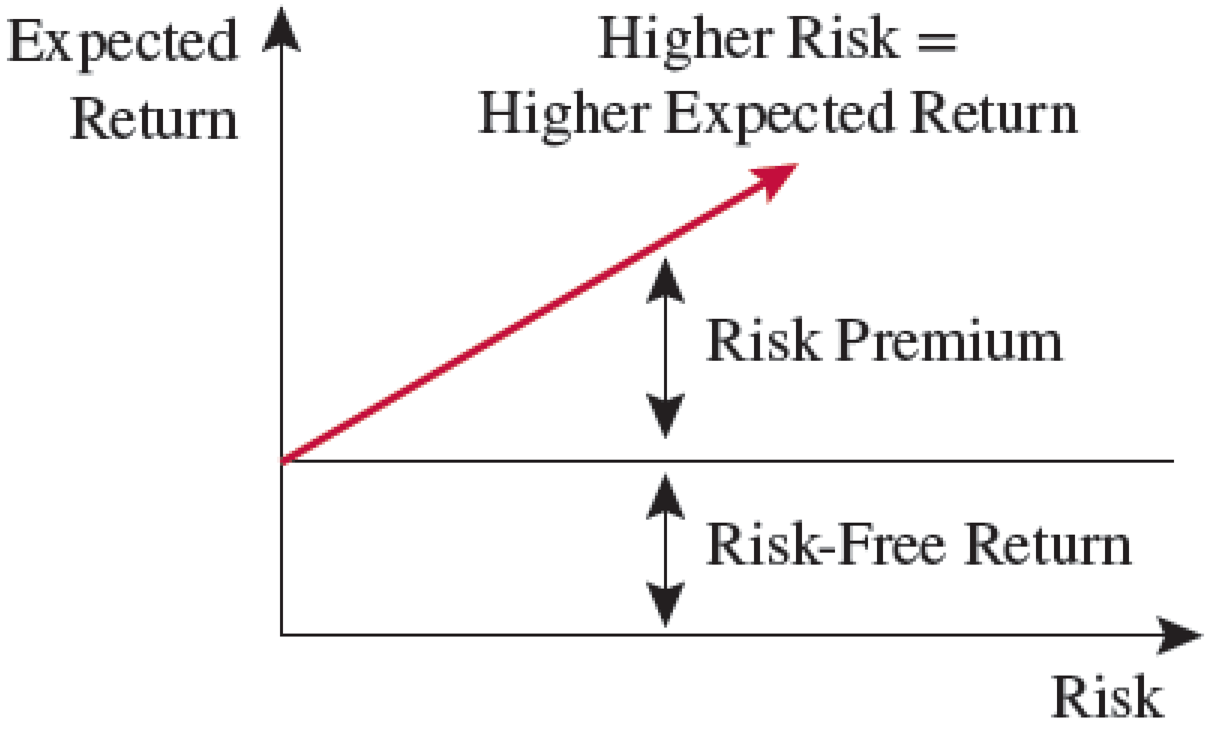
Value at Risk

- 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 <u>*classified*</u> *into two groups*:

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

    <u>Idiosyncratic</u> or *unique* **risks**

2. Those *affecting **everyone***:

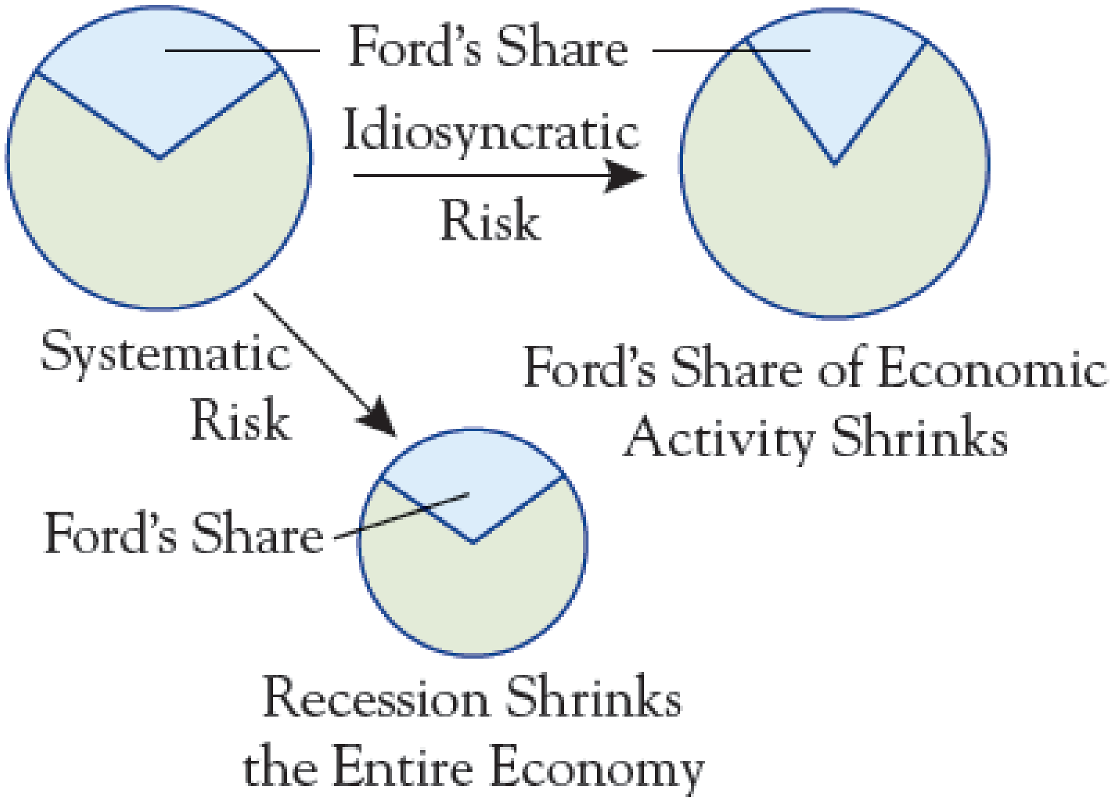
    <u>Systematic</u> or *economy-wide* **risks**

Sources of Risk: Idiosyncratic and Systematic Risk

Idiosyncratic risks can be classified into two types:

1. A ***risk*** *is* ***<u>bad for one sector</u>*** *of the economy* but good for another.
   - A **rise in oil prices** is ***<u>bad</u> for car industry*** but ***<u>good</u> for the energy industry.***
2. ***Unique risks*** *<u>specific to one</u> 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 **<u>portfolio</u>**

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

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 $(\text{dollars})^2$ 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 ***<u>square root of the variance</u>***:

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

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

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 (dollars)^2 and
   $100 – $110 = (–$10)^2 =100 (dollars)^2

3. **Multiply each result** *times* its **probability,** and **add up the results**:
   0.5 [100 (dollars)^2] + 0.5 [100 (dollars)^2] = 100 (dollars)^2

4. The **Standard deviation** is the ***<u>square root of the variance</u>***:

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

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

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 (dollars)^2 and

   $110 – $110 = ($0)^2 = 0 (dollars)^2

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

   ½ [0 (dollars)^2] + ½ [0 (dollars)^2] = 0 (dollars)^2

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

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

Spreading Risk

- You **can't always hedge** as ***investments <u>don't</u> always move in a predictable fashion***.
- The *alternative* is to **<u>spread risk</u>** around.
  - Find investments ***whose payoffs are <u>unrelated</u>***.
  - ***Unrelated diversification*** *occurs when <u>a firm lacks any similarities with other firms</u>, 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

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:
   $\$120 - \$110 = (\$10)^2 = 100\ (\text{dollars})^2$ 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***:
   Standard deviation = $\sqrt{variance} = \sqrt{100} = 10$

(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

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:

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

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

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

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

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

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

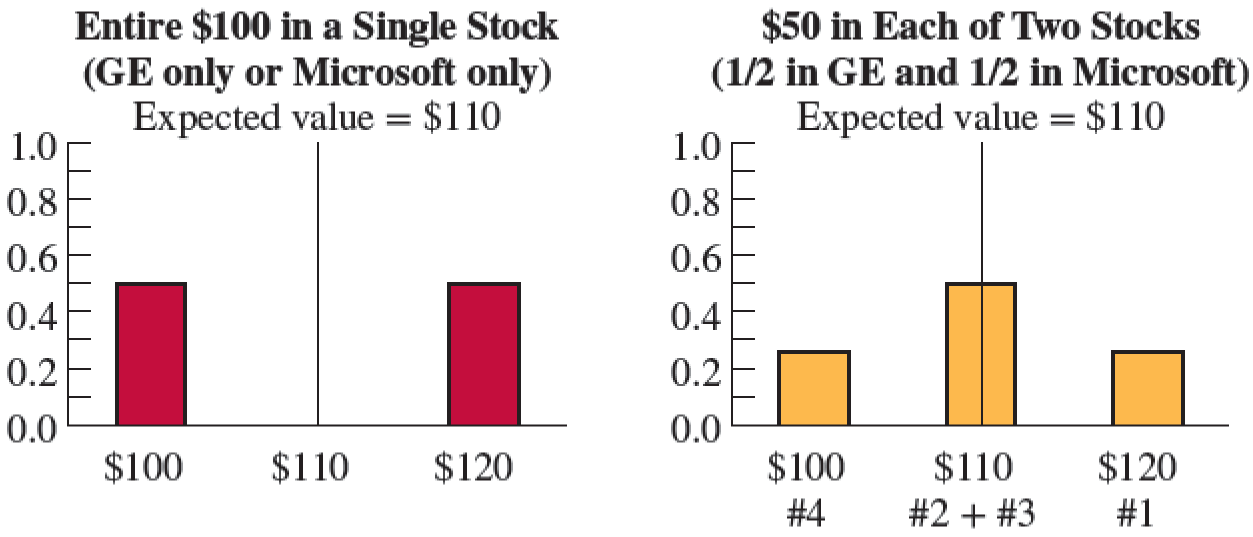
    $+ 0.25\ [100\ (\text{dollars})^2] = 50\ (\text{dollars})^2$

4. The **Standard deviation** is the ***<u>square root of the variance</u>***:

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

Spreading Risk

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