

Econ 301: Managerial Economics

Topic 1: The Fundamentals of Managerial Economics

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Foundations of Effective Management

7 Principles of Effective Managerial Decision Making

1. Identify goals and constraints.
2. Recognize the nature and importance of profits.
3. Understand incentives.
4. Understand markets.
5. Recognize the time value of money.
6. Use marginal analysis.
7. Make data-driven decisions.

1. Identify Goals and Constraints

- Goals must be well-defined (This is the case for everyone, not just for firms) .
- What is the goal of the firm?
 - Firm's overall goal is to maximize profits.

Constraints make it difficult to achieve goals.

- Available technology
- Prices of inputs used in production

2. Recognize the Nature and Importance of Profits

Firm's overall goal is to maximize profits.

Max Π

$$\max \Pi = TR - TC$$

- Example:
- Lamar sold 50 cups of lemonade for \$3 each. He spent \$40 on cups, lemons, sugar, and water.

2. Recognize the Nature and Importance of Profits

Accounting profit:

- total revenue – total explicit costs

However, economic profit differs from accounting profit.

• Economic Profit:

- total revenue – total explicit costs – total implicit costs
- Given that implicit costs are often non zero, economic
- profit is usually less than accounting profit.

2. Recognize the Nature and Importance of Profits

Accounting profit:

- total revenue – total explicit costs

However, economic profit differs from accounting profit.

For example, let's say I invite you for lunch and say that I will pay for your meal. Is this a “free” lunch?

2. Recognize the Nature and Importance of Profits

We almost always face trade-offs when making decisions (as a result of scarcity):

Trade-offs consist of the **entire** set of things we might have done.

2. Recognize the Nature and Importance of Profits

Economic Profit:

total revenue – total explicit costs – **total implicit costs**

Example: Time doesn't enter into 'total explicit costs', but there are always other things you can be doing with your limited time.

- Given that implicit costs are often non-zero, economic profit is usually less than accounting profit.

2. Recognize the Nature and Importance of Profits

In Economics, we think about costs as ‘opportunity costs’

- **Opportunity cost:** value of the best alternative = explicit cost (monetary) + implicit cost (foregone opportunity)
- We don't consider **sunk costs**, as part of the opportunity cost.
 - Costs incurred regardless of a decision
- **Opportunity Cost Example:**
 - If you study abroad for summer, explicit costs include travel, tuition,
 - Implicit cost includes the salary you gave up by not doing an internship
 - But what about spending on food? Suppose you spend \$30 per day on food in either scenario? How should we evaluate this?

2. Recognize the Nature and Importance of Profits

A quick detour:

Imagine that you bought a concert ticket a few weeks ago for \$50. Beyond the cost, you are super excited. All of your friends will be in attendance and the band playing is one of your favorites. However, on the day of the concert, you feel sick, and it's raining outside (classic mid-west cold weather). You know that traffic will be worse because of the rain and that you risk getting sicker by going to the concert.

Do you still go?

- Would your decision be different if you had received the ticket for free?

2. Recognize the Nature and Importance of Profits

- **Sunk Cost:** A cost that cannot be recovered.
 - In other words, no matter what decisions you take, that money is gone!

Optimally, we should ‘ignore’ sunk costs.

- It should not impact the decision in the present. Only the Marginal Benefit vs Marginal Cost of the present should matter.
- But people do ‘honor’ sunk costs– **sunk cost fallacy!**
- Sunk costs are used as *reasons* for decision making all the time.
 - There is literally a saying “In for a penny, in for a pound.”

2. Recognize the Nature and Importance of Profits

Suck Cost Fallacy Examples.

- An entrepreneur has invested \$50,000 in a failing restaurant over two years. Despite clear signs it won't succeed, they invest another \$20,000 because "I can't waste everything I've put into this."
- You paid \$15 for a movie ticket. After 30 minutes, you realize it's awful, but you stay for the remaining 90 minutes because "I already paid for it."
 - Michael Lewis on Amos Tversky *"If he didn't like a movie, he'd simply walk out – 'They've already taken my money. Should I give them my time, too?'" – The Undoing Project*
- An NFL team not cutting a player, simply because they spent a high draft pick on them.

A Return to a previous example

- When Lamar used his labor to produce and sell lemonade, that was not available for other uses (no opportunity cost of ingredients).
- If his best alternative if to play Madden, which would have generated enjoyment he values at \$30, then we need to include that as part of the cost of producing lemonade:
- $\Pi =$

What is the opportunity cost of attending college?

Question: If you go to college for four years, you will spend \$10,000 in tuition and \$1,250 in books each year and give up a job that would have paid you \$40,000 a year. What is your opportunity cost?

What is the opportunity cost of attending college?

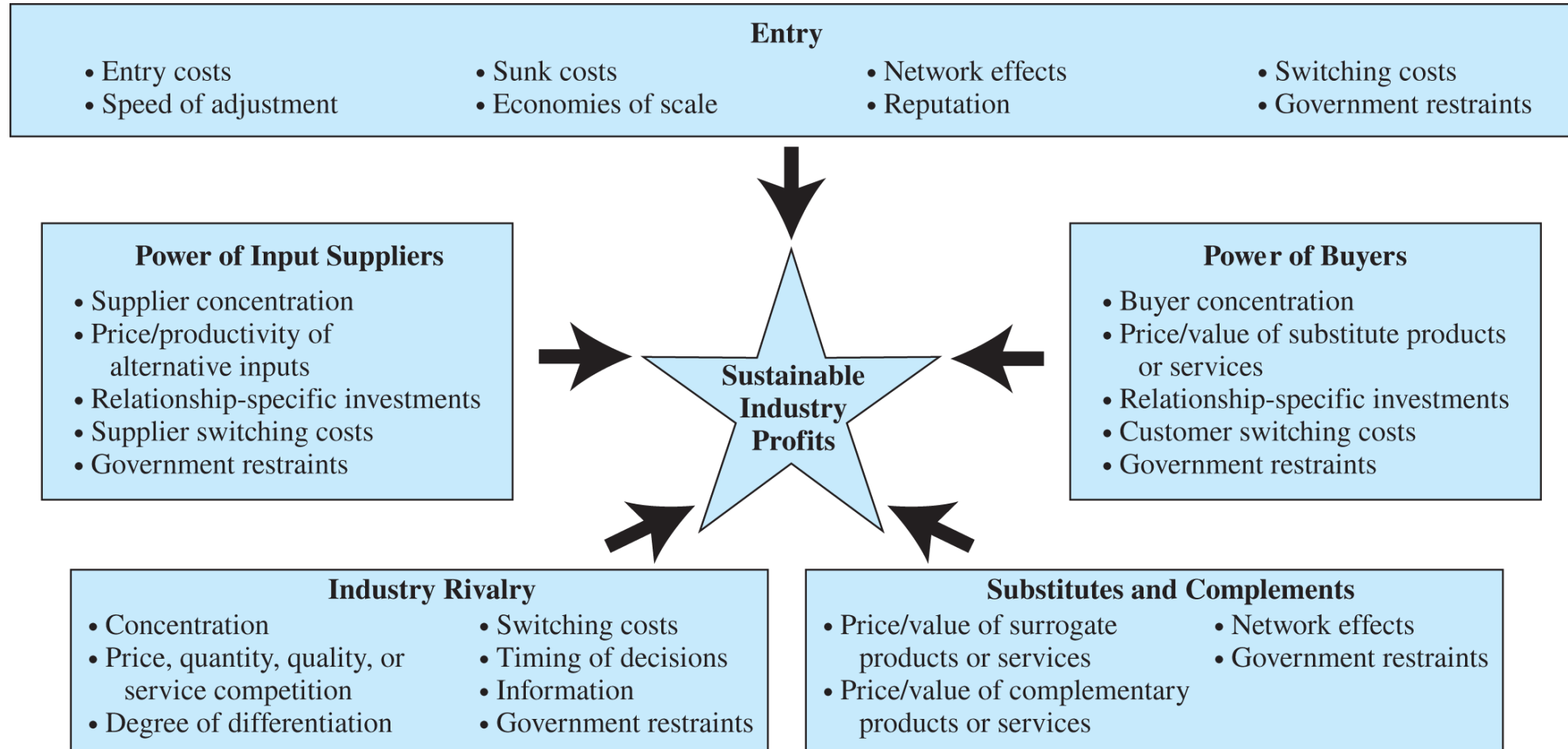
Question: If you go to college for four years, you will spend \$10,000 in tuition and \$1,250 in books each year and give up a job that would have paid you \$40,000 a year. What is your opportunity cost?

- What are you giving up?

What determines Profitability: The Five Forces Framework

- Entry
- Power of Buyers
- Power of Sellers
- Industry Rivalry
- Substitutes and Complements

What determines Profitability: The Five Forces Framework



- [Access the text alternative for slide images.](#)

Entry

- How hard or easy is it for other companies to start up and enter the industry.
- Lower barriers to entry reduce sustainability of profit in the long run. The easier a market/industry is to enter, the harder it will be to sustain economic profit
- Examples:
 - Food trucks are relatively easy to start
 - Creating new technologies (such as high-powered computers) are relatively hard to start.
 - Is starting a YouTube channel relatively easy or hard?

Power of Input Suppliers

- The more concentration of power in input markets (where you got your supplies from), the more difficult it is to sustain profit in the long run.
- Examples:
 - If you sell lemonade and there is only one producer of lemons in the whole world. They will charge a lot for lemons!
 - if labor union power increases -> workers have more power -> more leverage for higher wages.

Power of Buyers

- More concentration of power among consumers reduces sustainability of profit in the long run

Examples:

- If switching costs are low, this gives buyers more power (to choose another product)

Industry Rivalry

- The more intense rivalry there is, the less ability to sustain profit in the long run.

Examples:

- low price guarantees
- the less differentiated your product is from others
 - Coke vs Pepsi?
 - Trader Joes vs Payless?

Substitutes and Complements

- **Substitutes:** Goods that can be used in place of each other:
 - Butter and margarine
 - Netflix and Hulu
 - Pink Lady and Red Gala apples
- The more substitutes (in consumption) there are the less ability to sustain profit in the long run.
- **Complements:** Goods that are used or consumed together
 - Fries and dipping sauce
 - Shoes and socks
 - Cinema Ticket and Popcorn
- The less complementarities there are, less ability to sustain long run profit.
- Examples:
 - You make a video game console, but game makers don't make many games that work on your console
 - Netflix started as the only streaming service, now there a lot!

3. Understand Incentives

- Incentives (both positive & negative) usually influence our actions in **predictable** ways (caveat, we need to properly understand what motivates people).
- A common saying in economics is that “incentives matter”.
 - What do we mean by that?
- People will do things if their marginal benefit is greater than the marginal cost.
- For example:
 - Sales Commissions: This incentivizes workers to put in more effort (cost), since they receive more money (benefits) the more they sell
 - Policing Behavior: Increasing how often ticket inspectors go on a train will incentivize people to buy tickets more
- Within a firm, incentives impact how resources are used and how hard workers work.
 - One role of a manager is to construct incentives to induce maximal effort from employees.

3. Understand Incentives

- An unplanned result (usually **negative** and **unwanted**) of an incentive.

Perverse Incentives

- As we have discussed incentives matter
- However, if implemented in correctly, they can backfire. These are known as ***Perverse Incentives***
- In other words, the incentive can actually make the problem worse!

Window Tax

- In 1696 England implemented a window tax, where landlords were taxed 2 shillings for having a certain number of windows.
- Designed to be a tax that reflected prosperity
- As it was the landlord who paid the tax, they responded by either boarding up windows or building new properties without windows

Why are There so Many Unfinished Buildings in Peru?

- A problem in Peru was that constructing homes was difficult as halfway through property taxes meant that these houses were too costly to complete.
- In 1990 President Fujimori introduced a new policy that did away with property taxes while homes were being constructed.
- However, this resulted in Peruvians 'almost' finishing their homes just enough to be comfortable to live in, but not all the way so they could avoid property taxes.

The Great Hanoi Rat Massacre

- During 1902, in Hanoi, Vietnam (while under French colonial rule) the government created a bounty program that paid a reward of 1 cent for each rat killed.
- To prove they had killed the rat, people had to show the rats tail.
- However, officials then noticed an abundance of rats without tails scurrying around the city.
- The Ratcatchers would cut off the rats tails, claim the bounty, and then release them back in the wild, so they could produce more rats.

Miscellaneous

- **Physician Bonuses:** Pay-for performance bonuses sometimes cause doctors to avoid sicker patients (refuse to operate on them) to ensure positive outcomes, rather than treat everyone.
- **Wells Fargo Scandal:** Employees were incentivized to open new customer accounts (commission). To meet these unrealistic goals, employees began opening unauthorized accounts (illegally).
- **Rage Baiting:** Social media platforms (X, Youtube, Tiktok, Twitch etc) incentivizes the online practice of creating content that is deliberately provocative or offensive to make people angry, with the goal of increasing engagement such as likes, shares, and comments

4. Understand Markets

Two sides to every market transaction: buyer and seller (hirer and labor supplier)

Bargaining position of consumers and producers is limited by three rivalries in economic transactions:

- [Consumer-producer rivalry](#)
 - Buyer wants to buy for lowest amount possible, seller wants to sell for highest amount possible
- Consumer-consumer rivalry
 - Limited goods (think Taylor Swift tickets)
- Producer-producer rivalry
 - More firms, more competition to be the one that sells (quality, product differentiation, price, all matter)
- Government and the market
 - Firms may try and lobby the government to intervene to avoid these rivalries
 - In some states there is only one sole electricity supplier

5. Time Value of Money

- Time is important in most decisions because the choices we make will also have future consequences
 - So far, the decisions/experiments we have analysed do not have a temporal component.
 - **Intertemporal choices** relate to decisions involving trade-offs between costs and benefits occurring in different time periods:
 - How do we value them?
1. Immediate costs and delayed benefits
 - Can we force ourselves to do it now?
 - Exercising, Dieting, Studying
 2. Immediate benefits and delayed costs
 - Can we fight the temptation to pursue immediate gratification?
 - Drinking, Gambling, High Sugar food etc

What is better?

- Would you rather:

A) \$1000 Today

B) \$1000 in 1 year

Discounting the future

- People tend to be **impatient**—they prefer immediate rewards to delayed rewards.
- \$100 today is preferred to \$100 tomorrow.
 - Why?
- Impatience
- Uncertainty about the future
- Option Value
 - Investment opportunities:
 - With an interest rate of 6%: In 1 year $\$100 = \106

Time Value of Money Example

- I put \$100 in the bank. There is 10% interest paid in a lump sum annually.
 - After one year, I get paid \$10 in interest. I now have \$110 in the bank.
 - That additional \$10 is now effectively part of my principle and I earn interest on that too!
 - After the second year, I get paid $0.1 * \$110 = \11 in interest. I now have \$121 in the bank.

Time Value of Money Example

- I have \$100.
- If I put this money in the bank for two years, what will it be worth then? That is the future value (FV).

In two years time, that money will have a present value (PV) of \$121

Time Value of Money Example

- $FV = (1 + i)^n PV$
- Where i =interest rate and n is the number of time periods in the future.
- Which means

$$PV = \frac{FV}{(1 + i)^n}$$

- * the larger n , the smaller the PV (sometimes also t)
- * the larger i , the smaller the PV

Time Value of Money Example

- Present value reflects the difference between the *future value* and the *opportunity cost of waiting*:
 - $PV = FV - OCW$

Time Value of Money Example

Present value of a *stream of* future values

$$PV = \frac{FV_1}{(1+i)^1} + \frac{FV_2}{(1+i)^2} + \frac{FV_3}{(1+i)^3} + \text{L} + \frac{FV_n}{(1+i)^n}$$

$$PV = \sum_{t=1}^n \frac{FV_t}{(1+i)^t}$$

Time Value of Money Example

Consider two possible projects:

Project A: Generates \$150,000 income today (year 0).

Project B: Generates the following income: Year 0, \$0; Year 1, \$10,000; Year 2, \$50,000; and Year 3, \$100,000

- The annual interest rate is 3 percent

Time Value of Money Example

Net Present Value

The present value of the *income stream* generated by a project minus the current cost of the project:

$$NPV = \frac{FV_1}{(1+i)^1} + \frac{FV_2}{(1+i)^2} + \frac{FV_3}{(1+i)^3} + \text{L} + \frac{FV_n}{(1+i)^n} - C_0$$

Net Present Value

- NPV: The difference between the present value of an investment and the cost.
- Example: My uncle borrows \$100 from me and promises to pay me back \$150 in 5 years. Is this a good deal if I know I can earn 10% interest?
- No! The FV of the \$100 in 5 years is $(1+0.1)^5 100 = \$161.04$

The PV of the Uncles offer is $\frac{150}{(1+0.1)^5} = \93.18

Net Present Value

- NPV: The difference between the present value of an investment and the cost.
- In our case, if we give the money to our uncle, we give up \$100 today and get the PV of \$93.14 in return.
- If I give up \$100 and get only \$ in return, the NPV of that investment is
- $\$93.14 - \$100 = -\$6.86$.
- If $NPV < 0$, the costs of the investment outweigh the benefits, so it's not a good deal.
- If $NPV > 0$, the benefits of the investment outweigh the costs, so it's a good deal.
- If $NPV = 0$, the benefits and the costs of the investment offset one another. You're no better off or worse off accepting this deal.

Net Present Value

- Net present value gets trickier if the costs or benefits of an investment accrue at different points in time.

Example:

- I lend my uncle \$50 today and \$50 one year from now. He agrees to pay me back \$35 per year for three years after the loan (so he starts paying back 3 years after the first money he got from me. The interest rate is 3%.
- Is this a good deal? What is the NPV of this deal?

Net Present Value

- NPV: The difference between the present value of an investment and the cost of that investment.
- **Costs (outflows)**
- **Benefits (inflows)**

Net Present Value

$$PV = \sum_{t=1}^n \frac{FV_t}{(1+i)^t}$$

Net Present Value of indefinitely lived asset

- Present value of decisions that indefinitely generate cash flows:

$$PV_{Asset} = CF_0 + \frac{CF_1}{(1+i)^1} + \frac{CF_2}{(1+i)^2} + \frac{CF_3}{(1+i)^3} + L$$

- Present value of this perpetual income stream when the same cash flow is generated ($CF_1=CF_2=\dots=CF$)

$$PV_{Perpetuity} = \frac{CF}{i}$$

Net Present Value of indefinitely lived asset

- I loan my uncle \$100. He says he will pay me back \$1 next year and for the rest of his life, and then his children will pay me, and then his grandchildren, in perpetuity. Assume the interest rate is 10%

$$\text{PV (in perpetuity)} = \frac{\text{future payment}}{i} = \frac{\$1}{0.1} = \$10$$

$$\text{NPV} = \$10 - \$100 = \$90.$$

- What is minimum amount he (and his heirs) need to pay me to make NPV=0?

Net Present Value of indefinitely lived asset

- What is minimum amount he (and his heirs) need to pay me to make NPV=0?
- PV of cost is \$100.

$$\text{NPV} = \text{PV}(\text{benefits}) - \text{PV}(\text{costs})$$

$$0 = \text{PV}(\text{benefits}) - 100,$$

$$\text{therefore } \text{PV}(\text{benefits}) = 100$$

$$\text{PV}(\text{benefits}) = \frac{\text{future payment}}{i}$$

$$100 = \frac{\text{future payment}}{0.1}$$

$$\text{Future Payment} = 10$$

Net Present Value of indefinitely lived asset

The value of a firm with *current profits* π_0 , with *no dividends paid out* and *expected, constant profit growth rate* of g (assuming $g < i$) is:

$$PV_{Firm} = \pi_0 + \frac{\pi_0(1+g)}{(1+i)^1} + \frac{\pi_0(1+g)^2}{(1+i)^2} + \frac{\pi_0(1+g)^3}{(1+i)^3} + L$$
$$= \pi_0 \left(\frac{1+i}{i-g} \right)$$

How do we get that result?

$$PV_{Firm} = \pi_0 + \frac{\pi_0(1+g)}{(1+i)^1} + \frac{\pi_0(1+g)^2}{(1+i)^2} + \frac{\pi_0(1+g)^3}{(1+i)^3} + L$$

- $\frac{1+g}{1+i}$ is a common factor (except for the first term of π_0).

Define, $r = \frac{1+g}{1+i}$

Geometric Series: $1+r+r^2+r^3+\dots = \frac{1}{1-r}$

How do we get that result?

$$PV = \pi_0 \left(\frac{1}{1 - \frac{1+g}{1+i}} \right)$$

Simplify the denominator

$$1 - \frac{1+g}{1+i} = \frac{1+i - (1+g)}{1+i} = \frac{i-g}{1+i}$$

$$PV = \pi_0 \left(\frac{1}{\frac{i-g}{1+i}} \right) = \pi_0 \left(\frac{1+i}{i-g} \right)$$

Net Present Value of indefinitely lived asset

When dividends are immediately paid out of current profits, the present value of the firm is (at ex-dividend date):

$$PV_{Firm}^{Ex-dividend} = PV_{Firm} - \pi_0$$

$$= \pi_0 \left(\frac{1+g}{i-g} \right)$$

Short-Term and Long-Term Profits.

Short-term and long-term profits

- If the growth rate in profits is less than the interest rate and both are constant, maximizing current (short-term) profits is the same as maximizing long-term profits.

6. Use Marginal Analysis

Given a control variable, Q , of a managerial objective, denote the

- total benefit as $B(Q)$.
- total cost as $C(Q)$.
- Manager's objective is to maximize net benefits:

$$N(Q) = B(Q) - C(Q).$$

Can also be written as, $\text{Max } \Pi = B(Q) - C(Q)$

6. Use Marginal Analysis

How can the manager maximize net benefits?

Use marginal analysis.

Marginal benefit: $MB(Q)$

- The change in total benefits arising from a change in the managerial control variable

Marginal cost: $MC(Q)$

- The change in the total costs arising from a change in the managerial control variable, Q

Marginal net benefits: $MNB(Q)$

$$MNB(Q) = MB(Q) - MC(Q)$$

- To maximize net benefits, the manager should increase the managerial control variable up to the point where marginal benefits equal marginal costs.
 - This level of the managerial control variable corresponds to the level at which marginal net benefits are zero; nothing more can be gained by further changes in that variable.
 - If $MB > MC$, you are leaving money on the table!

6. Use Marginal Analysis

- If your revenues exceed your costs, your profit is positive.
- Should you produce one more unit?
 - If the additional revenue from that unit exceeds the additional cost of that unit, profit will increase.

Example: if Lamar makes one more glass of lemonade, and the additional costs (economic costs) of producing that are \$1, and he sells for \$3, then he earns \$2 more in profit (profit increase). Should he make one more?

What if the next glass of lemonade now costs \$1.5, and he can sell it for \$2....so on and so forth

6. Use Marginal Analysis

- When we make decisions (as managers or just people) we compare the costs and benefits of an action.
- When we decide “how much” of something, we compare the cost of each unit with the benefit of each unit and are engaging in marginal analysis

Examples:

- How many slices of pizza will you eat? Stop at 3? Stop at 6?
- How many times will you see the same movie?

6. Use Marginal Analysis: Example

It is estimated that the benefit and cost structure of a firm is:

$$B(Q) = 250Q - 4Q^2$$

$$C(Q) = Q^2$$

- What are the MB(Q) and MC(Q) functions?

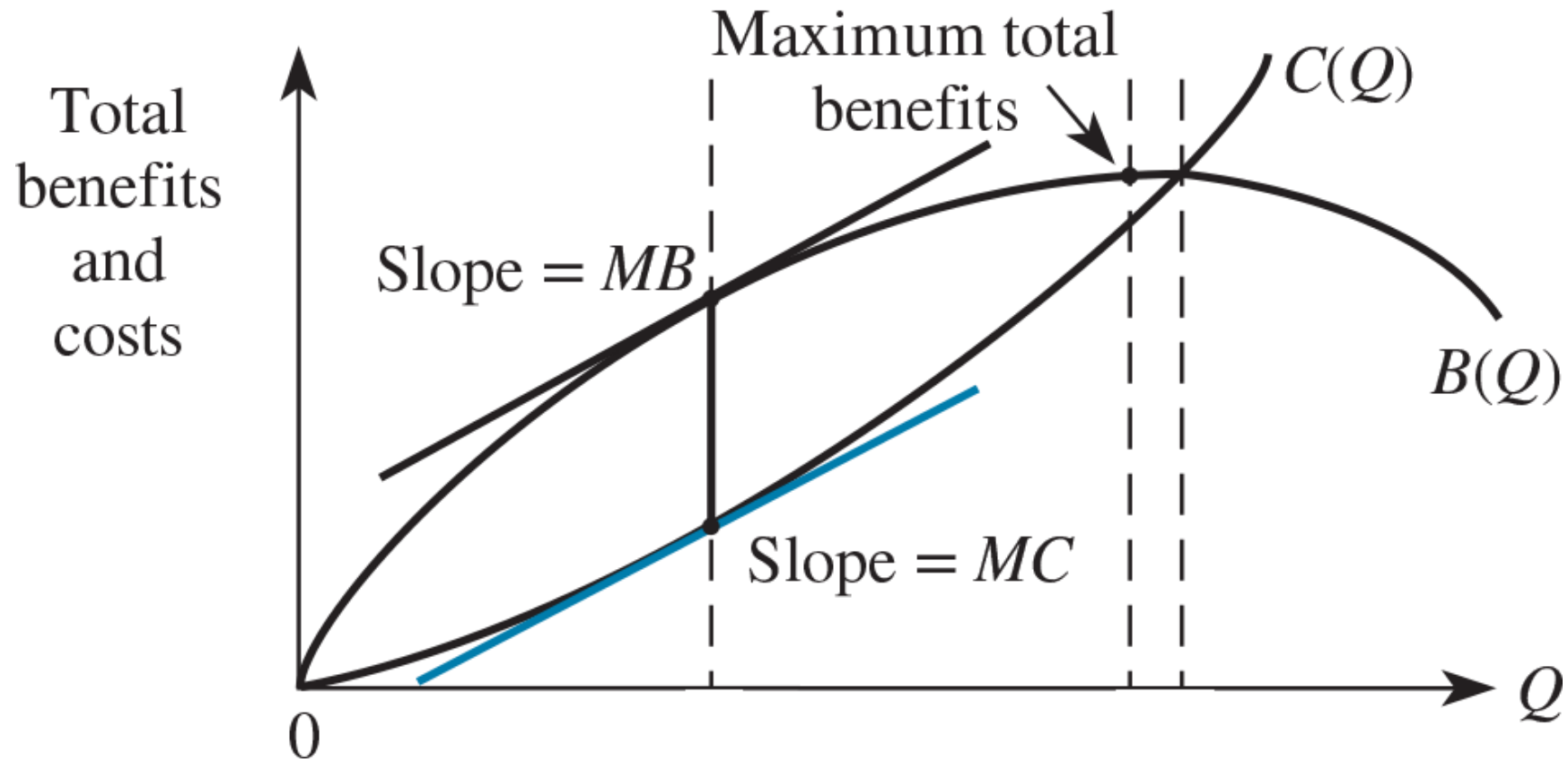
$$MB(Q) = 250 - 8Q$$

$$MC(Q) = 2Q$$

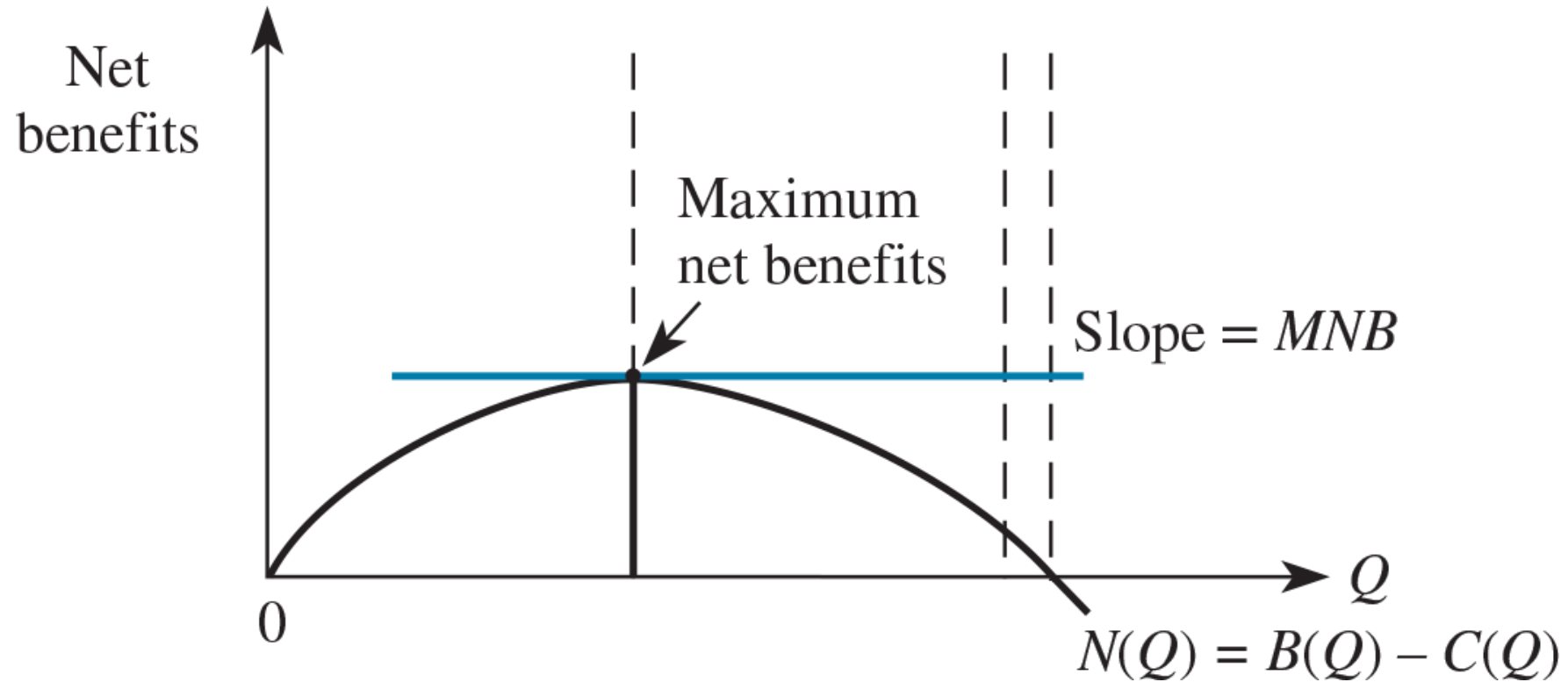
- What value of Q makes NMB(Q)=0?
- Set MB(Q)=MC(Q)

$$250 - 8Q = 2Q \Rightarrow Q = 25$$

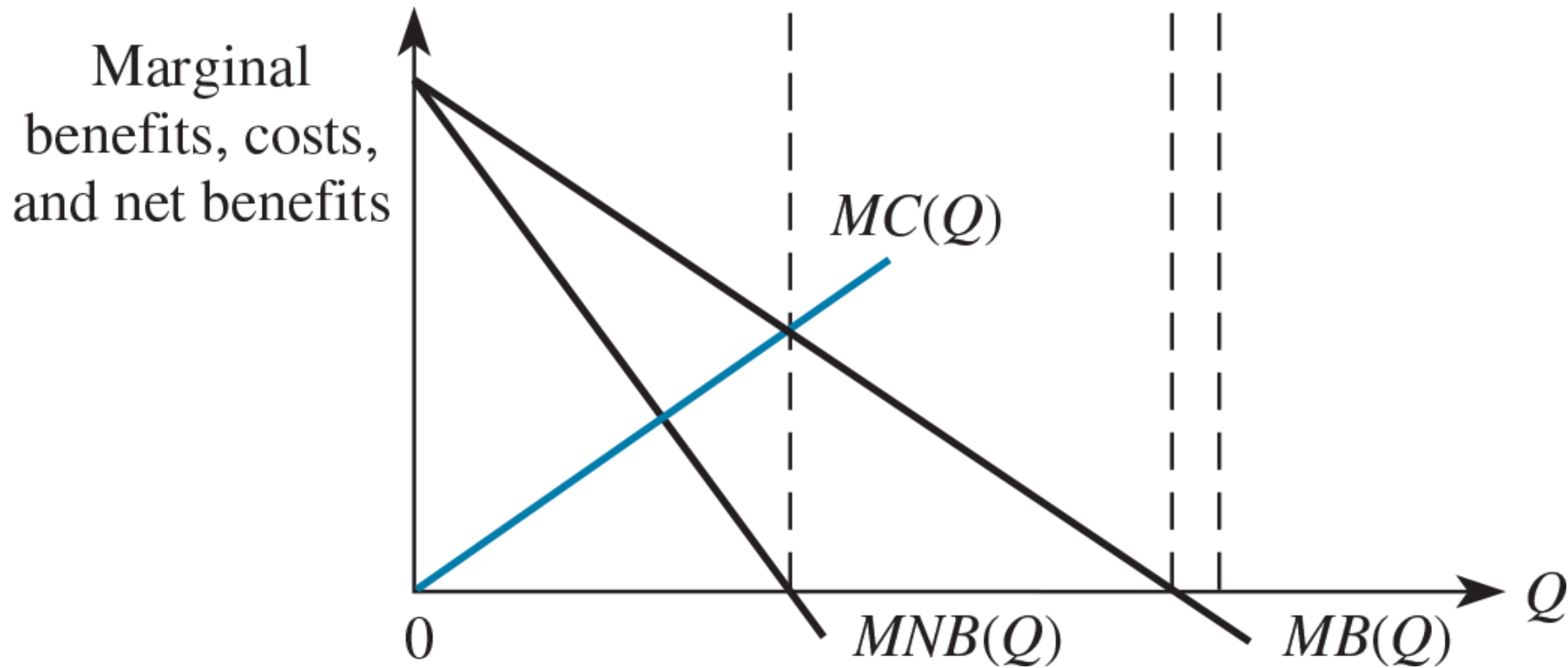
6. Use Marginal Analysis: Example



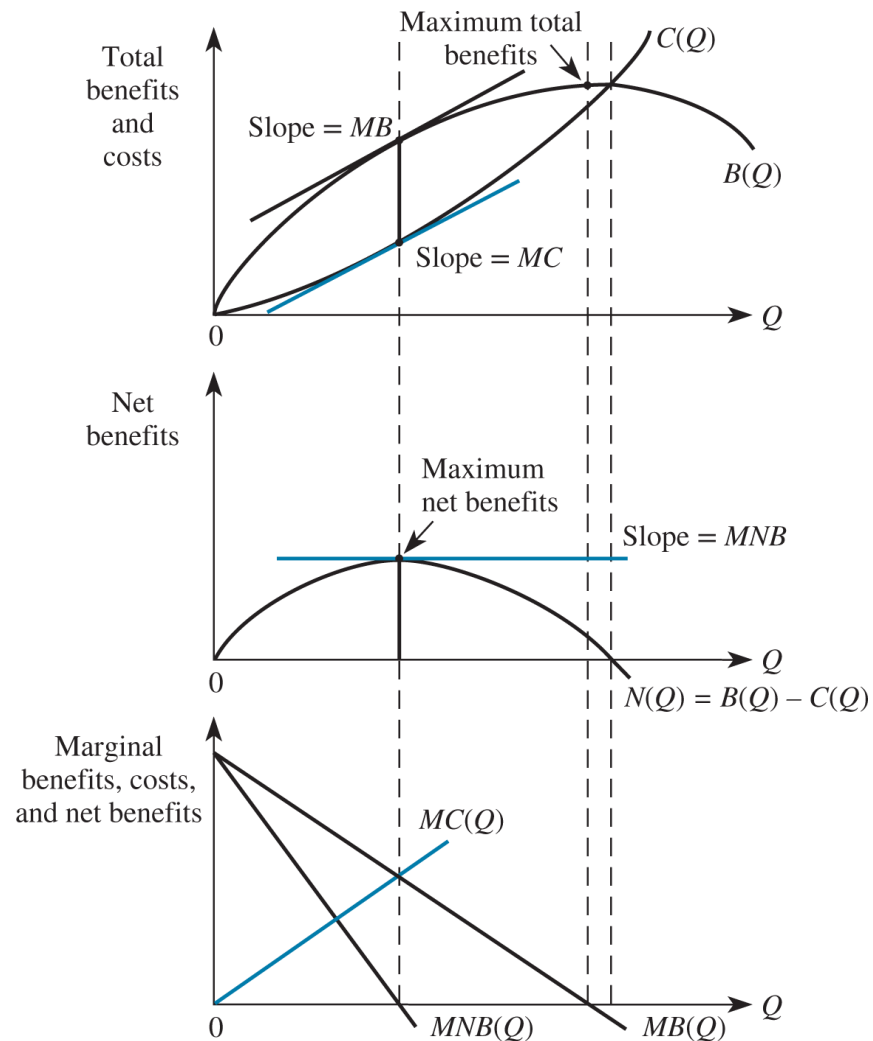
6. Use Marginal Analysis: Example



6. Use Marginal Analysis: Example



6. Use Marginal Analysis: Example



• [Access the text alternative for slide images.](#)

6. Use Marginal Analysis

- When the control variable is infinitely divisible, the slope of a total value curve at a given point is the marginal value at that point.
- The slope of the total benefit curve at a given Q is the marginal benefit of that level of Q .
- The slope of the total cost curve at a given Q is the marginal cost of that level of Q .
- The slope of the net benefit curve at a given Q is the marginal net benefit of that level of Q .
- Note: The slope is what we get by taking the first derivative (calculus) of the 'curve'.

6. Use Marginal Analysis: Summary

Incremental revenues

- The additional revenues that stem from a yes-or-no decision

Incremental costs

- The additional costs that stem from a yes-or-no decision

“Thumbs up” decision

- $MB > MC$.

“Thumbs down” decision

- $MB < MC$.

7. Make Data-Driven decisions!

How does one obtain information on the demand function?

- Data available to quantify decisions (published papers)
- Econometric models
- Hire a consultant
 - Ask Claude
- Statistical technique called regression analysis using data on quantity, price, income and other important variables

7. Make Data-Driven decisions!

True regression model

$$Y = a + bX + e$$

- a unknown population intercept parameter
- b unknown population slope parameter
- e random error term with mean zero and standard deviation σ

Least squares regression line.

$$Y = \hat{a} + \hat{b}X$$

- $\hat{a}$ least squares estimate of the unknown parameter a
- $\hat{b}$ least squares estimate of the unknown parameter b

The ***parameter estimates*** $\hat{a}$ and $\hat{b}$ represent the values of a and b that result in the smallest sum of squared errors between a line and the actual data.

7. Make Data-Driven decisions!

Some important note on OLS regression:

- We want to know the true 'b'
- If we have all the data in the world we would have the true b!
- However, most of the time, we have a limited sample of data, thus b is a prediction of what will happen to Y if there is a change in X (correlation).

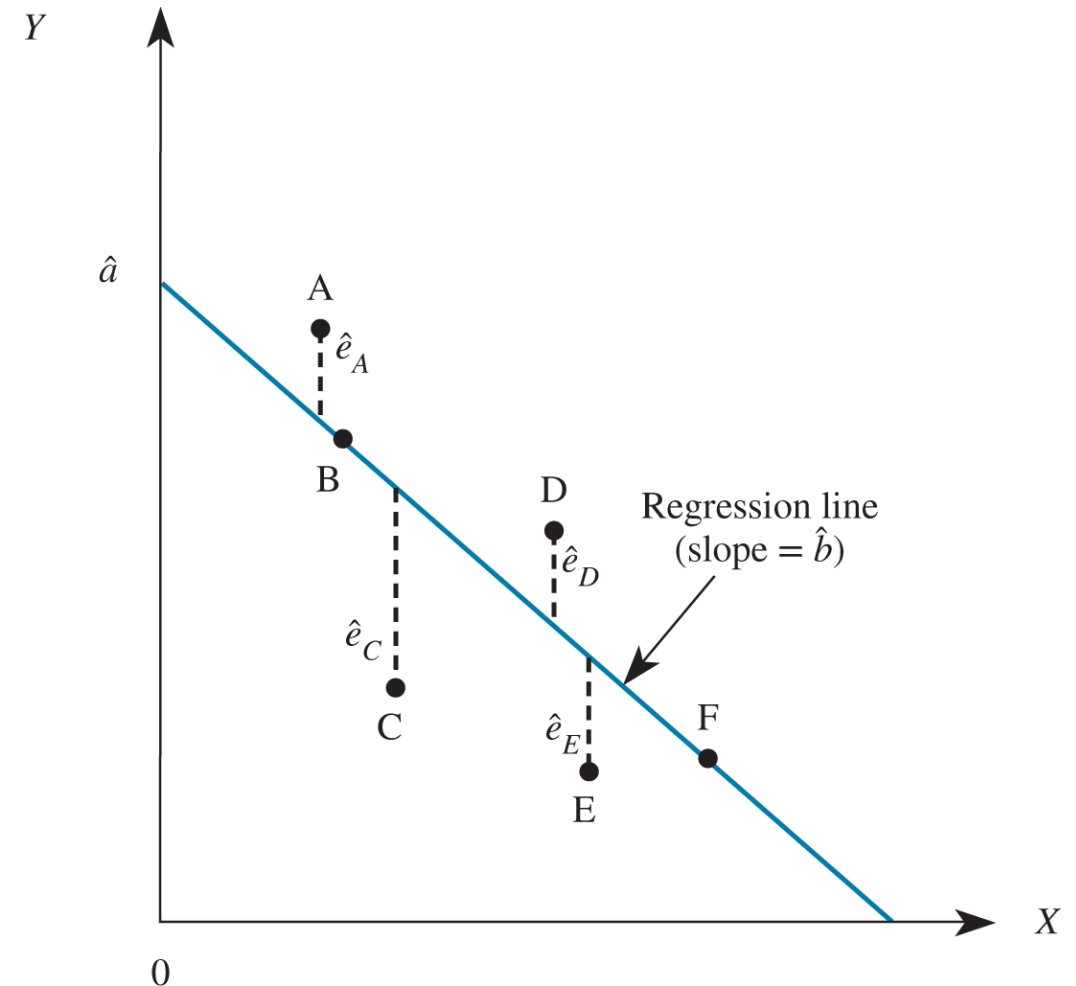
7. The OLS Regression Line

- Find the line that minimizes the sum of squared deviations between the line and the actual data points.
- The least squares regression line for the equation
 - $Y = a + bX + e$

Where a and b are unknown parameters and e is a random variable

- Is given by $Y = \hat{a} + \hat{b}X$

Parameter estimates $\hat{a}$ and $\hat{b}$ represent the values of a and b that result in the smallest sum of squared errors between a line and the actual data.



Running Regressions

	A	B	C
1	Observation	Quantity	Price
2	1	180	475
3	2	590	400
4	3	430	450
5	4	250	550
6	5	275	575
7	6	720	375
8	7	660	375
9	8	490	450
10	9	700	400
11	10	210	500
12	Average	450.50	455.00
13			

Running Regressions

SUMMARY OUTPUT

<i>Regression Statistics</i>	
Multiple <i>R</i>	0.87
<i>R</i> -Square	0.75
Adjusted <i>R</i> -Square	0.72
Standard Error	112.22
Observations	10.00

Estimated Demand:

$$Q = 1631.47 - 2.60 \text{ PRICE}$$

$$\hat{a} = 1631.47$$

$$\hat{b} = -2.60$$

Analysis of Variance

	<i>Df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	301470.89	301470.89	23.94	0.0012
Residual	8	100751.61	12593.95		
Total	9	402222.50			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t-Stat</i>	<i>P-Value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
Intercept	1631.47	243.97	6.69	0.0002	1068.87	2194.07
Price	-2.60	0.53	-4.89	0.0012	-3.82	-1.37

Running Regressions

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.87
R-Square	0.75
Adjusted R-Square	0.72
Standard Error	112.22
Observations	10.00

$$se(\hat{a}) = 243.97$$

$$se(\hat{b}) = 0.53$$

$t_{\hat{a}} = |6.69| > 2$, the intercept is different from zero.

$t_{\hat{b}} = |-4.89| < 2$, the intercept is different from zero.

Analysis of Variance

	Df	SS	MS	F	Significance F
Regression	1	301470.89	301470.89	23.94	0.0012
Residual	8	100751.61	12593.95		
Total	9	402222.50			

	Coefficients	Standard Error	t-Stat	P-Value	Lower 95%	Upper 95%
Intercept	1631.47	243.97	6.69	0.0002	1068.87	2194.07
Price	-2.60	0.53	-4.89	0.0012	-3.82	-1.37

Multiple Regressions

Regression techniques can also be applied to the following settings:

- Log-Linear Regression Line

- $\ln Y = a + b \ln X + e$,

by using a spreadsheet to compute $Y' = \ln Y$ and $X' = \ln X$, this can be viewed.

Equivalently as $Y' = a + bX' + e$

- Multiple regression

$$Y = a + b_1X_1 + b_2X_2 + \dots + b_kX_k + e$$