1

WHAT IS GAME THEORY?

Branch of economics concerned with the analysis of optimal decision-making in **competitive situations**.

The actions of each decision maker have a significant impact on the "payoffs" of rival decision makers.

Game Theory can be used to model…

1. Honda and Toyota's decision to enter a new market or build a new production plant
2. General Mills and Kellogg's decision to introduce a new cereal.
3. Production decisions in a duopoly.
4. Pricing decisions in a duopoly.
5. XM and Sirius's decision to exit or stay in the satellite radio market

…and many more!

2

IMPORTANT TERMINOLOGY

Game: any situation in which players make **strategic decisions**.

Decisions that take into account each other's actions and responses

Payoffs: The value that each player expects to get from each possible outcome of the game.

Strategy: A plan for the actions that a player in a game will take under every conceivable circumstance that the player might face.

ONE-SHOT SIMULTANEOUS MOVE GAME

A game in which two (or more) players make a single decision at the same time.

For example…

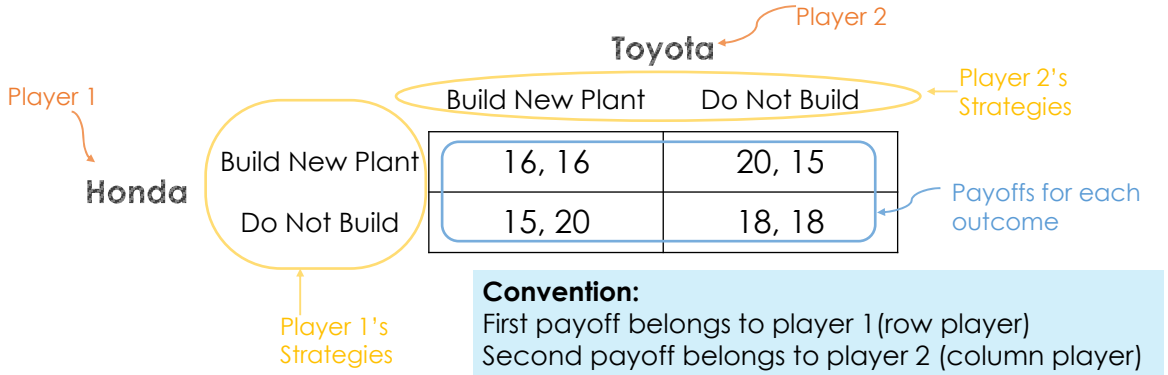
Toyota and Honda compete in the automobile market

They are both trying to decide whether or not to build a new production plant.

- Honda's choice impacts Toyota's profits
- Toyota's choice impacts Honda's profits

A PAYOFF MATRIX

Visual representation of the players, strategies, and payoffs of a game.



Convention:
First payoff belongs to player 1 (row player)
Second payoff belongs to player 2 (column player)

The payoffs above are fictitious… but accurately reflect the dynamic that existed between the two firms.

FINDING THE "LIKELY" OUTCOME… → Goal of Game Theory

Nash Equilibrium (we've seen this before!)

Each player chooses the strategy that yields the highest payoff, given the strategies chosen by the other players.

		Toyota: Build New Plant	Toyota: Do Not Build
Honda	Build New Plant	16, 16	20, 15
	Do Not Build	15, 20	18, 18

Nash Equilibrium of this capacity expansion game is…
both firms build a new plant.

FINDING THE "LIKELY" OUTCOME… → Goal of Game Theory

How do we know this is the Nash Equilibrium?

If Toyota Builds a new plant…

Honda Maximizes their payoff by also building a new plant.

		Toyota: Build New Plant	Toyota: Do Not Build
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FINDING THE "LIKELY" OUTCOME… → Goal of Game Theory

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FINDING THE "LIKELY" OUTCOME… → Goal of Game Theory

This is the Nash Equilibrium because…

Each player is choosing the strategy that yields the highest payoff, given the strategies chosen by the other players.

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FINDING THE "LIKELY" OUTCOME… → Goal of Game Theory

Why isn't "both do not build" a Nash Equilibrium?

If Toyota does not build a new plant…Honda maximizes their payoff by building a new plant.

If Honda does not build a new plant…Toyota maximizes their payoff by building a new plant.

		Toyota: Build New Plant	Toyota: Do Not Build
Honda	Build New Plant	16, 16	20, 15
Honda	Do Not Build	15, 20	18, 18

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DOMINANT STRATEGY

A strategy that is optimal (payoff maximizing) no matter what strategy your opponent chooses.

		Toyota: Build New Plant	Toyota: Do Not Build
Honda	Build New Plant	16, 16	20, 15
Honda	Do Not Build	15, 20	18, 18

Does Honda have a dominant strategy?

YES!

Build a new plant

For each <u>column</u> compare the blue values to the purple values…

16 >15

(implication: if Toyota builds, Honda gets a higher payoff from building)

20 >18

(implication: if Toyota does not build, Honda gets a higher payoff from building)

12

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DOMINANT STRATEGY

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		Toyota: Build New Plant	Toyota: Do Not Build
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	Do Not Build	15, 20	18, 18

Notice…

If both companies choose their dominant strategy, the outcome is the Nash equilibrium!

This result is always true.

If both players in a game have a dominant strategy, then those are also the Nash equilibrium strategies.

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THE PRISONERS' DILEMMA

This capacity expansion game illustrates an important feature of the Nash equilibrium.

It is not always the outcome that maximizes total payoffs for the players.

Toyota and Honda would be better off collectively agreeing to not build a new plant

Self-interest (higher payoffs) prevent this cooperation from occurring.

This type of scenario is referred to as a **prisoners' dilemma**

↓

A game situation in which there is a tension between the collective interest of all the players and the self-interest of individual players.

This idea is often represented by a fun story about captured criminals…

THE PRISONERS' DILEMMA

Two suspects are arrested and placed in separate cells and encouraged to confess…

		Prisoner B: Confess	Prisoner B: Don't Confess
Prisoner A	Confess	-5, -5	0, -10
	Don't Confess	-10, 0	-1, -1

Observe…

Both have a dominant strategy of confess.

The best collective outcome is for neither of them to confess.

Alternative Definition of a Prisoners' Dilemma: a game in which every player has a dominant strategy, but there is some other outcome that yields higher payoffs for all players.

The preferred outcome is not stable, each player has an individual incentive to "cheat".

COMPLICATIONS TO FINDING THE NASH EQUILIBRIUM

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WHAT IF ONLY ONE PLAYER HAS A DOMINANT STRATEGY?

Requires a little more strategic thinking…

		Toyota: Build New Plant	Toyota: Do Not Build
Honda	Build New Plant	**14**, 16	20, 15
	Do Not Build	15, 20	18, 18

Does Honda have a dominant strategy?

No!

For each <u>column</u> compare the blue values to the purple values…

15 >14

(implication: if Toyota builds, Honda gets a higher payoff from not building)

20 >18

(implication: if Toyota does not build, Honda gets a higher payoff from building)

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WHAT IF ONLY ONE PLAYER HAS A DOMINANT STRATEGY?

Requires a little more strategic thinking…

		Toyota: Build New Plant	Toyota: Do Not Build
Honda	Build New Plant	**14**, 16	20, 15
	Do Not Build	(15) 20	18, 18

Honda knows that Toyota has a dominant strategy of Build New Plant

So, they focus only on that row…

What can we say?

Given that Toyota will Build a New Plant, Honda's best response is to Not Build a New Plant.

Nash Equilibrium is…
Honda: Do Not Build
Toyota: Build New Plant

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DOMINATED STRATEGIES

Unfortunately, not every game will have a dominant strategy.

That's okay!

We can look for (and eliminate) **dominated strategies** instead.

A strategy is **dominated** when the player has another strategy that gives them a higher payoff no matter what the other player does.

A few notes…

1. If there are only two strategies and one is dominant, the other is automatically dominated.
2. If there are more than two strategies, it is possible for there to be a dominated strategy, but no dominant strategy.
3. A player will never choose to play a dominated strategy, and the other player knows this.

FINDING DOMINATED STRATEGIES

		Toyota		
		Build Large Plant	Build Small Plant	Do Not Build
Honda	Build Large Plant	0, 0	12, 8	18, 9
	Build Small Plant	8, 12	16, 16	20, 15
	Do Not Build	9, 18	15, 20	18, 18

Does Honda have a dominant strategy?

No!

Build Small Plant is always better than Build Large Plant but only sometimes better than Do Not Build.

Does Honda have a dominated strategy?

Yes!

Build Small Plant is always better than Build Large Plant

FINDING DOMINATED STRATEGIES

		Toyota: Build Large Plant	Toyota: Build Small Plant	Toyota: Do Not Build
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Yes!

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ELIMINATE DOMINATED STRATEGIES (and reassess)

		Toyota: Build Small Plant	Toyota: Do Not Build
Honda	Build Small Plant	16, 16	20, 15
	Do Not Build	15, 20	18, 18

Does Honda have a dominant strategy?

Yes!

Build Small Plant is always better than Do Not Build.

Does Toyota have a dominant strategy?

Yes!

Build Small Plant is always better than Do Not Build.

Nash Equilibrium: Each Firm Builds a Small Plant.

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SUMMARIZING WHAT WE LEARNED SO FAR...

1. If both players have a dominant strategy, those strategies will constitute the Nash equilibrium in the game.
2. If just one player has a dominant strategy, that strategy will be the player's Nash equilibrium strategy. We can find the other player's Nash equilibrium strategy by identifying that player's best response to the first player's dominant strategy.
3. If neither player has a dominant strategy, but both have dominated strategies, we can often deduce the Nash equilibrium by eliminating the dominated strategies and thereby simplifying the analysis of the game.

A GAME OF CHICKEN

Two teenagers drive straight at each other

- The first to swerve is the "loser"
- The one who doesn't swerve is the "winner"
- If neither swerve…they crash
- If both swerve, then there is no winner or loser

		Teen 2: Swerve	Teen 2: Stay
Teen 1	Swerve	0, 0	-10, 10
	Stay	10, -10	-100, -100

This game has two Nash Equilibria…
(Swerve, Stay) and (Stay, Swerve)

How do I know?

- ✓ If **Teen 1 Swerves**, then the best Teen 2 can do is to **Stay**.
- ✓ If **Teen 2 Stays**, then the best Teen 1 can do is **Swerve**.

- ✓ If **Teen 1 Stays**, then the best Teen 2 can do is to **Swerve**.
- ✓ If **Teen 2 Swerves**, then the best Teen 1 can do is **Stay**.

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A GAME OF CHICKEN

This game can be used to model…

1. The nuclear showdown between the U.S. and the Soviet Union
2. When two firms compete in a market than can only support one firm.

What does this game teach us?

We don't know which equilibrium will occur.

But we do know that one player will always "swerve".

For Example:
Consider the battle between XM and Sirius satellite radio companies…

		Sirius: Stay	Sirius: Exit
XM	Stay	-200, -200	300, 0
	Exit	0, 300	0, 0

What actually happened in this market?

XM "Swerved"

(they were bought by Sirius in 2008)

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A COORDINATION GAME

A game in which players would like to coordinate their behavior on a specific outcome.

Can be used to model…

1. Two people deciding whether to see a Bach or Stravinsky concert
2. A bank run…

		Betsy: Bach	Betsy: Stravinsky
Axel	Bach	2, 2	0, 0
	Stravinsky	0, 0	1, 1

This game has two Nash Equilibria…
(Bach, Bach) and (Stravinsky, Stravinsky)

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WHAT IS A BANK RUN?

Occurs when a large number of bank customers withdraw their deposits because of fear about the bank failing…

(basically, it's a situation where people's panic is self-fulfilling)

Does this actually happen?

Yes!

Most recently…Silicon Valley Bank in March 2023 (3rd largest bank run in history)

- SVP announced that they had to sell $21 billion in securities and borrow $15 billion to increase cash reserves.
- This announcement caused a $42 billion bank run and ultimately lead to the closure of the bank by regulatory agents.

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MODELLING A BANK RUN…

Two individuals have deposited $100 in Bailey Building and Loan. The money has been invested and is earning interest.

Depositor 1 \ Depositor 2	Withdraw	Don't Withdraw
Withdraw	(25) [25]	50, 0
Don't Withdraw	0, 50	(110), [110]

Game Theory cannot tell us whether a bank run will occur…

Only that it is a possibility.

This game has two Nash Equilibria…
(Withdraw, Withdraw) and (Don't, Don't)

FINDING ALL THE NASH EQUILIBRIA OF A GAME

Basic Strategy…

Find **Player 1's** best response to each of the three possible **Player 2** strategies (circle).

Find **Player 2's** best response to each of the three possible **Player 1** strategies (box).

Nash equilibrium occurs in cells with both a box and a circle.

Player 1 \ Player 2	D	E	F
A	4, 2	(13), [6]	1, 3
B	11, 2	0, 0	(15) [10]
C	(12), [14]	4, 11	5, 4

This game has three Nash Equilibria…
(C, D), (A, E), and (B, F)

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REPEATED GAME

Game in which actions are taken and payoffs received repeatedly.

The prisoners' dilemma demonstrates that self-interest can lead to a less than optimal outcome.

However, this result may not hold if the game is played more than once.

This is a more realistic situation!

Competing firms tend to interact in the same ways over and over again.

There are many more potential strategies in a repeated game.

We will consider two.

1. Grim-trigger
2. Tit-for-tat

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A DUOPOLY THAT IS MODELLED AS A GAME

Firm 1 and 2 are duopolists that compete by setting price.

Notice…

Both have a dominant strategy of "Low price".

Nash equilibrium is (low price, low price)

		Firm 2	
		Low price	High price
Firm 1	Low price	10, 10	100, -50
	High price	-50, 100	50, 50

There is an outcome they both prefer!

(high price, high price)

If the game is played once, there is no way to achieve this outcome.

If the game is played repeatedly for the foreseeable future, then they may be able to cooperate.

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THE GRIM-TRIGGER STRATEGY

How does it work?

You cooperate (set a high price) the first time you play the game.

You cooperate in the next period if your competitor cooperated with you.

If you observe that your competitor cheated (set a low price), then you set a low price all following periods.

		Firm 2	
		Low price	High price
Firm 1	Low price	10, 10	100, -50
	High price	-50, 100	50, 50

Basic idea…

If you cheat, you get a one-time payoff of $100.

But…there is a very **severe punishment** for cheating, a payoff of $10 in every period after that.

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THE GRIM-TRIGGER STRATEGY

When does it work?

If both players follow this strategy, then it will support cooperation if...

Both players prefer $50 in every period

to

$100 one time and $10 in every following period.

Firm 1		Firm 2: Low price	Firm 2: High price
	Low price	10, 10	100, -50
	High price	-50, 100	50, 50

Basic idea...

If you cheat, you get a one-time payoff of $100.

But…there is a very **severe punishment** for cheating, a payoff of $10 in every period after that.

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THE TIT-FOR-TAT STRATEGY

How does it work?

You cooperate (set a high price) the first time you play the game.

Maintain cooperation as long as competitor continues to cooperate.

If your competitor charges a low price, you do the same in the following period.

If competitor raises prices, you do the same in the following period.

Firm 1		Firm 2: Low price	Firm 2: High price
	Low price	10, 10	100, -50
	High price	-50, 100	50, 50

Punishment is much less severe than in the grim-trigger strategy.

In computer simulations, this is the "best" strategy.

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WHAT CAN WE SAY ABOUT COOPERATION?

It is more likely if…

1. The players are patient
2. Interactions between players are frequent
3. Cheating is easy to detect
4. The one-time gain from cheating is relatively small

What does the Repeated Prisoners' Dilemma teach us?

In competitive setting you must anticipate the reactions of your competitors.

Specifically…

You need to understand if and how your competitors respond to actions they consider "cheating"

Otherwise, you might find yourself in a price war you did not intend to start.

DIAPER WARS

Diaper industry is dominated by two firms:

1. Proctor & Gamble (50%)
2. Kimberly Clarke (30-40%)

Competition mostly occurs in the form of *cost-reducing innovation*

- If both firms spend aggressively, they can maintain their current market shares.
- If one innovates and the other does not, the innovator is the "winner"
- They are both better off if neither spends in R&D.

The two firms are in a Prisoners' Dilemma
Both have dominant strategy of R&D
Both prefer the No R&D outcome

		K-C: R&D	K-C: No R&D
P&G	R&D	40, 20	80, -20
P&G	No R&D	-20, 60	60, 40

Why have they never cooperated?

1. Hard to monitor you rival's R&D expenditures
2. Long time-horizon on innovation makes strategies like tit-for-tat impractical.
3. R&D expenditures act as an entry deterrent to new firms.

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SEQUENTIAL MOVE GAMES

Games in which one player (the first mover) takes an action before another player (the second mover).
The second mover observes the action taken by the first mover before deciding what action it should take.

Toyota ← **Second mover**

First mover ↓ Honda

	Build Large Plant	Build Small Plant	Do Not Build
Build Large Plant	0, 0	12, 8	18, 9
Build Small Plant	8, 12	16, 16	20, 15
Do Not Build	9, 18	15, 20	18, 18

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GAME TREE (extensive form)

A diagram that shows the different strategies that each player can follow in a game and the order in which those strategies get chosen

		Toyota		
		Build Large Plant	Build Small Plant	Do Not Build
Honda	Build Large Plant	0, 0	12, 8	18, 9
	Build Small Plant	8, 12	16, 16	20, 15
	Do Not Build	9, 18	15, 20	18, 18

GAME TREE (extensive form)

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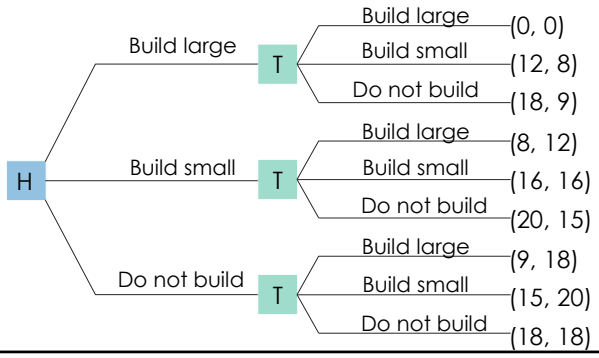
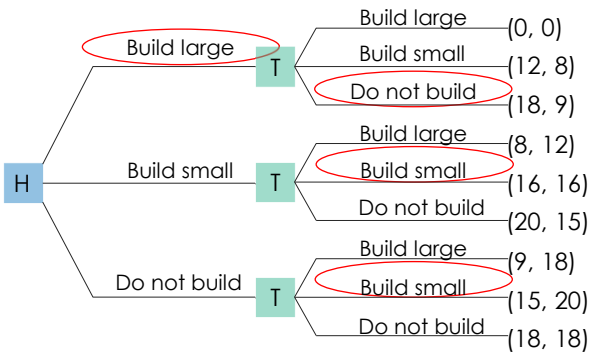


GAME TREE (extensive form)

Solve via **Backwards Induction** - start at the end of the game tree and find the optimal decision for the player at each point.



If H "builds large"
- T's optimal choice is "do not build"

If H "builds small"
- T's optimal choice is "build small"

If H "does not build"
- T's optimal choice is "build small"

Given these responses…
- H's optimal choice is to "build large"

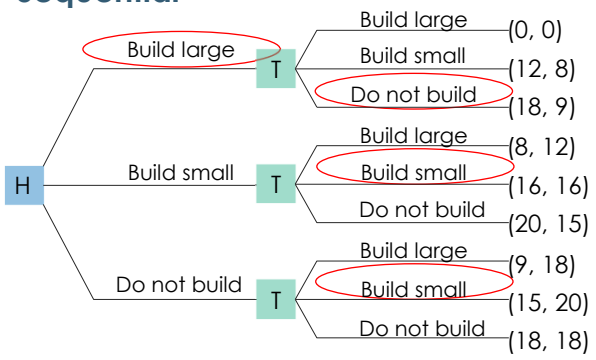
DIFFERENT OUTCOMES?

Simultaneous

		T: Build Large	T: Build Small	T: Do Not Build
H	Build Large	0, 0	12, 8	18, 9
H	Build Small	8, 12	16, 16	20, 15
H	Do Not Build	9, 18	15, 20	18, 18

Nash Equilibrium Outcome?
Honda "builds small"
Toyota "builds small"

Sequential



Nash Equilibrium Outcome?
Honda "builds large"
Toyota "does not build"

A SECOND EXAMPLE...

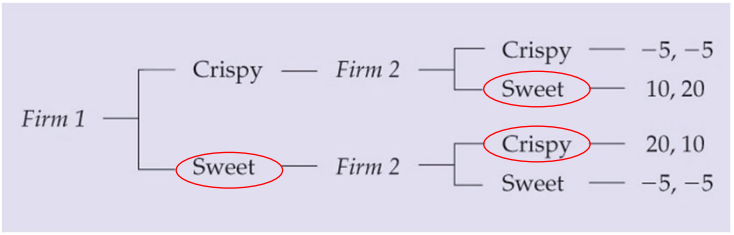
Consider a product choice game between two cereal producers.

Suppose that Firm 1 is able to introduce its new cereal first…

The game is transformed into a sequential move game where Firm 1 acts first.

Firm 1 \ Firm 2	Crispy	Sweet
Crispy	-5, -5	10, 20
Sweet	20, 10	-5, -5

Simultaneous move game has two Nash equilibria…
(Sweet, Crispy) and (Crispy, Sweet)



One Equilibrium…
(Sweet, Crispy)

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STRATEGIC MOVES

Actions that one player takes in an early stage of the game that alter their behavior and the other player's behavior later in the game in a way that is favorable to the first player.

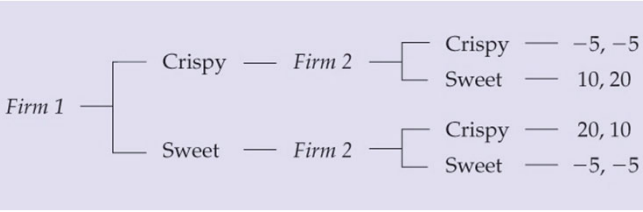
The firm that introduces it cereal first will be better off (first mover advantage!)

Announcing your intentions isn't enough…

Your rival will not believe you unless you can **commit**.

Commitment could be in the form of

1. Launching an expensive advertising campaign
2. Sign a contract for large amounts of sugar.



Must convince your rival that you have no choice but to produce sweet cereal.

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STRATEGIC MOVES

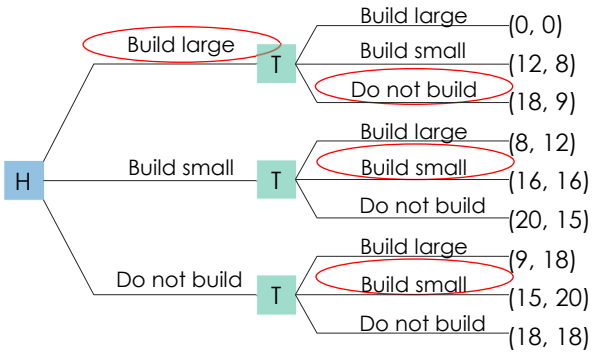
Actions that one player takes in an early stage of the game that alter their behavior and the other player's behavior later in the game in a way that is favorable to the first player.

Honda's decision to build a large plant ensures that they get a higher payoff.

By **committing** to expansion, they are able to "force Toyota's hand"

How do they credibly commit?

They built a large plant



MORE ON STRATEGIC MOVES...

A successful strategic move must be

1. visible
2. understandable
3. hard to reverse

Otherwise, the promised behavior is not credible, and the second mover may believe that the first mover intends to back out once the second mover acts.

Put another way… the second mover may think the first mover is "bluffing" and disregard their behavior.

In the product choice game, the first mover can credibly commit by…

- Launching an expensive advertising campaign
- Signing a contract for sugar
- Making a public announcement (only works if reputation is important and established).

In the expansion game, Honda can credibly commit by…

- Beginning the process of building a new plant
- Making a public announcement about their plans (only works if reputation is important and established).

EMPTY THREATS

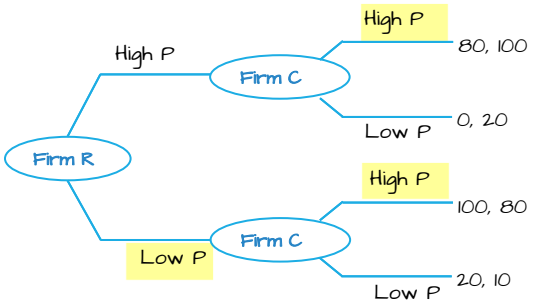
Suppose Firm C produces personal computers that can be used as both word processors and to do other tasks.

Firm R produces only dedicated word processors.

Firm R is the leader in the sequential move game.

Start by building the Extensive Form of the game and identifying the equilibrium…

		Firm C: High P	Firm C: Low P
Firm R	High P	80, 100	0, 20
	Low P	100, 80	20, 10



EMPTY THREATS

Firm C would really like Firm R to charge a high price…

They want a payoff of $100!

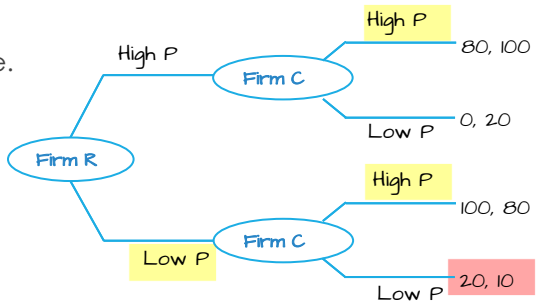
So, they try the following threat:

- If Firm R charges a low price, then Firm C will retaliate by also charging a low price.
- Outcome: R will get 20 and C will get 10

Is this a credible threat? Can Firm C force Firm R's hand?

No! Firm C would never follow through because 20<100

		Firm C: High P	Firm C: Low P
Firm R	High P	80, 100	0, 20
	Low P	100, 80	20, 10



COMMITMENT AND CREDIBILITY

How can a threat be made credible?

RCM produces cars.

FOE produces specialty car engines which they sell almost exclusively to RCM.

So, we have a sequential game where **RCM is the leader**.

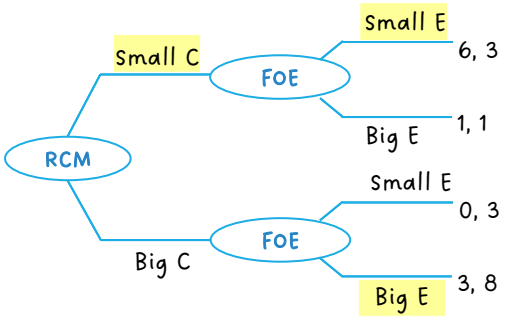
Can FOE credibly threaten to produce only big engines?

Not as things currently stand!

If they somehow **visibly and irreversibly** reduce some of their own payoffs, then they can make their threat credible…

RCM

	FOE: Small engines	FOE: Big engines
Small cars	6, 3	1, 1
Big cars	0, 3	3, 8



COMMITMENT AND CREDIBILITY

How can a threat be made credible?

RCM produces cars.

FOE produces specialty car engines which they sell almost exclusively to RCM.

So, we have a sequential game where **RCM is the leader**.

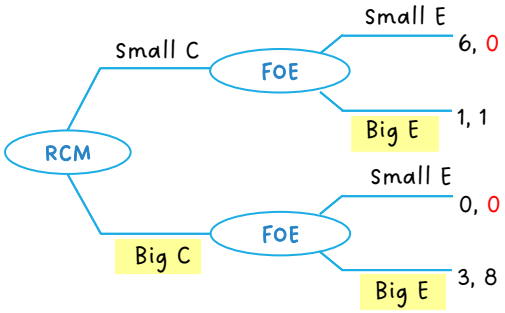
Can FOE credibly threaten to produce only big engines?

Not as things currently stand!

If they somehow **visibly and irreversibly** reduce some of their own payoffs, then they can make their threat credible…

RCM

	FOE: Small engines	FOE: Big engines
Small cars	6, 0	1, 1
Big cars	0, 0	3, 8



WE ARE DONE!

The final exam is on Friday, May 9th at 10:05 am