BUEC 311: Business Economics, Organization and Management
Strategic Behaviour Part 2
Strategies Over Time and Dynamic Games

Fall 2020

Strategic Interaction Over Time

- Last topic: Strategic interaction in static setting.
  - But in practice, many interactions occur dynamically over time.
- Dynamic games: Games where players play the game over and over, and move either repeatedly or sequentially.

Outline

1. Repeated Games
2. Sequential Games
3. Deterring Entry
4. Cost and Innovation Strategies
5. Disadvantages of Moving First
6. Behavioural Game Theory

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Repeated Games

- A repeated game is a game in which a static *constituent* game is repeated a finite and pre-specified number of times, or is repeated indefinitely.

- We still need to know:
  - Players
  - Rules
  - Information
  - Payoffs

- Key difference from a static game: How we think about actions and strategies.

Repeated Games

- In a repeated game:
  - An action is a single move that a player makes at a specified time, such as choosing an output level or a price.
  - A strategy is a battle plan that specifies the *full set* of actions that a player will make throughout the game.
    - It may involve actions that are conditional on prior actions of other players, or on new information available at a given time.

Repeated Games

- As an example, we will revisit game between American and United.
- Recall: The Nash equilibrium in the static game is both firms producing high (64k passengers) and making $4.1 million.

Repeated Games

		American Airlines	
		$q_A = 64$	$q_A = 48$
United Airlines	$q_U = 64$	4.1 / 4.1	3.8 / 5.1
	$q_U = 48$	5.1 / 3.8	4.6 / 4.6

Note: Quantities are in thousands of passengers per quarter; (rounded) profits are in millions of dollars per quarter.

Repeated Games

- Now assume that the same game gets repeated indefinitely.
  - Now firms must consider both current and future profits.
- With repetition, the outcome may be different than in the static game.
  - Depends on the strategies used by the firms.

Repeated Games

- Suppose, for example, that American adopts the following strategy:
  - It cheap-talks United that it will produce the collusive or cooperative quantity of 48k in the first period.
  - But its subsequent decisions depend on United:
    - If United produces 48k in period t, American will produce 48k in period $t+1$.
    - If United produces 64k in period t, American will produce 64k in period $t+1$.

- What is United's best response to this strategy?

Repeated Games

		American Airlines	
		$q_A = 64$	$q_A = 48$
United Airlines	$q_U = 64$	4.1 4.1	3.8 5.1
	$q_U = 48$	5.1 3.8	4.6 4.6

Note: Quantities are in thousands of passengers per quarter; (rounded) profits are in millions of dollars per quarter.

Repeated Games

- American's strategy is an example of a trigger strategy.
  - Trigger strategy: Rival's defection from a collusive outcome *triggers* punishment.
- If United adopts the same trigger strategy, the Nash-equilibrium is the collusive outcome.
  - Neither firm has an incentive to deviate.
  - One period gains from doing so are not sufficient to offset all future losses.
- In reality, cooperation may not be sustainable because of regulation, bounded rationality, or if the firm cares little about future profits.

Repeated Games

- Trigger strategy is just one possible option for American.
- They could instead adopt a tit-for-tat strategy.
  - Tit-for-tat: Cooperate in first round, then copy rival's action in each subsequent round.
- Tit-for-tat may induce cooperation if the payoff from deviating in any period is less than the loss from punishment in the subsequent period.
  - It depends on how firms discount the future.
- Cooperation is also more likely if the tit-for-tat strategy is modified to extend punishment for more than one period.
  - Extension of punishment needs to offset the one-time gains from not cooperating.

Repeated Games

- The equilibrium of the repeated game between American and United is an example of a collusive outcome.

- In most modern economies, explicit collusion is illegal.
  - However, antitrust and competition laws typically do not strictly prohibit choosing the cooperative (or cartel) quantity or price as long as no explicit agreement is reached.
  - Firms may be able to engage in implicit collusion or tacit collusion using trigger, tit-for-tat, or other similar strategies, as long as firms do not explicitly communicate with each other.
    - Tacit collusion lowers society's total surplus just as explicit collusion does.

Repeated Games

- Sustaining the cooperative outcome requires that players believe the game will repeat for ever.
- if there is a known end to the game, and players have complete foresight, the cooperation can be impossible to maintain.

Repeated Games

- To see this, suppose that American and United know that they will play the game a finite number of times (T).
- Suppose both firms use the trigger strategy that sustained collusion when the game was infinitely repeated.
- Now, the trigger strategy does not lead to a Nash Equilibrium.
- Why not?

Repeated Games

		American Airlines	
		$q_A = 64$	$q_A = 48$
United Airlines	$q_U = 64$	4.1 / 4.1	3.8 / 5.1
	$q_U = 48$	5.1 / 3.8	4.6 / 4.6

Note: Quantities are in thousands of passengers per quarter; (rounded) profits are in millions of dollars per quarter.

Repeated Games

- When the game is repeated a finite number of times, the only Nash Equilibrium is for both firms to produce a high level of output in all periods.
  - There is no cooperation again.

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Sequential Games

- So far, we've maximized strategic interactions where players make simultaneous decisions.
- But in many interactions, players alternate moves.
- We can model this type of strategic interaction as a sequential game.

Stackelberg Oligopoly

- As an example, we will again revisit the interaction between American and United, but we will now assume that the firms move sequentially in two stages:
  - First, American (the leader) chooses its output level.
  - Second, United (the follower) chooses its output level.

- This is an example of a Stackelberg oligopoly.
  - Stackelberg oligopoly involves one leader and one or more followers.

Stackelberg Oligopoly

		American Airlines $q_A = 96$	American Airlines $q_A = 64$	American Airlines $q_A = 48$
United Airlines	$q_U = 96$	0 / 0	2.0 / 3.1	2.3 / 4.6
	$q_U = 64$	3.1 / 2.0	4.1 / 4.1	3.8 / 5.1
	$q_U = 48$	4.6 / 2.3	5.1 / 3.8	4.6 / 4.6

Note: Quantities are in thousands of passengers per quarter; (rounded) profits are in millions of dollars per quarter.

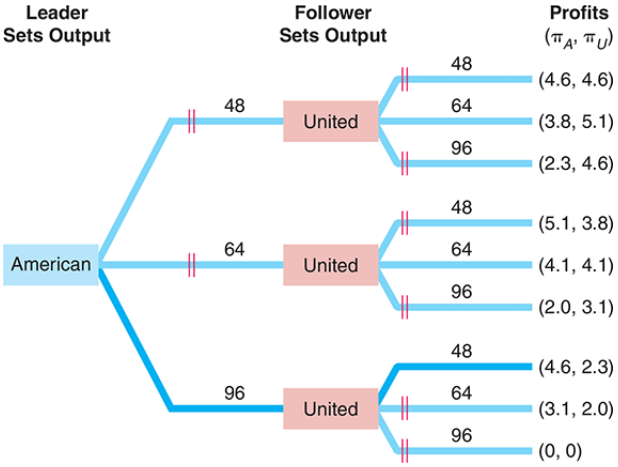
Figure: Payoffs in the Stackelberg game

Decision trees

- Key issue with the payoff matrix:
  - It does not show the sequential nature of the game.

- We can better illustrate the game using an extensive form diagram.
  - Also known as a game tree, or a decision tree.
  - The extensive form is a branched diagram that shows the players, the sequence of moves, the actions players can take at each move, the information that each player has about previous moves, and the payoff function over all possible strategy combinations.

Stackelberg Game Tree



Subgames

- The sequential game depicted in the extensive form has four subgames.

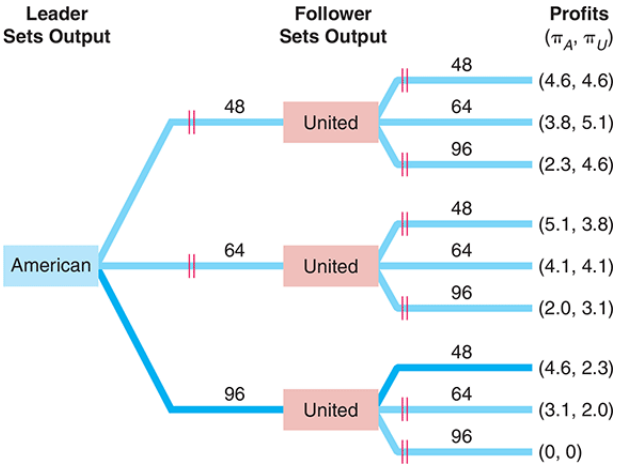
Definition (Subgame)

A subgame consists of all of the actions (and the corresponding payoffs) that a player can take at a given stage in the game, *given the actions that have already been taken*.

Subgame Perfection

- To predict the outcome of the sequential game, we need to know the set of strategies that form a Nash equilibrium in each subgame.
  - These strategies yield the subgame-perfect Nash Equilibrium.
- We can solve for the subgame-perfect Nash Equilibrium through backward induction.
  - First, we determine the best response by the last player to move, then we determine the best response for the player who makes the next-to-last move, and so on, until we reach the first move of the game.

Subgame Perfection



Subgame Perfection

- In the game between American and United, American first determines what United (the follower), will do in the second stage of the game in each of the three subgames.
  - This is the q_U with the highest profit at each node.
- American then determines the best action in the first stage given the choices that United will make *conditional on its actions* in the second stage.
  - This amounts to choosing the q_A with the highest profit.
- Thus, American chooses $q_A = 96$ in the first stage, and United chooses $q_U = 48$ in the second stage.
  - This is a subgame perfect Nash equilibrium; neither firm wants to change its strategy given what the other player is doing.

Simultaneous vs. Sequential Games

- It is worth noting that if this game was played simultaneously, the Nash equilibrium would be $q_A = q_U = 64$.

- Simultaneous and sequential games have different solutions because of credible threats and first mover advantage.
  - For a firm's strategy to be a credible threat, rivals must believe that the firm's strategy is rational (that is, it works in the firm's best interest).
  - In the simultaneous move game between United and American, United will not believe a threat by American to produce 96. However, in the sequential game, commitment to produce 96 is credible because American makes the first move.

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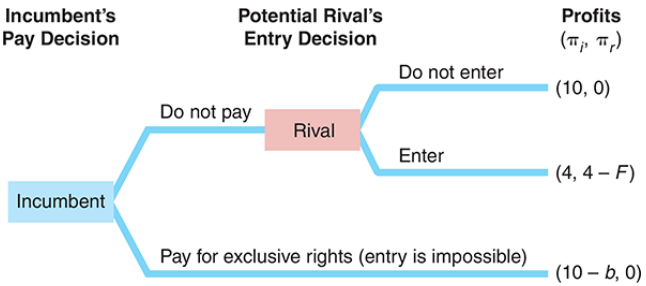
Deterring Entry

- The Stackleberg game demonstrates the leader can benefit from moving before followers.
- In some markets, by moving first, a firm can act strategically to deter a (potential) rival from entering the market.
- Two possible approaches:
  1. Exclusion contracts.
  2. Limit pricing.

Deterring Entry

- As an example of an exclusion contract, suppose a mall has a single shoe store, the incumbent firm.
  - The incumbent has an option to pay the mall's owner to add a clause to its rental agreement that guarantees exclusivity.
    - In the incumbent pays b, the landlord agrees to rent remaining space to non-shoe firms.
  - If the rental agreement does not guarantee exclusivity, a potential rival can decide whether to enter.
    - If the rival enters, it incurs a fixed fee of F to build its store in the mall.
  - This interaction can be viewed as a two-stage game.

Deterring Entry



Deterring Entry

- Should the incumbent pay for the exclusive contract?

- It depends on the values of b and F:
  1. Blockaded entry ($F > 4$): Potential rival will stay out, ensuring $\pi_r = 0$. Incumbent avoids paying b and still earn monopoly profit of $\pi_i = 10$.
  2. Deterred entry ($F \leq 4, b \leq 6$): Potential rival will enter unless the incumbent pays the exclusivity fee. The incumbent chooses to pay b because $b \leq 6$ ensures a profit that is at least as large as the duopoly profit of 4 ($\pi_i = 10 - b \geq 4$).
  3. Accommodated entry ($F \leq 4, b > 6$): Potential rival will enter and earn a positive profit of $\pi_r = 4 - F$. The incumbent does not pay the exclusivity fee because b is so high that it is better to ensure $\pi_i = 4$ than earn less ($\pi_i = 10 - b < 4$).

- The incumbent will only pay if it is profit maximizing to do so.

Deterring Entry

- In many industries, it may not be possible to deter entry.

- Instead, firms may try to *delay* entry.
  - Example: Pharmaceutical companies in the U.S.
    - When drug patents expire, the first company to file with FDA has 180-day window to be exclusive producer of generic drug. After 180 days, other generics can enter.
    - Companies with expired patents used pay-to-delay schemes to prevent entry of generics. Firms pay potential competitors to not enter the market.
    - The US supreme court ruled this was illegal *if* it violated antitrust.
    - The FTC has pursued some firms; they reached a $1.2 billion dollar settlement with Teva Ltd to compensate purchasers of Provigil who paid high prices due to pay-to-delay agreement.

Limit Pricing

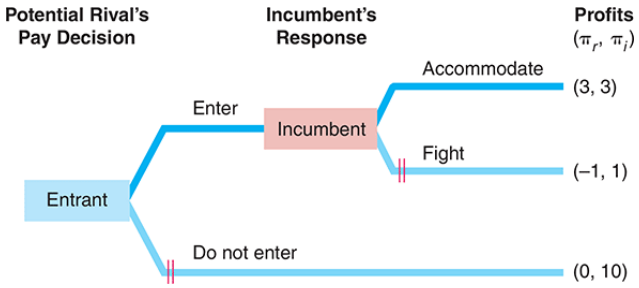
- Alternative deterrence strategy: Limit Pricing
  - A firm is limit pricing if it sets its price (or equivalently, its output) os that another firm cannot enter the market profitably.
  - Credible limit pricing requires the firm to have an advantage over its rivals.
    - Ex: A monopolist with a significant cost advantage can threaten to reduce its price if another firm enters to the point where entrant makes a loss.
    - Ex: A Stackleberg leader can act first and commit to producing a large enough quantity to ensure that any follower would earn no profit.

Deterring Entry Over Time

- Entry games can be repeated over time or over space.
  - A profitable firm will likely face repeated entry threats from potential rivals over time/locations.

- Example: A grocery chain with a monopoly in many small towns.
  - Chain may face entry in some, or all locations.
  - Two stage game:
    1. Rival decides on entry.
    2. Incumbent decides to accommodate or fight.
  - Outcome depends on repetition, level of information.

Deterring Entry



Knowledge and Deterring Entry

- The incumbent will accommodate if the game is played once, and profits are common knowledge.
- The incumbent will still accommodate if the game is repeated and profits are common knowledge.
  - If profits are common knowledge, rival knows that fighting each time is not rational.
- If profits are not common knowledge and game is repeated, the best strategy may be for incumbent to fight.
  - Fighting builds reputation.
  - Can be part of a subgame perfect Nash equilibrium in which entry is deterred.

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Cost and Innovation Strategies

- Another benefit to moving first: potential to gain a cost advantage over a rival.

- Two cases:
  1. Lowering own marginal cost.
  2. Increasing rival's marginal cost by more than own.

Cost and Innovation Strategies

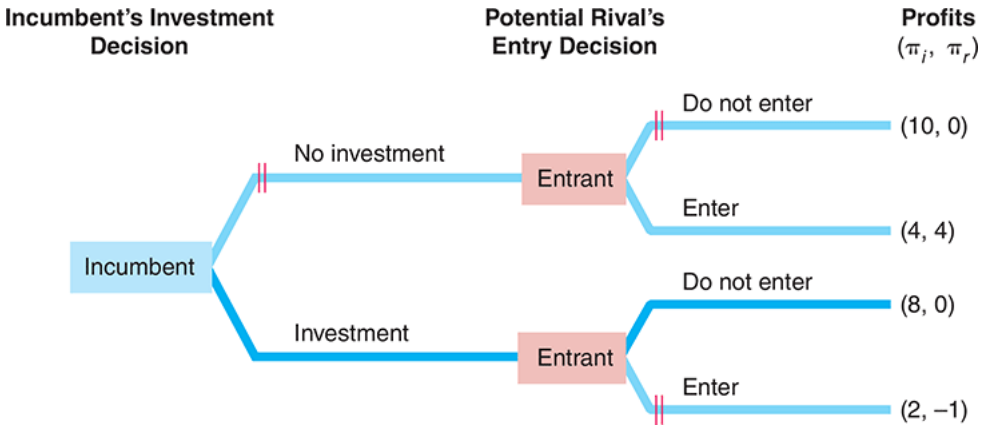
- Previously, we discussed process innovation as a means to reduce marginal costs.
  - Invest if profit from reduced MC exceeds the cost of innovation.

- Important secondary motive for process innovation: deterring entry.
  - This can provide justification for investment even if the profit from lower MC does not exceed the cost of innovation.

Cost and Innovation Strategies

- Example: A monopoly considers investment (installing robots on its assembly line) that would lower marginal costs.
  - The threat of entry may induce the monopolist to invest even though it will reduce profits.

Cost and Innovation Strategies



Cost and Innovation Strategies

- Learning by doing can also induce strategic behaviour.
  - In the presence of learning by doing, the first firm in the market may want to produce more than the short-run profit maximizing quantity so that its marginal cost is lower than that of a late-entering rival.

- Two examples:
  1. Aircraft: Price of Lockheed L-1011 was below static *MC* for most of production run because of steep learning curve.
  2. Computer chips: AMD?s cost of producing computer chips was about 12% higher than Intel because of less learning by doing.

Cost and Innovation Strategies

- Firms may also benefit from adopting a strategy that raises own cost, but raises rivals? cost by more.
  - Such strategies usually favour the first mover, or incumbent.

- Strategies for incumbents to raise rival?s costs:
  1. Lobby the government for more industry regulations that raise costs, as long as the legislation grandfathers existing firm's plants.
  2. Increase the cost of switching by imposing a switching fee to customers that take their business elsewhere or designing products that don't work with those of rivals.
  3. Use patents to prevent rivals from entering the market and increasing competition.

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First Mover Disadvantages

- While moving first can create many advantages, it is not always beneficial.
- One potential disadvantage: the holdup problem.
  - The holdup problem arises when two firms want to contract or trade with each other but one firm must move first by making a specific investment (can only be used in its transaction with the second firm).
    - Problem: The second firm can take advantage of the first.
    - If the first firm does not anticipate the opportunistic behaviour and invests, it may earn no profit.
    - If the first firm anticipates the opportunistic behaviour and does not invest, both firms lose.

First Mover Disadvantages

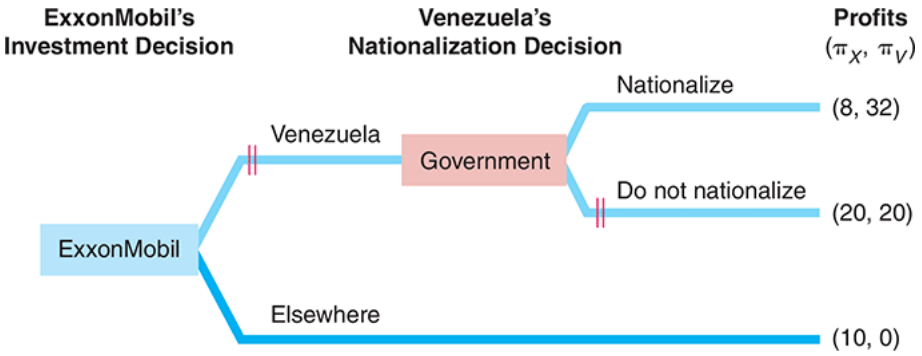

Figure: Venezuela - Exxon-Mobile Holdup Problem

First Mover Disadvantages

- There are several possible strategies for avoiding the holdup problem.
  1. Contracts
  2. Vertical integration.
  3. Quasi-vertical integration.
  4. Reputation building.
  5. Multiple/open sourcing.

First Mover Disadvantages

- Another potential disadvantage of moving first: too-early product innovation.
  - Advantage of innovating and creating new product: customer loyalty. Later entrants find it difficult to take market share away from the leader.
  - But entering with a new product too early can raise costs, increase the odds of miscalculating demand, and later rivals may build on the leader's research to produce a superior product.

- Example: Tagamet.
  - Tagamet was the first entrant of a new class of anti-ulcer drugs; it was extremely successful when introduced.
  - Zantac, the second entrant, rapidly took over the market.
  - Tagamet moved too early; Zantac had fewer side effects, needed to be taken less frequently, and was promoted more effectively.

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Behavioural Game Theory

- While it is reasonable to assume that people are rational in their decision making, psychological biases and cognitive limitations may lead to departures from rational behaviour.

- Two examples:
  1. The ultimatum game and reciprocity.
  2. The beauty contest game and levels of reasoning.

The Ultimatum Game

- The ultimatum game:
  - Game: Divide \$10 between two students.
  - Students are seated in a computer lab. Each one is designated as either a proposer or responder and matched anonymously using computers.
  - Each proposer makes an ultimatum ("take it or leave it") offer to give the responder an amount x of the \$10. If the responder accepts the offer, the responder gets x and the proposer gets $10 - x$. If the responder rejects the offer, both parties get nothing.
  - What should the proposer offer? Why?

The Ultimatum Game

- If players are rational $x = 0.01$.
  - Why?
- In practice, an offer of $x = 0.01$ is almost never made. When it is, it is rejected.
  - Offers under \$2 are relatively rare; when made, they are rejected 3/4 of the time.
  - The most common offers are between \$3 and \$4.

Reciprocity

- The key issue is that most people believe in reciprocity.
  - If others treat us well, we want to return the favour. If they treat us badly, we want to "get even".
    - Some responders who reject lowball offers feel that the proposer is being greedy and "unfair".
    - Most people accept that the advantage of moving first should provide some extra benefit to proposers, but not too much.

Reciprocity

- The issue of reciprocity is present in many business setting.
  - Many situations can be viewed as a version of the ultimatum game where manager must make (or respond to) a take it or leave it offer.

- Example: Labor negotiations.
  - Manager needs to account for reciprocity by providing benefits over and above the minimum needed.
  - Such an approach makes sense if workers who feel exploited might quit or go on strike even when it is against their economic interest. Conversely, workers who feel well treated often develop a sense of loyalty that causes them to work harder than needed or expected by contract – such as staying late to get a job finished.

Opponent Sophistication

- Another key issue: how sophisticated your opponents are.
- Issue exemplified in John Maynard Keynes' advice for picking stocks:
  - Deciding which stock to buy is like predicting the outcome of a beauty contest. Your prediction should not be based on what you think of the contestants; it should be based on what you think other people will think.
- What you think other people will think depends on your level of reasoning.

Beauty Context Game

- The Financial Times tested this in what is now known as a "beauty contest game."
- The FT asked readers to choose an integer between 0 and 100. The submission closet to 2/3 of the average of all numbers submitted would win.
- What number should be chosen?

Behavioural Game Theory

- Results of the Beauty Contest game:
  - The average was 18.9, and the winning submission was 13.
- The experiment has been repeated many times. The overall average is about 22, implying a winning number of about 15.

Behavioural Game Theory

- These results suggest that people are not fully rational.
  - The rational, unique Nash Equilibrium is for everyone to choose zero.

- Explanation: differences in levels of reasoning.
  - Level 0: Guess the average randomly. A few people in the FT experiment.
  - Level 1: Think most people will guess randomly. So, mean=50 and number chosen=33. A large group in the FT experiment.
  - Level 2: Think most people will use Level 1 reasoning. So mean=33, and number chosen=22. Many people in FT experiment.
  - Level 3: Think most people will use Level 2 reasoning. So mean=22, and number chosen=15. Winner of experiment is usually in this category.
  - Most sophisticated: Think most people are fully rational, so mean=0, number chosen=0. approx. 5% of people in experiment.

Behavioural Game Theory

- On average, participants seem to exhibit level 2 reasoning. To win the game, it is therefore usually necessary to go through 3 layers of reasoning –not more, not less– so as to be 1 step ahead of other players.

- Key lesson:
  - A manager who under/over estimates the capability of rivals for strategic thinking will make mistakes. The best approach is to have a good sense of exactly how sophisticated rivals are and stay one step ahead.

Takeaways

1. Repeated interaction can sustain an otherwise unobtainable collusive outcome.

2. If firms move sequentially, the first mover may be able to take actions to make entry more difficult for rivals. But moving first also has downsides.

3. Good managers need to be aware of reciprocity and levels of reasoning when making decisions.