# Entry and Predation Notes

## Free Entry

### Bertrand Free Entry

- Parameters
  - Consider Bertrand oligopoly with free entry. In the first stage of a two stage game, each of $n^e$ potential entrants chooses whether to enter the market at fixed set-up cost $F$. In the second stage, each firm $i$ of $n^a$ active firms chooses price $p_i$ and enjoys gross profit $\pi_i = (p_i - c)q_i$, where $c$ is the common constant marginal cost of active firms and $q_i$ is firm $i$'s quantity. Demand $Q(p) = SD(p)$, where $S$ is the market size, is downward-sloping and consumers buy only from the firm(s) with the lowest price. Each active firm $i$'s payoff is given by net profit $\pi_i - F$ and payoff of all other potential entrants is normalised to $0$.
- Analysis
  - In the second stage, if there are two or more active firms, the unique subgame Nash equilibrium is such that each active firm chooses price equal to marginal cost and enjoys zero gross profit. If there are two or more active firms, each active firm has payoff $-F$ and would be better off if it had not entered the market. If there is only one active firm, the unique subgame Nash equilibrium is such that the active firm chooses monopoly price $p^M = \arg\max_p (p-c)SD(p)$ enjoys gross profit $\pi^M = (p^M - c)SD(p^M)$ and has payoff $\pi^M - F$.
  - Supposing that $\pi^M - F > 0$, in the first stage, the subgame perfect Nash equilibrium is such that only one potential entrant enters the market. If two or more potential entrants enter the market, each active firm has payoff $-F$ and would be better off if it had not entered the market. If no potential entrant enters the market, each potential entrant has payoff $0$ and would be better off if it had entered the market. If only one potential entrant enters the market, then that firm has payoff $\pi^M - F$ and each other potential entrant has payoff $0$. No player would be better off if it had chosen otherwise.
- Result (Monopoly)
  - In the subgame-perfect equilibrium, the market is a monopoly. This is because competition between two or more firms yields the perfectly competitive outcome, under which each active firm has zero gross profit and fails to cover the fixed cost of entry.
- Result (Market Size)
  - Since marginal cost is constant, monopoly price $p^M$ is independent of market size $S$. Analytically, $\pi = (p-c)SD(p) = S\pi^I$ where $\pi^I = (p-c)D(p)$, hence $p^M = \arg\max_p \pi = \arg\max_p S\pi^I = \arg\max_p \pi^I$, and is independent of $S$.
  - Given that $p^M$ is independent of $S$, by inspection, equilibrium firm size $p^M Q(p^M) = p^M SD(p^M)$ increases in direct proportion to $S$ and equilibrium profit $\pi^M = (p^M - c)SD(p^M)$ increases in direct proportion to $S$.
  - Equilibrium number of firms increases with market size only in the sense that there is one active firm iff market size is sufficiently large such that $\pi^M - F > 0$ and there are no active firms otherwise.

### Bertrand Hit-and-Run Entry

- Parameters
  - Suppose that set-up costs are fixed but not sunk. Effectively, entry and exit are costless, and active firms incur some fixed cost $f$ such that total cost of producing output $q$, $C(q) = f + cq$. This describes, for example, a case in which a firm rents its capital equipment and/or can sell its capital equipment upon exit without capital loss. Suppose also that prices are rigid for some duration whereas entry and exit are instantaneous.
  - It is natural to suppose that there is one incumbent since given that average cost $\frac{C(q)}{q}$ is decreasing for all $q$, minimum efficient scale is infinite, and the industry cannot support multiple firms operating at minimum efficient scale, it is a natural monopoly.
- Analysis
  - The unique Nash equilibrium is such that the incumbent chooses price such that demand at this price is produced with average cost equal to this price, i.e. price given by the intersection of the demand curve and the average cost curve.
  - If the incumbent chooses a higher price, such that price exceeds average cost, a potential entrant has incentive to enter the market, choose price arbitrarily below the incumbent's price, capture all demand, enjoy positive profit, and

exit before the incumbent is able to respond by decreasing price.
    - If the incumbent chooses a lower price, such that price is less than average cost, the incumbent has negative profit, and would be better off if it exits the industry.
- Result (Average Cost Pricing)
    - In equilibrium, the industry is a monopoly, but price is equal to average cost. This outcome is identical to that which would maximise social welfare subject to the constraint that firms must enjoy non-negative profit and thus have no incentive to exit, and receive no subsidies. While the incumbent monopolist does not face actual competition, potential competition is sufficient to prevent the full exercise of market power.
- Evaluation (Assumptions)
    - The model of hit-and-run entry is unrealistic because it assumes that entry and exit occur more quickly than the adjustment of prices. In reality, prices generally adjust more rapidly than entry since entry generally requires capital accumulation and mobilisation. If prices adjust more rapidly than entry, then the Bertrand free entry result is restored, under which the monopolist is unconstrained in its exercise of market power to extract consumer surplus as profit. The threat of hit-and-run entry is not credible because such entry is not profitable since the incumbent will respond by decreasing price before entry occurs.
    - The model of hit-and-run entry is unrealistic because it assumes that entry costs are fixed but not sunk. In reality entry costs are often sunk or only partially recoverable. If entry costs are only partially recoverable, even if entry and exit occur more quickly than the adjustment of prices, the incumbent monopolist can maintain profit equal to the unrecoverable portion of entry costs such that the net (of unrecovered entry costs) profit of any entrant is negative, and there is no incentive for entry. The incumbent is only partially constrained in its exercise of market power, and is able to choose price above marginal cost and above average cost in order to extract consumer surplus as profit.

## Cournot Free Entry

- Parameters
    - Consider Cournot oligopoly with free entry. In the first stage of a two stage game, each of $n^e$ potential entrants chooses whether to enter the industry at fixed set-up cost $F$. In the second stage, each firm $i$ of $n^a$ active firms chooses output $q_i$ and enjoys gross profit $\pi_i = [P(\frac{q_i+Q_{-i}}{S}) - c]q_i$, where $P(\frac{Q}{S})$ is the downward-sloping inverse demand function, $Q_{-i}$ is the joint output of all firms except $i$, $S$ is the market size, and $c$ is the common constant marginal cost of active firms. Demand $Q(p) = SD(p)$, hence price $p = P(\frac{Q}{S})$, where $P(x) = D^{-1}(x)$. Each active firm's payoff is given by net profit $\pi_i - F$ and payoff of all other potential entrants is normalised to $0$.
- Analysis
    - In the second stage, if there are $n^a$ active firms, by symmetry, the unique subgame Nash equilibrium is such that each firm enjoys gross (of set-up cost) profit $\pi^*_{n^a} = [P(\frac{Q^*_{n^a}}{S}) - c]\frac{Q^*_{n^a}}{n^a}$, where $Q^*_{n^a}$ is the aggregate output at this equilibrium.
    - Since $S$ affects only the scale of the market, $Q^*_{n^a}$ is directly proportionate to $S$, i.e. active firms increase output in direct proportion to the size of the market. Hence $P^*_{n^a} = P(\frac{Q^*_{n^a}}{S})$ is independent of $S$.
    - In the first stage, the subgame-perfect Nash equilibrium is such that $n^*$ potential entrants enter the market (disregarding the integer constraint on the number of active firms) such that gross profit in the second stage Cournot game is equal to the fixed set-up cost, i.e. $\pi^*_{n^*} = F$. If more firms enter, gross profit in the second stage Cournot game falls below the fixed set-up cost, net profit of active firms is negative, and each active firm would be better off if it had not entered. If fewer firms enter, gross profit in the second stage Cournot game exceeds the fixed set-up cost, net profit of active firms is positive, and each potential entrant that did not enter would be better off if it had entered. Under this strategy profile, no active firm nor potential entrant has incentive to deviate.
- Result (Size of Firms)
    - An increase in market size $S$ has the first-order effect of increasing the gross profit of active firms since Cournot price $P^*_{n^a}$ hence price-cost margin $P^*_{n^a} - c$ is independent of market size and Cournot (individual) output $q^*_{n^a} = \frac{Q^*_{n^a}}{n^a}$ is directly proportionate to market size. Given free entry, the increase in gross profit of active firms in the second stage increases incentive for entry, and firms enter the market such that the equilibrium condition $\pi^*_{n^*} = F$ is restored. Entry increases the number of active firms hence decreases the Cournot price and price-cost margin. Output of each active firm increases such that gross profit remains equal to fixed set-up cost, i.e. the equilibrium condition continues to hold. An increase in market size results in an increase in the size of active firms.
- Result (Number of Firms)
    - An increase in market size results in a less than proportionate increase in the number of active firms. If the number of active firms decreases or remains unchanged, potential entrants have incentive to enter and the market is not at equilibrium. If the number of active firms increases proportionately or more than proportionately, the positive effect of

the increase in market size on active firms' profit is more than offset by the negative effect of the increase in competition on active firms' profit, hence (gross) profit of active firms decreases, each active firm would be better off had it not entered, and the market is not at equilibrium.

- Result (Welfare)
  - At equilibrium, disregarding the integer constraint on the number of active firms, the number of active firms exceeds the socially optimal, i.e. there is excessive entry. The marginal effect of entry on social surplus can be decomposed into the net profit per firm (which the entrant enjoys), the change in total gross profit due to depressed output per firm (which other firms suffer), and the effect on consumer surplus due to increased total output. Informally, these are the effects of entry on the entrant, on other firms, and on consumers (neglecting the effect of entry on price because a change in price as such constitutes only a transfer in surplus between consumers and producers, and has no effect on total surplus). At the free entry equilibrium, the marginal entrant has zero net profit, and the marginal consumer has valuation equal to price, so the first and third term are zero. The second term is negative because a decrease in output per firm as such causes a decrease in each firm's profit. The marginal effect of entry on social surplus is negative because of the business stealing effect. Each potential entrant does not account for the negative externality imposed on all other active firms when deciding whether to enter. Since the marginal effect of entry on social surplus is negative, social surplus is increased by a decrease in the number of active firms, there is socially excessive entry. Mankiw and Whinston find that, accounting for the integer constraint on the number of active firms, entry is sometimes socially insufficient, but never by more than one firm.
- Empirical Data (Bresnahan and Reiss)
  - Bresnahan and Reiss (1991) study the relationship between market size and the number of local providers of (relatively) homogenous services (e.g. doctors, dentists, and druggists) in 202 geographically isolated markets in the U.S. Bresnahan and Reiss find that the town population required to support two firms is significantly more than double the population required to support one firm, and that in general, the number of firms increases less than proportionately with the size of the market, up to $4$ firms.
  - This observation is mostly consistent with the Cournot free entry model. That the market size per firm does not increase beyond $4$ firms suggests that firms' margins are not eroded by entry of subsequent firms.
  - Bresnahan and Reiss also studied the prices of tire dealers in the U.S., and find that the prices of tires falls as entry occurs and the number of tire dealers in the market increases.
  - This observation is consistent with the Cournot free entry model, under which entry erodes margins.
- Empirical Data (Campbell and Hopenhayn)
  - Campbell and Hopenhayn (2005) study the size of producers in 13 retail trade industries in 225 markets of different sizes in the U.S. in 1992. Campbell and Hopenhayn find that in most industries, market size has a significant positive effect on firms' average sales and employment. A doubling of market size corresponds to an increase in average sales of $3\%$ to $19\%$.
  - This observation is consistent with the Cournot free entry model. Under this model, firm size increases less than proportionately with market size.

# Entry Deterrence

## Dixit-Spence Model

- Parameters
  - Consider the Dixit-Spence model of entry deterrence by capacity investment. In the first stage of a three stage game, the incumbent $I$ chooses capacity $k_I$. In the second stage, the potential entrant $E$ decides whether to enter the industry at fixed set-up cost $F$, given $k_I$. In the third stage, if the potential entrant chose to enter in the second stage, the incumbent and entrant compete by choosing output $q_I$ and $q_E$ to maximise profit $\pi_I$ and $\pi_E$ respectively. Price $p = P(Q)$ is given by downward-sloping inverse demand $P(Q)$ where $Q = q_I + q_E$ denotes aggregate output. One unit of output requires one unit of capacity $k$ at cost $r$ and one unit of labour $l$ at cost $w$ to produce. The incumbent is free to expand capacity in the third stage, but the cost of capacity in the first stage is sunk. The incumbent's payoff is equal to its gross profit. The potential entrant's payoff is equal to its net (of set-up cost) profit if it enters, and is normalised to $0$ if it does not.
- Analysis
  - In the third stage, the incumbent can produce up to $k_I$ units of output at marginal cost $w$ and produces all further units at marginal cost $w + r$. Investment shifts the incumbent's reaction function upward and rightward (in output space) for all units of incumbent output up to $k_I$. Investment makes the incumbent act more aggressively.
  - By varying its choice of $k_I$ in the first stage, the incumbent can choose any point along the entrant's reaction function, between $A$ and $B$ as the result of the third stage game, supposing that the entrant chooses to enter the market in the

second stage.

  - If, at all points along $AB$ the entrant's profits in the third stage exceed $F$, entry is ineffectively impeded, the entrant is better off if it enters than if it does not, regardless of the incumbent's choice of investment, hence the entrant enters the market. The incumbent accommodates entry by choosing the point along $AB$ which maximises its profit, and choosing $k_I$ equal to incumbent output at this point.
  - If, by choosing some $k_I$ no greater than the monopoly output, the incumbent is able to decrease the entrant's potential profit in the third stage such that it is less than $F$, entry is blockaded. If the incumbent so chooses, the potential entrant optimally responds by choosing not to enter in the second stage, and the incumbent chooses monopoly output and sells at monopoly price in the third stage.
  - If, by choosing some $k_I$ greater than the monopoly output, the incumbent is able to decrease the entrant's potential profit in the third stage such that it is less than $F$, the incumbent may choose to either deter entry by so choosing or accommodate entry by choosing the point along $AB$ which maximises incumbent profits.
- Result (Over-Investment)
  - The incumbent over-invests in capacity, regardless of whether it aims to accommodate entry or deter entry. Investment in capacity makes the incumbent "tough", i.e. choose a more aggressive response given any choice by the incumbent, i.e. choose a higher quantity $q_I$ given any $q_E$. Quantities in this model are strategic substitutes, i.e. each player optimally responds by being less aggressive when its rival is more aggressive. By over-investing, the incumbent becomes more "tough", and at equilibrium, the incumbent is more aggressive and the entrant is less aggressive. Over-investment deters entry since the incumbent is more aggressive at equilibrium and the entrant's profit is lower. Over-investment maximises incumbent profit if the incumbent accommodates entry since the entrant is less aggressive at equilibrium.
  - The incumbent over-invests in capacity, regardless of whether it aims to accommodate entry. If the incumbent aims to accommodate entry, the relevant comparison is to the "open-loop" (Fudenberg and Tirole, 1984) case in which investment has no strategic effect on the incumbent's profit. In this case, the incumbent chooses capacity no greater than the Cournot Nash quantity given by $A$. Except in the case where the Stackelberg quantity coincides with the Cournot Nash quantity, the incumbent chooses (strictly) greater capacity in the subgame-perfect equilibrium than in the open-loop case. If the incumbent aims to deter entry, the relevant comparison is to the monopoly case, where there is no threat of entry. In this case, the incumbent chooses capacity no greater than the monopoly quantity given by the incumbent's reaction function where the entrant's quantity is zero. If, in the subgame-perfect equilibrium, entry is deterred rather than blockaded, the incumbent chooses capacity greater than its monopoly quantity, hence capacity greater than that in the monopoly case.
- Discussion (Sunk Cost)
  - The outcome in the Dixit-Spence model of entry deterrence by capacity investment is different from the Cournot Nash outcome because the incumbent's capacity investment cost in the first stage is sunk, i.e. the incumbent cannot, in the third stage, choose an output that does not fully utilise capacity and recover the cost of excess capacity. If the investment cost is recoverable, the incumbent's effective marginal cost of production is $w + r$ over all units, and its reaction function is unchanged. If this is common knowledge, the third stage subgame Nash equilibrium is always the Cournot Nash equilibrium. The incumbent is unable to deter entry since entry occurs iff Cournot Nash profit exceeds the set-up cost.
- Empirical Data (Lieberman)
  - Lieberman (1987) studied rates of market growth and capacity utilisation in periods just prior to the construction of new plants by entrants and incumbents in a sample of $38$ chemical product industries from 1952 to 1982. Lieberman found that the threshold levels of market growth and capacity utilisation required to induce investment in an additional plant were similar for incumbents and entrants.
  - This observation is not consistent with the hypothesis that incumbent firms over-invest in capacity in order to deter entry. If incumbents over-invest in capacity in order to deter entry, we would expect that incumbents expand capacity pre-emptively at a lower threshold than entrants.
  - This finding is, however, not decisive, since the decision of an incumbent to open an additional plant and the decision of an entrant to open an additional plant are not symmetrical decisions. Incumbents can often expand through incremental additions to existing plants, which plausibly increases the threshold of market growth and capacity utilisation required to induce investment in an additional plant. Incumbents may open an additional plant not in an effort to expand capacity, but to replace existing capacity. This would reduce the sensitivity of incumbent investment to rates of market growth and capacity expansion, hence impose a negative bias on the observed thresholds. If the net effect of these asymmetries increases the threshold at which incumbents invest in an additional plant, the empirical observation could be consistent with an incentive for incumbents to deter entry by maintaining excess capacity.

## Fudenberg-Tirole (1984) Taxonomy

- Analysis (Deterrence)
  - To deter entry, an incumbent firm must reduce the potential profits of potential entrants, such that potential entrants are better off if they do not enter a market.
  - Let $k_i, x_i, x_e$ denote the investment of the incumbent, the strategic variable of the incumbent, and the strategic variable of the (potential) entrant respectively. Let $\pi_i, \pi_e$ denote the profit of the incumbent and the (potential) profit of the entrant respectively. Let $x_i, x_e$ be such that a higher value corresponds to more aggressive action, i.e. $\frac{\partial \pi_e}{\partial x_i} < 0$ and $\frac{\partial \pi_i}{\partial x_e} < 0$. Under Cournot competition, for example, $x_i, x_e$ would denote the output of the incumbent and entrant respectively. Under Bertrand competition, $x_i, x_e$ would denote the inverse of the incumbent's price and the inverse of the entrant's price respectively.
  - The effect of investment on the profits of potential rivals, $\frac{d\pi_e}{dk_i}$ can be decomposed as: $\frac{d\pi_e}{dk_i} = \frac{\partial \pi_e}{\partial k_i} + \frac{\partial \pi_e}{\partial x_i}\frac{dx_i}{dk_i} + \frac{\partial \pi_e}{\partial x_e}\frac{dx_e}{dk_i}$. At the Nash equilibrium, the entrant chooses $x_e$ to maximise $\pi_e$, hence the first order condition $\frac{\partial \pi_e}{\partial x_e} = 0$ holds, and the above decomposition simplifies to $\frac{d\pi_e}{dk_i} = \frac{\partial \pi_e}{\partial k_i} + \frac{\partial \pi_e}{\partial x_i}\frac{dx_i}{dk_i}$. Total effect of investment by the incumbent on the profits of the entrant can be decomposed into a direct effect and a strategic effect (through the incumbent's strategic variable). In general, investment by the incumbent has no direct effect on the profits of the entrant, since this is typically a function of the two firms' strategic variables. The above decomposition further simplifies to $\frac{d\pi_e}{dk_i} = \frac{\partial \pi_e}{\partial x_i}\frac{dx_i}{dk_i}$. Total effect of investment by the incumbent on the profits of the entrant is given by the strategic effect of investment.
  - Given that strategic variable $x_i$ is defined such that an increase in $x_i$ constitutes more aggressive action which decreases $\pi_e$, $sign(\frac{\partial \pi_e}{\partial x_i}) = -1$, hence $sign(\frac{d\pi_e}{dk_i}) = -sign\frac{dx_i}{dk_i}$.
  - Whether the incumbent should over-invest or under-invest to deter entry therefore depends on whether investment makes the incumbent tough or soft.
  - If investment makes the incumbent tough, an increase in $k_i$ causes an increase in the optimal $x_i$ given any $x_e$. The incumbent's best response curve in $x_i, x_e$ space shifts rightwards and upwards. The incumbent's optimal response to any choice by the entrant becomes more aggressive. An increase in investment causes the incumbent to act more aggressively, driving down the entrant's profit and deterring entry. The incumbent should act as "Top Dog" by over-investing to appear tough.
  - If investment makes the incumbent soft, an increase in $k_i$ causes a decrease in the optimal $x_i$ given any $x_e$. The incumbent's best response curve in $x_i, x_e$ space shifts leftwards and downwards. The incumbent's optimal response to any choice by the entrant becomes less aggressive. A decrease in investment causes the incumbent to act more aggressively, driving down the entrant's profit and deterring entry. The incumbent should act "Lean and Hungry" by under-investing to appear tough.
- Analysis (Accommodation)
  - When an incumbent firm decides to accommodate entry, it is interested in maximising its own profits given that entry occurs.
  - The effect of investment on incumbent's profit can be decomposed as: $\frac{d\pi_i}{dk_i} = \frac{\partial \pi_i}{\partial k_i} + \frac{\partial \pi_i}{\partial x_i}\frac{dx_i}{dk_i} + \frac{\partial \pi_i}{\partial x_e}\frac{dx_e}{dk_i}$. At the Nash equilibrium, the incumbent chooses $x_i$ to maximise $\pi_i$, hence the first order condition $\frac{\partial \pi_i}{\partial x_i} = 0$ holds, and the above decomposition simplifies to $\frac{d\pi_i}{dk_i} = \frac{\partial \pi_i}{\partial k_i} + \frac{\partial \pi_i}{\partial x_e}\frac{dx_e}{dk_i}$. Total effect of investment by the incumbent on its profits can be decomposed into a direct effect and a strategic effect (through the entrant's strategic variable). The effect of investment on the entrant's strategic variable can be analysed as $\frac{dx_e}{dk_i} = \frac{\partial x_e}{\partial x_i}\frac{dx_i}{dk_i}$. Suppose for the sake of argument that investment has no direct effect on the incumbent's profitability.
  - The above decomposition simplifies to $\frac{d\pi_i}{dk_i} = \frac{\partial \pi_i}{\partial x_e}\frac{\partial x_e}{\partial x_i}\frac{dx_i}{dk_i}$. Since $\frac{\partial \pi_i}{\partial x_e} < 0$ by definition of $x_e$, $sign(\frac{d\pi_i}{dk_i}) = -sign(\frac{\partial x_e}{\partial x_i}\frac{dx_i}{dk_i})$.
  - Whether the incumbent should over-invest or under-invest therefore depends on whether investment makes the incumbent tough or soft and whether the strategic variables of the incumbent and the entrant are strategic substitutes or strategic complements.
  - If investment makes the incumbent tough, an increase in $k_i$ causes an increase in the optimal $x_i$ given any $x_e$.
  - If $x_i, x_e$ are strategic substitutes, an increase in $x_i$ (only directly) causes a decrease in the marginal profitability of aggressive action by the entrant, i.e. a decrease in $\frac{\partial \pi_e}{\partial x_e}$. Since, at equilibrium, $\frac{\partial \pi_e}{\partial x_e} = 0$, assuming that $\pi_e$ is strictly concave in $x_e$, i.e. $\frac{\partial \pi_e}{\partial x_e}$ is decreasing with increasing $x_e$, an increase in $x_i$ is met with a decrease in $x_e$ such that this condition holds at equilibrium.
  - Reaction functions in $x_i, x_e$ space are downward-sloping. The entrant optimally responds to a more aggressive incumbent by acting less aggressively.
  - An increase in investment causes the incumbent to act more aggressively, and the entrant responds by acting less aggressively, which increases the incumbent's profits. The incumbent should act as "Top Dog" by over-investing to appear tough.

- If $x_i, x_e$ are strategic complements, an increase in $x_i$ (only directly) causes an increase in the marginal profitability of aggressive action by the entrant, i.e. an increase in $\frac{\partial \pi_e}{\partial x_e}$. Since, at equilibrium, $\frac{\partial \pi_e}{\partial x_e} = 0$, assuming that $\pi_e$ is strictly concave in $x_e$, i.e. $\frac{\partial \pi_e}{\partial x_e}$ is decreasing with increasing $x_e$, an increase in $x_i$ is met with an increase in $x_e$ such that this condition holds at equilibrium.
    - Reaction functions in $x_i, x_e$ space are upward-sloping. The entrant optimally responds to a more aggressive incumbent by acting more aggressively.
    - A decrease in investment causes the incumbent to act less aggressively, and the entrant responds by acting less aggressively, which increases the incumbent's profits. The incumbent should act as a "Puppy Dog" by under-investing to appear soft.
    - By similar reasoning, if investment makes the incumbent soft and strategic variables are strategic substitutes, the incumbent should act "Lean and Hungry" by under-investing to look tough. And if instead strategic variables are strategic complements, the incumbent should act as "Fat Cat" by over-investing to look soft.
- Case Study (Southwest Airlines)
    - Goolsbee and Syverson (2008) study the response of incumbent major airlines to the threat of entry by Southwest Airlines in the U.S. from 1993 to 2004. Goolsbee and Syverson find that when Southwest begins operating out of two airports, but has not yet offered direct flights between the two airports, such that incumbents offering flights on this route face a heightened threat of Southwest's entry but do not yet face actual entry, incumbents decrease average fares on this route substantially. The decrease in average fares by incumbents in response to the threatened entry is greater than the decrease in average fares by incumbents following actual entry. The decrease in fares is not explained by shifts in airport-specific operating costs.
    - The response of incumbents to the threat of entry by Southwest observed by Goolsbee and Syverson may be understood as an investment in customer loyalty, which has the direct effect of reducing Southwest's profit were it to enter, thus deterring entry. Alternatively, the investment in customer loyalty could be understood as an effort to accommodate entry, since investment in customer loyalty softens price competition in the event that Southwest enters.
- Case Study (Fuiji Photo)
    - In the U.S. consumer market for photographic film, Eastman Kodak enjoyed a virtual monopoly in the 1970s. Fuji Photo Film of Japan only successfully entered the market in 1980. Kodak accommodated the entry of Fuji by maintaining high prices (relative to its variable cost and to Fuji's price) in order to soften price competition and adopting a "Fat Cat" stance by over-investing in market-expanding advertising (which benefited Fuji more than it benefited Kodak), in order to soften price competition.
- Empirical Data (Ellison and Ellison)
    - Ellison and Ellison (2011) study incumbents' advertising, product proliferation, and pricing decisions as their pharmaceutical patents approached expiry in the U.S. between 1986 and 1992. Ellison and Ellison find that, in some cases, the relationship between strategic investment (in advertising, product proliferation, or customer loyalty or goodwill through lower pricing) has a non-monotonic relationship with market size. Incumbents over-invest in intermediate-sized markets and under-invest in small or large markets.
    - This observation is consistent with the theory of strategic entry deterrence. In small markets, no investment is required to deter entry. In large markets, it is impossible to deter entry. Therefore, the incentive to deter entry through strategic investment is greatest in intermediate-sized markets.

# Predatory Pricing

## Selten (1978) Chain Store Paradox

- Parameters
    - Consider the Selten (1978) chain store paradox. An incumbent monopolist operates in $n$ identical markets, and $n$ potential entrants threaten entry in each of these markets. The potential entrant in market $n$ decides whether or not to enter at some fixed set-up cost, if it enters, the incumbent then decides whether or not to prey on the entrant or share the market. Then the potential entrant in market $n-1$ moves and the incumbent responds, and so on. The incumbent's payoff in each market is highest if there is no entry, moderate if it shares the market with the entrant, and lowest if it preys on the entrant. The incumbent's total payoff is equal to the sum of its payoff in each market. Each potential entrant's payoff is highest if it shares the market, moderate if it does not enter, and lowest if it is preyed on.
- Analysis
    - Consider the final market, market $1$. Given common knowledge of rationality and perfect information about each firm's payoffs, the potential entrant in this market knows that if it enters, the incumbent optimally responds by choosing to share the market. This entrant thus chooses to enter, regardless of the outcomes in all earlier markets, since its

payoff is greater if the incumbent shares the market than if it does not enter. Then, in the penultimate market, market $2$, since the outcome in this market has no effect on the outcome of all subsequent markets, only payoffs in this market are relevant to the incumbent and potential entrant's decisions. Again given common knowledge of rationality and perfect information about each firm's payoffs, the potential entrant knows that if it enters, the incumbent optimally responds by choosing to share the market. The potential entrant thus chooses to enter, regardless of the outcomes in all earlier markets. By backward induction, entry occurs in every market and is never met with predation.

- Discussion
  - Entry occurs in every market and is never met with predation because past predatory behaviour has no effect on subsequent potential entrants' assessment of the incumbent's likely response, hence no effect on their behaviour, given common knowledge of rationality. Even if the incumbent were to prey on an entrant, subsequent entrants would not evaluate predation as a more likely outcome since the threat of predation by the incumbent is not credible. Setting a low price would be ineffective in deterring entry. "What is lacking, apparently, is a plausible mechanism that connects behaviour in otherwise independent markets".

## Milgrom-Roberts (1982) Signalling Model

- Parameters
  - Consider the simplified Milgrom-Roberts (1982) signalling model of predatory pricing. In the first stage of a three stage game, an incumbent monopolist chooses price given marginal cost. In the second stage, a potential entrant decides whether to enter the market at some fixed set-up cost. In the third stage, if the potential entrant chose to enter the market in the second stage, the two firms compete in prices, otherwise, the incumbent continues to operate as a monopolist. The payoff to the incumbent is the undiscounted sum of its profit in the first stage and its profit in the third stage. The payoff to the potential entrant is its net profit, equal to its gross profit in the third stage less the fixed set-up cost if it enters, and is normalised to zero if it does not enter. Suppose that the incumbent's marginal cost is known to the incumbent, and that the potential entrant knows only that the incumbent's marginal cost is either high or low. Suppose that the potential entrant's payoff would be negative were it to enter and compete against a low-cost incumbent.
- Analysis
  - A low-cost incumbent can deter entry by signalling that it is such an incumbent with a sufficiently low price such that it would be irrational for a (hypothetical) high-cost incumbent to choose the same. This price is such that the (hypothetical) high-cost incumbent would be better off were it to set monopoly price in the first stage and share the market in the third stage, than if it were to choose this low price in the first stage and enjoy monopoly profit in the third stage. Given common knowledge of rationality, the potential entrant knows that only a low-cost incumbent would set such a price, and thus would choose not to enter if such a price is observed. The low-cost incumbent has incentive to deter entry by signalling that it is such an incumbent with a low price iff the cost of signalling (forgone profit in the first stage) is no greater than the benefit of signalling (increased profit in the third stage since the incumbent continues to act as a monopoly and need not share the market with an entrant).

## Kreps-Wilson (1982) Reputation Model

- Parameters
  - Consider the simplified Kreps-Wilson (1982) reputation model of predatory pricing. An incumbent monopolist is threatened by the entry of a potential entrant in each of $n$ markets, as in the Selten chain store model. As in the Selten chain store model, in each market, the potential entrant decides whether to enter, then the incumbent monopolist, if entry occurs, decides whether to prey on the entrant or to share the market, and markets "play out" sequentially.
  - Suppose that, unlike in the Selten chain store model, each potential entrant, a priori, entertains some non-zero probability that the incumbent is "strong" rather than "weak". A "strong" incumbent receives a greater payoff if it were to meet entry with predation than if it were to share the market (though both "strong" and "weak" incumbents are best off if no entry occurs).
- Analysis
  - If, in some market, a strong incumbent responds to entry by sharing the market, potential entrants in all subsequent markets evaluate predation as less likely and hence have greater incentive to enter. Since the incumbent is always worse off if entry occurs than if it does not, and a strong incumbent is worse off if it shares the market than if it preys on the entrant, a strong incumbent has no incentive to share the market. Given common knowledge of rationality, if a weak incumbent shares the market, it reveals itself as a weak incumbent to all subsequent potential entrants. By analysis similar to that in the Selten chain store paradox, entry occurs in all subsequent markets and is never met with predation. If a weak incumbent ever shares the market, it suffers a large decrease in total payoff which increases

    with the number of remaining markets, hence a weak incumbent has strong incentive to prey on early entrants to "preserve" its "reputation". Early entry is almost certainly to be met with predation, given the incumbent's incentives, hence potential entrants choose not to enter. If entry occurs in early stages, the incumbent can deter subsequent entry by preying on the entrant.

- Evaluation
    - Potential entrants may entertain some non-zero probability that the incumbent is strong because they are uncertain about the monopolist's costs, or about the non-pecuniary benefits that the monopolist potentially enjoys.
- Extension (Milgrom-Roberts Reputation Model)
    - Milgrom and Roberts suggest that potential entrants could be uncertain about not only the incumbent's payoffs, but also about the options available to the incumbent. Potential entrants could, a priori, entertain some non-zero probability that the incumbent does not have a choice between predation and sharing the market, and preys on entrants under a "general pattern of aggressive behaviour". The incumbent, for example, may be involved in some larger-scale game, in which its aggressive behaviour in the smaller-scale game is a necessary element of some optimal strategy. By a similar analysis, the incumbent can deter entry by preying on early entrants.

## Fudenberg-Tirole (1985, 1986b) Long Purse Model

- Parameters
    - Consider the Fudenberg-Tirole (1985, 1986b) long purse model of predatory pricing. In the first of two periods, an incumbent and an entrant compete in a market. Between the first and second period, the entrant must finance by either equity or debt an investment of fixed size to remain in the market. In the second period, if the entrant remains in the market, the incumbent and entrant again compete. The entrant's equity at the end of the first period depends on its retained earnings after first-period competition.
- Analysis
    - By preying on the entrant in the first period, the incumbent decreases the entrant's first period profit, and thus decreases the equity available for financing the fixed investment. If the entrant is to remain in the market, it must finance more of the fixed investment by debt. A decrease in equity and an increase in debt increases the risk of bankruptcy, hence the expected bankruptcy cost, which is passed onto the entrant as a higher interest rate. The increase in the cost of debt to the entrant decreases the entrant's incentive to continue in the market. The entrant exits the market if the return on equity from continuing in the market is lower than the opportunity cost of equity. The incumbent can deter entry by preying on the entrant, i.e. inflicting sufficiently large losses on the entrant through aggressive competition in the first period such that the entrant no longer finds it optimal to remain in the market in the second period.
- Discussion
    - Under this model of predatory pricing, predation is associated with imperfections in the capital market, where bankruptcy costs are incurred by the bank in observing the entrant's profits in the event of default, which are passed onto the entrant as interest (above the cost of funds to banks). Because the cost of debt exceeds the (opportunity) cost of equity, an incumbent can make remaining in the market less attractive for the entrant by forcing the entrant to finance its investment with more debt.