31E11100 - Microeconomics: Pricing

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Lectures 5-6: Models of pricing under asymmetric information
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Topics on pricing under asymmetric information

- In the next few lectures, we continue with pricing under asymmetric information
- First, we will continue a bit with menu pricing (or second-degree price discrimination, or screening)
  - We will apply the theory model developed in the previous lecture
- Second, we will consider another strategy available to the seller: bundling different goods together
- Third, we will consider an opposite informational environment: seller has private information about product quality
  - So far, we have assumed that the product characteristics are publicly known, but the buyers have private information about their tastes
  - Here we turn the situation around: seller knows the quality of the good, but buyers have only incomplete information
  - This will relate to two classical models of information economics: lemons and signalling

Screening

- We next consider the two main manifestations of screening by a monopolist seller:
- Quantity discounts
- Versioning:
  - Vertical vs Horizontal Differentiation
  - Quality Premia
  - Damaged Goods

Numerical Example on Quantity Discounts

- To illustrate quantity discounts, let us specify the model of the previous lecture as follows:
- $\theta^H = 2, \theta^L = 1$.
- $v(q) = \sqrt{q}$.
- $c(q) = cq$.
- $\Pr\{\theta = \theta^H\} = \frac{2}{5}$.

- Under full information, the monopolist sets:

$$\theta^i v'\left(\widehat{q}^i\right) = c'\left(q^i\right) \text{ for } i \in \{1, 2\}.$$

Hence

$$2 \times \frac{1}{2}\frac{1}{\sqrt{\widehat{q}^H}} = c,$$

or

$$\widehat{q}^H = \frac{1}{c^2},$$

and

$$\widehat{q}^L = \frac{1}{4c^2}.$$

- The corresponding transfers under full information are:

$$\widehat{t}^H = \frac{2}{c}, \widehat{t}^L = \frac{1}{2c}.$$

- Consider now the case where θ is private information to the buyer. If the monopolist chose $\left\{\left(\widehat{q}^H, \widehat{t}^H\right), \left(\widehat{q}^L, \widehat{t}^L\right)\right\}$, the θ^H would choose $\left(\widehat{q}^L, \widehat{t}^L\right)$. the resulting information rent to θ^H is

$$\left(\theta^H - \theta^L\right) v\left(\widehat{q}^L\right) = \frac{1}{2c}.$$

- Hence if $\left(\widehat{q}^L, \widehat{t}^L\right)$ is available to the buyers, the maximal t^H that will induce θ^H to choose $\left(\widehat{q}^H, t^H\right)$ over $\left(\widehat{q}^L, \widehat{t}^L\right)$ is

$$t^H = \widehat{t}^H - \left(\theta^H - \theta^L\right) v\left(\widehat{q}^L\right) = \frac{3}{2c}.$$

- The profit to the firm at $\left\{\left(\widehat{q}^H, t^H\right), \left(\widehat{q}^L, \widehat{t}^L\right)\right\}$ is given by:

$$\frac{2}{5}\left(\frac{3}{2c} - \frac{1}{c}\right) + \frac{3}{5}\left(\frac{1}{2c} - \frac{1}{4c}\right) = \frac{7}{20c}.$$

- How can the monopolist improve profit?
  - The only problem is the information rent going to θ^H.
  - Since it is $\left(\theta^H - \theta^L\right) v\left(q^L\right)$, it can be reduced by decreasing q^L.
  - For example, if $q^L = 0$, then θ^H gets no information rent.
  - Hence $\left\{\left(\widehat{q}^H, t^H\right), (0,0)\right\}$ is an incentive compatible offer.
  - You can calculate the profit from this to be $\frac{2}{5c} > \frac{7}{20c}$.
- Even better: Choose q^L from the formula in the previous lecture:

$$-\lambda\left(\theta^H - \theta^L\right) v'\left(q^L\right) = (1-\lambda)\left(c'\left(q^L\right) - \theta^L v'\left(q^L\right)\right).$$

- Plugging in the functional forms, the values for θ^i and $\lambda = \frac{2}{5}$, we get:

$$-\frac{2}{5}\frac{1}{2\sqrt{q^L}} = \frac{3}{5}\left(c - \frac{1}{2\sqrt{q^L}}\right),$$

  or

$$q^L = \frac{1}{36c^2}.$$

- Hence we can compute the optimal menu to be $\left\{\left(\widehat{q}^H, \widehat{t}^H\right), \left(\widehat{q}^L, \widehat{t}^L\right)\right\} = \left\{\left(\frac{1}{c^2}, \frac{11}{6c}\right), \left(\frac{1}{36c^2}, \frac{1}{6c}\right)\right\}$.
- Total profit is then

$$\frac{22}{30c} - \frac{2}{5c} + \frac{3}{30c} - \frac{3}{5 \cdot 36c} = \frac{25}{60c} > \frac{2}{5c}.$$

- Notice that if $\lambda \geq \frac{1}{2}$, it is optimal to set $q^L = 0$ and to sell only to θ^H at the monopoly price.
  - You can see this from the fact that the derivative of the monopolist's profit is negative in q^L for all $q^L \geq 0$.
- Finally, we can compute the implied per unit price in the two options:

$$\frac{t^L}{q^L} = 6c,$$

$$\frac{t^H}{q^H} = \frac{11}{6}c.$$

Hence first q^L units are sold at a higher per unit price than the next $\left(q^H - q^L\right)$ units. We say, that the model shows quantity discounts in this case.

Endogenous Quality Choice

- Let us modify the model slightly.
- Here, it is more natural to interpret q as quality.
- $\theta^H = 2, \theta^L = 1$.
- $v(q) = q$.
- $c(q) = \frac{1}{2}q^2$.
- $\Pr\{\theta = \theta^H\} = \frac{2}{5}$.
- It is left as an exercise for you to show that full information quantities and transfers are $\left\{\left(\widehat{q}^H, \widehat{t}^H\right), \left(\widehat{q}^L, \widehat{t}^L\right)\right\} = \{(2,4), (1,1)\}$. The information rent to θ^H is $\left(\theta^H - \theta^L\right) q^L = 1$.

- $\{(2,3),(1,1)\}$ is incentive compatible and yields expected profit of $\frac{2}{5}(3-2)+\frac{3}{5}\left(1-\frac{1}{2}\right)=\frac{7}{10}$.
- By offering $\{(2,4),(0,0)\}$, the profit is increased to $\frac{8}{10}$.
- Again, the optimal offer to θ^L can be calculated from

$$-\lambda\left(\theta^H-\theta^L\right)v'\left(q^L\right)=(1-\lambda)\left(c'\left(q^L\right)-\theta^L v'\left(q^L\right)\right).$$

or

$$-\frac{2}{5}=\frac{3}{5}\left(q^L-1\right)\ \Leftrightarrow q^L=\frac{1}{3}.$$

- The profit at $\left\{\left(2,\frac{11}{3}\right),\left(\frac{1}{3},\frac{1}{3}\right)\right\}$ is $\frac{2}{5}\left(\frac{11}{3}-2\right)+\frac{3}{5}\left(\frac{1}{3}-\frac{1}{18}\right)=\frac{2}{3}+\frac{1}{5}-\frac{3}{90}=\frac{75}{90}=\frac{5}{6}$.
- Notice that now the "per unit price" of the first $\frac{1}{3}$ quality units is 1 whereas for the higher quality level $q^H=2$, the per unit price is $\frac{11}{6}$. We say that this model of vertical quality differentiation displays quality premia.

- An extreme form of quality differentiation happens when the seller damages her goods intentionally and perhaps at a cost
- For an extensive discussion on various examples of such strategies, see Deneckere and McAfee (1996): "Damaged goods", Journal of Economics and Management Strategy.

Horizontal Quality Differentiation

- Sometimes, buyers do not agree on the ranking of the qualities and one buyer may prefer q to q' while another buyer prefers q' to q. In this case, we say that the products are horizontally differentiated.
  - The most common model of this assumes utility function

$$v_i\left(\theta^i, q, t\right) = v - c\left|q - \theta^i\right| - t.$$

- Here, θ^i is interpreted as the ideal point for buyer i in the set of all possible quality choices.
- Parameter c is interpreted as the cost of using a non-ideal product.
- Alternatively, you can imagine the buyers located on a line and q stands for the location of a store on the same line.
  - $c\left|q - \theta^i\right|$ measures then the transportation cost of buyer θ^i to shop at distance to the store located at q.
- t is the price of the product as before.

- The monopolist's cost is normally assumed to depend on just the number of different varieties that she chooses to produce.
- The monopolist's problem is to choose the *i)* The number of different product varieties. *ii)* How to position them in the product space, and *iii)* How to price the collection of product varieties.
- The economic questions for this model revolve around the monopolist's incentives to provide the right number of different varieties for the market.
  - Without price discrimination, excessive provision of variety.
  - This result follows from the fact that the monopolist also cares about turning consumer surplus into profit. For welfare calculations, only need to compare cost of adding varieties to resulting savings in transportation costs.
  - With personalized pricing, optimal provision of variety.
- Since oligopolistic models of horizontally differentiated firms feature heavily in Microeconomics III: Industrial Organization in the spring term, we will not consider them further here.

Summary

- We have demonstrated in the simple two-type model two features of non-linear pricing:
    - Quantity discounts
    - Quality premia.
- Do these properties hold more generally?
    - For quantity discounts: Maskin and Riley (1984), "Monopoly with Incomplete Information", *Rand Journal of Economics*.
    - For quality premia: Mussa and Rosen (1978), "Monopoly and Product Quality", *Journal of Economic Theory*.

Summary

- The key that makes analysis possible in a model with a continuum of types is Spence-Mirrlees single crossing condition:

$$\frac{\partial^2 v(\theta, q)}{\partial\theta\partial q}$$

  has constant sign.
- This just says that marginal valuation for higher allocation is monotonic in type
- Modeling the type set as a subset of the real line, this single-crossing condition makes analysis of optimal non-linear pricing possible.
- The same holds for more general allocation problems.
- For more on this, microconomics IV in the research track

Bundling

- So far, we have considered menus with one good
- When the firm is producing multiple goods, another alternative is to bundle them together
- Before going into that, consider potential reasons why a firm might want to bundle separate goods:
  - Complementary products
    - A very natural reason for bundling. Extreme example: right and left shoes
  - Anti-competitive behavior
    - Extending market power across markets, entry deterrence (Microsoft: OS and other software products)
    - Competitive authorities take a grim view of this.
  - Price discrimination strategy that increases rent extraction opportunities for the seller.
    - Exploit different buyers differential willingness to pay
    - We will consider this next.

Bundling: Examples

- Subscriptions for cable TV channels.
  - Do you want to sell larger packages of channels at a discount relative to sum of individual channel prices?
  - Do you offer individual channels at all?
  - If only a large package is available, we talk about pure bundling.
  - If buyers can select packages or individual channels, we talk about mixed bundling.
- Mobile handsets and operator contracts.
  - Used to be illegal to sell jointly.

Bundling: Examples

- Bundling of computer operating system with other software (Windows with IE, Office etc.)
- Online and paper newspaper (HS, NYTimes,...).
- Hotel room with or without breakfast, with or without free wifi etc.
- Selling packages of academic journals to university libraries.
- Copy machines and maintenance contracts (Kodak), elevator sales and maintenance contracts (Kone), computer mainframes and consulting contracts (IBM).

Simple Example of Bundling

- Suppose a monopolist sells two different goods in a single market consisting of buyers with different valuations for the goods.
- The valuations are private information to the buyers.
- For simplicity, assume that the buyers have either a high or a low willingness to pay for each of the products.
- Let $v^i \in \{v^H, v^L\}$ with $v^H > v^L$ denote a buyer's willingness to pay for product i with $i \in \{1, 2\}$.

Simple Example Continued

- We can write a table for the probabilities of valuations as follows:

$$\begin{array}{ccc} v^1 \backslash v^2 & v^H & v^L \\ v^H & \pi^H & \frac{1}{2}\pi^M \\ v^L & \frac{1}{2}\pi^M & \pi^L \end{array}.$$

- Here π^H stands for the probability that a buyer has valuation v^H for both of the goods, π^L for the probability that valuation is v^L for both goods and π^M for the probability of mixed valuations.
- The case where $\pi^M = 0$ stands for perfectly correlated valuations across the goods. The case $\pi^H = \pi^L = 0$ stands for negatively (perfectly) correlated values.
- If $\pi^H \pi^L = \frac{1}{4}\left(\pi^M\right)^2$, we have independently distributed values across products. (For example if $\pi^H = \pi^L = \frac{1}{2}\pi^M = 1/4$).

Simple Example Continued

- Let's assume that the valuations of the buyers across the two goods are additive so that her willingness to pay for both goods is $v^1 + v^2$.
- The monopolist must decide whether to sell the two goods separately at prices p^1 and p^2, or whether to engage in pure bundling, i.e. sell them as a package at price $p^{1,2}$ or whether to give the buyers the option of either buying separately or as a package.
- Clearly in the last case, we must have $p^{1,2} < p^1 + p^2$ if buyers cannot be prevented from buying the two goods separately.

Simple Example Continued

- Clearly pure bundling at price $v^H + v^L$ is the optimal strategy if $\pi^H = \pi^L = 0$, i.e. in the case of pure negative correlation.
- In the case of perfectly correlated valuations fraction π^H of buyers have valuation $2v^H$ and fraction π^L of buyers have valuation $2v^L$ Therefore it is optimal to sell both products at their separate optimal monopoly price. $p^1 = p^2 = v^H$ if $\pi^H v^H \geq \left(\pi^H + \pi^L\right) v^L$ and $p^1 = p^2 = v^L$ if $\pi^H v^H \leq \left(\pi^H + \pi^L\right) v^L$.
- What about the independent case?

Independent valuations and Bundling

- We will now work in a slightly richer setting:
- A monopolist sells two products $i \in \{1, 2\}$.
- There is a continuum of buyers that have independent valuations for the two products.v^i.
  - Each v^i is distributed on $[0, 1]$
  - Each v^i has a distribution function $F^i\left(v^i\right)$ with a density $f^i\left(v^i\right)$.
- Suppose the monopolist sets prices separately for the two products: p^1, p^2.
- Assume that production cost is zero (so that valuation is really the net valuation over production cost).

Independent valuations and Bundling

- At price p^i, the monopolist's profit in market i is:

$$p^i(1 - F^i\left(p^i\right)),$$

where $(1 - F^i\left(p^i\right))$ is the fraction of buyers with valuation above p^i.

- First order condition for optimal price:

$$p^{*i} \text{ solves } (1 - F^i\left(p^{*i}\right)) - p^{*i} f^i\left(p^{*i}\right) = 0.$$

- Is it optimal for the monopolist to offer prices $\left(p^{*1}, p^{*2}\right)$ with $p^{*1,2} = p^{*1} + p^{*2}$?
- Consider a change to prices $\left(p^{*1} + \varepsilon, p^{*2}, p^{*1,2}\right)$.
  - In words, keep all other prices unchanged, just increase the price of good 1 by ε.

Independent valuations and Bundling

- What happens to total profit?
  - No change to buyers with $v^1 < p^{*1}$.
  - No change for buyers with $v^1 > p^{*1}$ and $v^2 > p^{*2}$.
  - Loss of sales to buyers with $p^{*1} < v^1 < p^{*1} + \varepsilon$ if $v^2 < p^{*2}$.
  - Gain in revenue of ε on those with $v^1 > p^{*1} + \varepsilon, v^2 < p^{*2} - \varepsilon$.
  - Gain in revenue of p^{*2} on those with $v^1 > p^{*1}$, $p^{*2} - \varepsilon < v^2 < p^{*2}$.

Independent valuations and Bundling

- Counting together the changes:

$$-\varepsilon p^{*1} f^1\left(p^{*1}\right) F^2\left(p^{*2}\right) + \varepsilon\left(1 - F^1\left(p^{*1}+\varepsilon\right)\right) F^2\left(p^{*2}-\varepsilon\right)$$
$$+p^{*2}\left(1 - F^1\left(p^{*1}\right)\right)\varepsilon f^2\left(p^{*2}\right).$$

- Since $F^2\left(p^{*2}-\varepsilon\right) = F^2\left(p^{*2}\right) - \varepsilon f^2\left(p^{*2}\right)$, $F^1\left(p^{*1}+\varepsilon\right) = F^1\left(p^{*1}\right) + \varepsilon f^1\left(p^{*1}\right)$, and $\left(1 - F^1\left(p^{*1}\right)\right) - p^{*1} f^1\left(p^{*1}\right) = 0$ (by monopolist's first order condition in the choice of p^{*1}), we have after ignoring terms of order ε^2 the net change as:

$$p^{*2}\left(1 - F^1\left(p^{*1}\right)\right)\varepsilon f^2\left(p^{*2}\right) > 0.$$

- Hence increasing one of the original separate monopoly prices results in an increase in profit.

Uniform distribution

- Assuming that v^i:s are drawn from the uniform distribution, the model can be solved explicitly
- Start by deriving optimal monopoly prices for individual products, and compute associated profit
- Then consider optimal price if only pure bundling possible:
  - What is the demand function for the bundle?
  - What is the optimal price and associated profits?
- Finally, consider the mixed bundle.
  - Derive the demands for products 1 and 2 and for the bundle with some prices p^1, p^2, $p^{1,2}$
  - Argue that it is optimal to choose $p^1 = p^2 := p$
  - Find optimal p and $p^{1,2}$
- What kind of welfare effects can you identify?

Many Items for Sale

- What if the seller has more than two different products?
- Continue with the basic setting above.
- n items for sale.
- Valuation of each buyer for a collection $\{1, ..., k\}$ of the items is $v^1 + ... + v^k$.
- Assume that each v^i is an independent draw from the uniform distribution on $[0, 1]$.
- In other words, $F^I\left(v^i\right) = v^i$ for all i and all $0 \leq v^i \leq 1$.
- Easy to calculate the optimal monopoly price for single items to be $\frac{1}{2}$.

- We saw already that with $n = 2$, a local improvement in profits possible through bundling.
- One can compute the optimal mixed bundling solution explicitly (turns out, $p^1 = p^2 = \frac{2}{3},\ p^{1,2} = \frac{4-\sqrt{2}}{3} \approx 0.86$)
- What about $n = 3$? Can be done but gets harder
- $n = 4$? Can be done numerically.

- Is $n \to \infty$ even harder?
- To get full optimum, yes, but to get qualitative features of optimum, not so
- What can we say about the random variable $v = v^1 + ... + v^n$?
- If the v^i are independent , all with variance σ^2 and mean μ, then v has variance $n\sigma^2$.
- With uniform, $\mu = \frac{1}{2}$, $\sigma^2 = \frac{1}{12}$.
- On the other hand, the expected value of v is $n\mu$.
- Hence the willingness to pay per item $\frac{v}{n}$ has mean μ and variance $\frac{\sigma^2}{n}$.
- How does the aggregate demand function for a bundle of n goods change as n grows?

Many Items for Sale

- How much can the monopolist get at maximum per item?
- Recall Chebyshev's inequality from Statistics course: consider a random variable X with density $f(x)$, mean μ_x and variance σ_x^2. Then for all $\delta > 0$,

$$\Pr\{|X - \mu_x| > \delta\} \leq \frac{\sigma_x^2}{\delta^2}.$$

- Hence using $\mu_x = \frac{1}{2}n, \sigma_x^2 = \frac{1}{12n}$, we get that for all δ,

$$\Pr\left\{\left|\frac{v}{n} - \frac{1}{2}\right| > \delta\right\} \leq \frac{1}{12n\delta^2}.$$

- $\frac{1}{2}$ per item is an upper bound results as $n \to \infty$.

Other modifications of the model

- Interrelated products
  - Bundle of products will become more attractive to buyers
  - At the same time, advantage of bundling strategy to the seller as compared to separate selling may diminish
- Correlated values
  - As our simple example above suggested, negative correlation makes bundling strategy more profitable
- Bundling and competition
  - Bundling can soften or increase competition.
  - See e.g. Belleflamme and Peitz: "Industrial Organization", Chapter 11.3.
- Marginal costs of production
  - Our example above has zero marginal cost (good approximation for information goods such as software)
  - A higher marginal cost of production makes bundling less attractive relative to separate selling (can you see why?)

Application: Collection Sales of Academic Journals

- In publisher owned model, the setting is as above.
- Monopolist (publisher) seller selling a collection of journals, i.e. the goods i in the previous example.
- Buyers are academic libraries.
- Why bundling?
  - Efficiencies in marketing, production etc.
  - Easing the purchasing task of librarians.
  - Rent extraction from libraries
- In privately operated model, individual journals price their own product (separate monopoly pricing in the model above).
- Which model is better?
- Depends on objective functions.

Application: Collection Sales of Academic Journals

- Bundling has many effects:
  - Increases outreach: almost all libraries buy the bundled good and journals get a large readership. Good for journals and publishers.
  - Publishers get a large profit: good for publishers.
  - Libraries get no consumer surplus: Bad for taxpayers.
- Alternatives:
  - If journals care about libraries, they could go separately and price to cover their cost only (non-profit mode).
  - Alternatively and better, all non-profit journals could band together and sell their good in a bundle at cost of production.

Conclusion on Price Discrimination

- Price discrimination can take many different forms as we have seen
- Basic motive for monopolist seller: transform consumer surplus into profit.
- How successful this can be depends on:
  - Buyers' possibilities for undoing differentiation: breaking bundles and resale etc.
  - Legislative concerns.
- Not covered here, but also important: strategic product design.
  - Compatibility with competitors.
  - Differentiation to relax price competition.

Informed seller - uninformed buyers

- So far we have analyzed situations where buyers are better informed than the seller: they have private information on their own taste
- We now consider the opposite situation
- Seller has private information about the quality of the product
  - Does this lead to efficient trade?
  - Is seller's private information beneficial to her?
    - Problem is that buyers are suspicious about quality
  - Can the seller signal credibly the true quality level?

Setup

- A single seller offers a product of two potential qualities $q \in \{q^L, q^H\}$
- Assume the quality is given, and privately known by the seller (seller's type).
- Buyers do not know the quality, and assign probability λ for high quality so that expected quality is:

$$\lambda q^H + (1 - \lambda) q^L.$$

- (Opportunity) cost of selling is c^i, $i = L, H$. Assume $c^H > c^L$.
- A mass of identical buyers with unit demand and reservation utility equal to the quality of the product $r^i = q^i$, $i = L, H$.
- The consumers prefer a higher quality: $q^H > q^L$.
- Assume: $q^i > c^i$ for $i = L, H$. In other words, trading is always efficient.

Setup

- Formally, we can models this as a three stage game:
  - 1. stage: Nature draws the true value q from the known distribution (i.e. with probability λ we have $q = q^H$ and with $1 - \lambda$ we have $q = q^L$). Only the seller observes the true q.
  - 2. stage: Seller decides whether and which price to post
  - 3. stage: Buyer forms beliefs about q and makes purchase decision (buy / do not buy)
- Contrast: in the screening model, the uninformed player moves first (seller postes a menu of contracts)
- Here: the informed party moves first. This opens the possibility for signalling.
- How do the buyers form their beliefs? Let us illustrate...

Expectations and belief formation

- Suppose that the buyers expect that both types of seller set the same price p
  - Then the belief by the buyer upon observing p is that with probability λ we have $q = q^H$, and hence expected quality is

$$\lambda q^H + (1 - \lambda) q^L.$$

  - This is called pooling: both types use the same strategy
- Suppose that only low types offer a price p (and high types withdraw from the market)
  - The belief by the buyer upon observing price p is that quality is $q = q^L$ for sure
- Or, low type could offer p' and high type would offer $p'' \neq p'$
  - Then the buyer would know the quality upon observing price: separating case
- The point is: the strategy of the seller affects the belief of the buyer

Possible equilibria

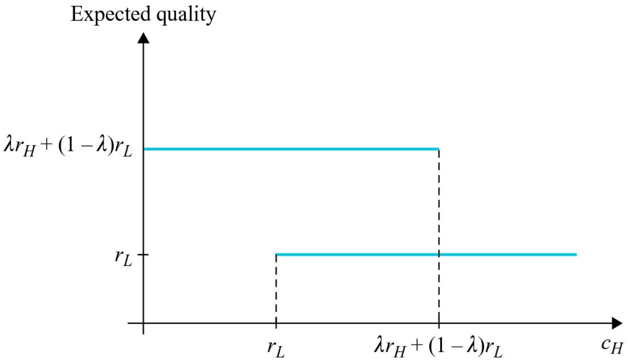
- Pooling equilibrium?
  - Then price must be $p = \lambda q^H + (1-\lambda) q^L$ (why?)
  - Such an equilibrium is feasible if

$$c^H < \lambda q^H + (1-\lambda) q^L,$$

    otherwise high type would withdraw.

- Equilibrium with adverse selection?
  - Low type sets price $p = q^L$ and high type withdraws
  - Such an equilibrium is feasible if $q^L < c^H$.
- For $q^L < c^H < \lambda q^H + (1-\lambda) q^L$, both types of equilibria co-exist

Equilibrium prices for different opportunity cost of high type



Discussion

- When quality is not observed by the buyers, high-quality products may not be offered for sale at all
- What if there are more than two quality levels?
  - Full unraveling is possible, so that only the very lowest possible quality survives in the market
  - This is the logic in the famous "market for lemons" by Akerlof
- Why is fully separating equilibrium not possible here?
  - A low type would mimic.
  - Is it possible in some circumstances for the high type seller to signal high quality by choosing a high price?
  - Yes, but to make this work, mimicking must be more costly for the low type. We come back to this shortly...

Voluntary information disclosure

- A natural question to ask is: what if there is a credible way for the firms to publicly disclose their quality level?
    - Low type does not want to disclose
    - High type naturally wants to disclose
    - But then, if a buyer sees a seller who does not want to disclose, what should she conclude about quality?
- What if there are more than two types?
    - Unraveling result: all types disclose their quality, see Milgrom (1981): "Good news and bad news: Representation theorems and applications", Bell Journal of Economics.
    - This follows from an induction argument
    - Asymmetric information problem is solved
- But is such credible and costless disclosure feasible in reality?

Endogenous quality and moral hazard

- What if quality choice is endogenous?
- Assume the model as before, but in the beginning the seller can choose quality level
- Benchmark case: quality choice is observable
  - Since seller can extract all surplus, quality choice is efficient
  - If $r^H - c^H > r^L - c^L$, then seller chooses high quality
- What if quality choice is unobservable?
  - Seller always chooses low quality (why?)
- This is a very simple model of moral hazard
  - Instead of hidden type (as in adverse selection), we have hidden action

Voluntary information disclosure

- Let us now return to the idea that seller can signal its quality by price
- For this to work, signal must be credible, in other words, buyers must believe that high price truly signals high quality
- For this to be the case, mimicking high quality must be too costly for the low quality producer
- Possible reasons for such costs are, for example:
  - Repeat purchasing (true quality will be revealed in time) and reputational effects
  - Existence of some better informed consumers (increasing price will mean low quality producer will lose all such consumers)
  - Higher production costs for a low type producer
  - ...

A model with some informed consumers: price signalling

- We will next demonstrate how signaling can work in a simple setting
- Assume the model as above with a mass of identical consumers with unit demand
- For simplicity, let $c^H = c^L := c$, and let $c < r^L < r^H$
- But now we assume that fraction λ of consumers know the true quality q
- Signalling models have typically multiple equilibria. Here we want to construct one.

- We want to construct a separating equilibrium: price posted by seller will reveal the true quality
- First consider a potential equilibrium, where high type chooses price $p^H = r^H$ and low type chooses price $p^L = r^L$
- If this is an equilibrium, then the buyers expect correctly that they get quality q^H at price p^H and q^L at price p^L
- Is this an equilibrium? We have to check if any player wants to deviate

- A high type gets the best possible deal, so naturally she does not want to deviate
- But a low type might want to mimick the high type. She wants to do that if

$$
\begin{aligned}
(1-\lambda)\left(r^H - c\right) &> r^L - c \\
&\Longleftrightarrow \\
\lambda &< \frac{r^H - r^L}{r^H - c} := \overline{\lambda}.
\end{aligned}
$$

- So, if $\lambda \geq \overline{\lambda}$, such deviations are not profitable. In that case, a fully separating equilibrium exists, where both types of seller can extract all surplus from the buyers

- What if $\lambda < \overline{\lambda}$?
- We can still constduct a fully separating equilibrium, but the high type must lower its price to make mimicking less attractive for the low type
- If high type sets price $\overline{p}^H$, low type is indifferent between choosing r^L and p^H if

$$
\begin{aligned}
(1-\lambda)\left(\overline{p}^H - c\right) &= r^L - c \\
&\Longleftrightarrow \\
\overline{p}^H &= c + \frac{r^L - c}{1-\lambda}
\end{aligned}
$$

- To make sure this is an equilibrium, we must now also consider what happens if high type (or low) type deviate by setting price above $\overline{p}^H$

- To make sure that pricing above $\overline{p}^H$ is not profitable, we can assume that any deviation to higher prices would be interpreted by the buyers as low quality: they will not buy
- This is not really "assumption" about model, this is part of equilibrium description
- Formally, to define a "Perfect Bayesian Equilibrium" in a game like this, we must define beliefs of the buyers for all possible prices (also "out-of-equilibrium" prices) in such a way that sellers set optimal prices and all beliefs are consistent with their behavior
- Signalling models have typically a large number of different equilibria. Our purpose here is to construct just one equilibrium.
- See additional material of game theory for this

- To summarize this model:
  - when λ is sufficiently high, there is an equilibrium where high type sets price $p^H = r^H$ and low type sets price $p^L = r^L$
  - When λ is smaller, there is still a separating equilibrium, where high type must lower price in order to prevent low type from mimicing

Summary of models with privately informed seller

- When seller has private information about quality of product, this may lead to market break-down (adverse selection)
- This may also lead to choice of too low quality by sellers (moral hazard)
- Voluntary disclosure of quality can be helpful, if technologically feasible
- Signalling by prices can also work, if mimicking is sufficiently costly for a low quality producer
  - This is the case, e.g., when some consumers are informed about the quality
  - This makes high price less attractive for the low type, since she would lose all informed consumers
- Signalling can also work through other channels than prices:
  - For example, high quality firm can signal through costly advertising, even when advertising is not directly informative (see literature starting with Nelson (1974): "Advertising as information", Journal of Political Economy)

Further readings

- The two classical papers modeling quality differentiation and quantity discounts as screening devices, see Mussa and Rosen (1978): "Monopoly and Product Quality", Journal of Economic Theory, and Maskin and Riley (1984): "Monopoly with Incomplete Information", Rand Journal of Economics.
- For a more detailed analysis of bundling, see McAfee, McMillan, and Whinston (1989): "Multiproduct Monopoly, Commodity Bundling, and Correlation of Values", Quarterly Journal of Economics.
- For a case on bunding on academic journals, see Edlin and Rubinfeld (2005): "The Bundling of Academic Journals", American Economic Review.
- Classical information economics papers relating to the case, where seller knows quality better than buyers are Akerlof (1970): "The Market for Lemons: Quality Uncertainty and the Market Mechanism", Quarterly Journal of Economics, and Spence (1973): "Job market signaling", Quarterly Journal of Economics.