IM 7011: Information Economics

Lecture 11: Moral Hazard
Kung and Chen (2011)

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Road map

- **Introduction**.
- Model.
- Analysis.
- Comparisons, extensions, and conclusions.

Manufacturer vs. salespeople

- A **manufacturer** typically sells its products to a **reseller**.
  - A reseller may be a retailer, a wholesaler, an importer, or any firm that simply "resell" the product.
- A reseller manages **salespeople** to sell the product.
  - The better the salespeople's **service** (**effort**), the higher the sales volume.
- From the manufacturer's perspective, the hidden **sales effort** creates a moral hazard problem.
- What's worse is: The **market condition** is hidden information.
  - If we reward a salesperson when he generates a high sales volume, we may be rewarding lucky people!
  - Risk-averse salespeople will have no incentive to work hard.
- The **mixture** of adverse selection and moral hazard makes contracting difficult and challenging!

Manufacturer vs. resellers

- In a manufacturer-salesperson relationship, we have hidden market condition and hidden sales effort.

$$\text{M} \xrightarrow{\text{AS + MH}} \text{S}$$

- It is thus natural to ask:
  - If the manufacturer can choose to **eliminate** one of them, which one should it choose?
  - What is the benefit of **direct monitoring**?
- While this question is natural in theory, it is **unrealistic**.
  - In practice, it is generally impossible/impractical for a manufacturer to monitor the market condition or the sales effort.
  - It should be the **reseller** that has the potential of doing that.

Knowledgeable and diligent resellers

- The manufacturer faces an **indirect monitoring** problem if it has the following two delegation options:
  - A "**knowledgeable**" reseller who can observe the market condition.
  - A "**diligent**" reseller who can observe the sales effort.
- If the manufacturer can choose to indirectly eliminate one of the two pieces of private information, which one should it choose?
  - Which of the following two supply chain structures is better?

$$\text{M} \text{ —— } \text{K} \overset{\text{MH}}{\text{——}} \text{S}$$

$$\text{M} \text{ —— } \text{D} \overset{\text{AS}}{\text{——}} \text{S}$$

- Actually, does **indirect monitoring** outperforms **no monitoring**?
  - Double marginalization may appear!

Two levels of contract design

- The manufacturer need to be able to solve a **bilevel program**.
  - Programs whose formulations depend on the solution of another program.
- In this three-layer supply chain:
  - The manufacturer first offers contracts to the reseller.
  - The reseller then offers contracts to the salespeople.
  - The manufacturer must anticipate what the reseller will do!
- In this paper:
  - There is a **mixture** of adverse selection of moral hazard.
  - There is a **cascade** of contract design.
- The central question: Hidden information and hidden action, which one to (indirectly) resolve?

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Supply chain structure

- There are a manufacturer (it), a reseller (she), and a salesperson (he).
- The supply chain is operated in the **make-to-order** (MTO) fashion.
  - The manufacturer produces after the demand is realized.
  - We eliminate the inventory decision to focus on the information issue.
- The unit production cost and unit retail price are normalized to 0 and 1, respectively.
- The demand volume or sales outcome is

$$x = \theta + a + \epsilon.$$

  - $\theta \sim F, f$ is the continuous **market condition** whose mean is $\mu \equiv \mathbb{E}[\theta]$.
  - θ satisfies the increasing failure rate assumption: $H(\theta) \equiv \frac{1-F(\theta)}{f(\theta)}$ is decreasing in θ.
  - The salesperson incurs a cost $\frac{1}{2}a^2$ for exerting **sales effort** $a \geq 0$.
  - The **random noise** $\epsilon \sim N(0, \sigma^2)$.

Resellers

- Both θ and a are observed by the salesperson but cannot be observed by the manufacturer.

$$\mathrm{M} \xrightarrow{\text{AS + MH}} \mathrm{S}_{(\theta,a)}$$

- There are two types of resellers: knowledgeable or diligent.
- The **knowledgeable** reseller is an expert in demand forecasting.
  - She observes θ and thus eliminates adverse selection.

$$\mathrm{M} \longrightarrow \mathrm{K}_{(\theta)} \xrightarrow{\text{MH}} \mathrm{S}_{(\theta,a)}$$

- The **diligent** reseller is an expert in performance measurement.
  - She observes a and thus eliminates moral hazard.

$$\mathrm{M} \longrightarrow \mathrm{D}_{(a)} \xrightarrow{\text{AS}} \mathrm{S}_{(\theta,a)}$$

Risk attitudes

- Firms are risk-neutral and individuals are risk-averse.
  - The manufacturer and reseller are **risk-neutral**.
  - The salesperson is **risk-averse**.
- The salesperson's utility function is $U(z) = -e^{-\rho z}$.
  - z is his net income.
  - $\rho > 0$ is his coefficient of absolute risk aversion.
- Both the manufacturer and reseller are expected profit maximizers.

Contract Forms

- For tractibility, we consider only **linear** contracts.
- The reseller offers $\alpha + \beta x$ to the salesperson.
  - α: fixed payment. β: commission rate.
- The manufacturer offers $u + vx$ to the reseller.
  - u: fixed payment. v: commission rate.
- When necessary, one offers a **menu** of contracts.
- This is an application of the **LEN model**:
  - linear contract, exponential utility, and normal noise.

Timing

- If the manufacturer chooses a knowledgeable reseller:
  - The manufacturer offers contract (u, v).
  - The reseller and salesperson observe the market condition θ.
  - The reseller offers a contract (α, β).
  - The salesperson determines his sales effort a.
  - The sales outcome x is realized.
- If the manufacturer chooses a diligent reseller:
  - The manufacturer offers a contract (u, v).
  - The salesperson observes the market condition θ.
  - The reseller offers a menu of contract $(\alpha(\theta), \beta(\theta), a(\theta))$.
  - The salesperson (truthfully) selects a contract and then exerts the specified sales effort.
  - The sales outcome x is realized.

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Salesperson's problem

- Suppose the salesperson has agreed with the contract (α, β) and has observed θ.
- By choosing effort level a, his net income is $\alpha + \beta x - \frac{1}{2}a^2$.
- To maximize his expected utility

$$\mathbb{E}\Big[- e^{-\rho(\alpha+\beta x-\frac{1}{2}a^2)}\Big],$$

it is equivalent to maximize the **certainty equivalent**

$$CE_S^K(\theta|a) = \alpha + \beta(\theta + a) - \frac{1}{2}a^2 - \frac{1}{2}\rho\sigma^2\beta^2.$$

- With the optimizer $a = \beta$, the maximized certainty equivalent is

$$CE_S^K(\theta) = \alpha + \beta\theta + \frac{1}{2}\beta^2(1 - \rho\sigma^2).$$

Knowledgeable reseller's problem

- Suppose the knowledgeable reseller has agreed with the contract (u, v) and has observed θ.
- **Anticipating** the effort level $a = \beta$, the expected sales is

$$\mathbb{E}[x] = \mathbb{E}[\theta + a + \epsilon] = \theta + \beta.$$

- The reseller's expected profit is

$$\mathbb{E}\Big[u - \alpha + (v - \beta)x\Big] = u - \alpha + (v - \beta)(\theta + \beta).$$

- The reseller's solves

$$\begin{aligned} R^K(\theta) = \max_{\alpha \text{ urs, } \beta \geq 0} \quad & u - \alpha + (v - \beta)(\theta + \beta) \\ \text{s.t.} \quad & \alpha + \beta\theta + \frac{1}{2}\beta^2(1 - \rho\sigma^2) \geq 0, \end{aligned}$$

where the constraint ensures the salesperson's participation.

Knowledgeable reseller's problem

Lemma 1

Given the contract (u, v) and the market condition θ, the knowledgeable reseller optimally offers the commission rate $\beta^K(\theta) = \frac{1}{1+\rho\sigma^2}v$, induces the service level $a^K(\theta) = \beta^K(\theta)$, and generates $R^K(\theta) = u + v\theta + \frac{1}{2(1+\rho\sigma^2)}v^2$.

- For this pure moral hazard problem, there is a **downward distortion** on the sales effort: $\frac{1}{1+\rho\sigma^2}v < v$.
- $1 + \rho\sigma^2$ is an indicator of how costly it is for the reseller to induce the salesperson to exert efforts.
- The commission rate and effort level decreases as the moral hazard problem becomes **more severe**:
  - the salesperson becomes more risk-averse (ρ increases),
  - the sales outcome is more volatile (σ^2 increases), and
  - the offer from the manufacturer is less generous (v decreases).

Manufacturer's problem

- The manufacturer could potentially design a menu of contracts for the reseller to choose.
- However, because the reseller observes θ after the contract is signed, this is unnecessary and a **single contract** (u, v) is optimal.
- Anticipating the effort $\frac{1}{1+\rho\sigma^2}v$, the manufacturer's expected profit is

$$\mathbb{E}\Big[(1-v)(\theta+a+\epsilon)-u\Big] = (1-v)\left(\mu+\frac{1}{1+\rho\sigma^2}v\right)-u.$$

- The manufacturer solves

$$\begin{aligned} M^K = \max_{u \text{ urs},\ v\geq 0} \quad & (1-v)\left(\mu+\frac{1}{1+\rho\sigma^2}v\right)-u \\ \text{s.t.} \quad & u+v\mu+\frac{1}{2(1+\rho\sigma^2)}v^2 \geq 0, \end{aligned}$$

where the constraint ensures that the reseller's expected profit (before observing θ) $\mathbb{E}_\theta\left[R^K(\theta)\right]$ is nonnegative.

Manufacturer's problem

Lemma 2

When including the knowledgeable reseller, the manufacturer's optimal contract (u^K, v^K) *consists of* $v^K = 1$ *and* $u^K = -\mu - \frac{1}{2(1+\rho\sigma^2)}$. *The manufacturer's expected payoff is* $M^K = \mu + \frac{1}{2(1+\rho\sigma^2)}$ *with the induced effort level* $a^K = \frac{1}{1+\rho\sigma^2}$ *for all* θ.

- The manufacturer finds it optimal to **sell the business** to the reseller (by setting $v^K = 1$) after charging a fixed payment, which can be interpreted as a franchise fee.
  - Note that $u^K < 0$: The reseller pays a fee to the manufacturer.
- This (pure) franchise fee contract allows the manufacturer to bypass the potential effort distortion due to the delegation.
  - Any distortion on the commission rate (with $v < 1$) distorts the effort.
  - Double marginalization is **avoided**.
- Inefficiency only comes from the downstream moral hazard.
- The manufacturer can fully extracts the reseller's surplus. Why?

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Salesperson's problem

- Because the diligent reseller can observe the effort level, the salesperson's effort exertion problem **disappears**.
  - He must follows what is specified in the contract.
- Fortunately (?), he is protected by his private market condition.
  - The reseller must offer a **menu** of contract $\{(\alpha(\theta), \beta(\theta), a(\theta)\}$.
- Suppose that the salesperson observes a market condition θ but chooses the contract $(\alpha(\tilde{\theta}), \beta(\tilde{\theta}), a(\tilde{\theta}))$.
- In this case, he will get $\alpha(\tilde{\theta}) + \beta(\tilde{\theta})(\theta + a(\tilde{\theta}) + \epsilon) - \frac{1}{2}[a(\tilde{\theta})]^2$ as his net income and

$$CE_S^D(\theta, \tilde{\theta}) = \alpha(\tilde{\theta}) + \beta(\tilde{\theta})(\theta + a(\tilde{\theta})) - \frac{1}{2}[a(\tilde{\theta})]^2 - \frac{1}{2}\rho\sigma^2[\beta(\tilde{\theta})]^2$$

as his certainty equivalent.

Diligent reseller's problem

- Let $CE_S^D(\theta) \equiv CE_S^D(\theta, \theta)$.
- The reseller solves

$$R^D = \max_{\substack{\{\alpha(\theta) \text{ urs}, \\ \beta(\theta) \geq 0, \ \} \\ a(\theta) \geq 0}} \mathbb{E}\Big[u - \alpha(\theta) + (v - \beta(\theta))(\theta + a(\theta))\Big]$$

$$\text{s.t.} \quad CE_S^D(\theta) \geq CE_S^D(\theta, \tilde{\theta}) \quad \forall \theta, \tilde{\theta} \in (-\infty, \infty)$$

$$CE_S^D(\theta) \geq 0 \quad \forall \theta \in (-\infty, \infty).$$

The IC constraint requires truth-telling and the IR constraint guarantees participation.

Diligent reseller's problem

Lemma 3

Given the contract (u, v), the diligent reseller offers $\alpha^D(\theta) = \frac{1}{2}v^2$, $\beta^D(\theta) = 0$, and $a^D(\theta) = v$ and receives $R^D = u + v\mu + \frac{1}{2}v^2$.

- The diligent reseller should offer **no commission** to the salesperson.
- By receiving no commission, the risk-averse salesperson can get rid of the **undesirable risks** and be motivated in the most efficient way.
- The reseller should enforce the salesperson to exert the first-best effort level v and compensate him just the cost ($\frac{1}{2}v^2$).
- The reseller bears **all the risks**.
- The hidden market condition does not protect the salesperson!
- The optimal contract is not a menu. It is a single contract. Why?

Manufacturer's problem

- When the manufacturer contracts with the reseller, the salesperson has not exerted the sales effort.
  - There is no information asymmetry in the upper level.
- Anticipating the downstream equilibrium, the manufacturer solves

$$M^K = \max_{u \text{ urs},\ v \geq 0} \quad (1-v)(\mu+v) - u$$
$$\text{s.t.} \quad u + v\mu + \frac{1}{2}v^2 \geq 0,$$

where the expected sales quantity $\mu + v$ comes from $a^D(\theta) = v$ and the constraint ensures the reseller's participation.

Manufacturer's problem

Lemma 4

When including the diligent reseller, the manufacturer's optimal contract (u^D, v^D) *consists of* $v^D = 1$ *and* $u^D = -\mu - \frac{1}{2}$. *Under this contract, the manufacturer's maximum expected payoff is* $M^D = \mu + \frac{1}{2}$ *with the induced service level* $a^D = 1$ *for all* θ.

- The manufacturer also passes the entire sales revenue to the diligent reseller ($v = 1$) in order to bypass the double marginalization problem.
- This "**selling-the-business**" strategy therefore motivates the reseller to enforce the efficient effort level ($a^D = 1$) for the whole supply chain.
- The supply chain is **efficient** due to the diligent reseller's monitoring.
- The manufacturer extracts the entire surplus from the reseller by the appropriately designed fixed payment.

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Comparisons

- We are now ready to answer our main research question: Knowledgeable or diligent reseller, which one to choose?

Proposition 1

The manufacturer can induce a higher effort and receive a higher expected profit by contracting with the diligent reseller than with the knowledgeable reseller.

Proof. According to the analysis, we have

$$a^K(\theta) = \frac{1}{1+\rho\sigma^2} < 1 = a^D(\theta)$$

and

$$M^K = \mu + \frac{1}{2(1+\rho\sigma^2)} < \mu + \frac{1}{2} = M^D$$

for every realization of θ. □

Comparisons: reseller vs. salesperson

- In the lower level, the **diligent** reseller's monitoring is more effective.
  - The knowledgeable reseller eliminates adverse selection.
  - The diligent reseller eliminates moral hazard.
  - The pure moral hazard problem (faced by the knowledgeable one) results in a distortion ($a^K = \frac{1}{1+\rho\sigma^2}v$) but the pure adverse selection problem (faced by the diligent reseller) results in no distortion ($a^D = v$).
- Why is the diligent one more effective?
  - The diligent reseller can observe the sales effort and compensate the risk-averse salesperson **according to his effort** instead of performance ($\beta^D = 0$).
  - She is able to exclude uncertainty in the salesperson's payoff. This is effective for the **risk-averse** salesperson.
  - Even if the knowledgeable reseller observes the market condition, the commission still exposes the salesperson to the undesirable risk.
  - Consequently, the induced effort level will be distorted downwards.

Comparisons: manufacturer vs. reseller

- But including a stronger partner is not always more beneficial.
  - Double marginalization may arise in the upper level, especially when the new player is strong.
- Fortunately, double marginalization can be **avoided** in the upper level.
- The manufacturer **sells the business** to the reseller ($v^K = v^D = 1$).
  - The reseller has no private information.
  - The reseller is also risk-neutral.
  - The reseller can pay any amount of franchise fee.
- The story may become different when any of the above three assumptions is removed.

Comparisons: direct sales vs. direct sales

- Is including a reseller beneficial?

Proposition 2

Indirect sales with either types of resellers is more profitable than direct sales.

- Why?
  - Double marginalization can be eliminated in our basic setting.
  - In this case, indirect monitoring is **equivalent** to direct monitoring.
  - Therefore, indirect monitoring is beneficial.
- Again, if the three assumptions are not valid, direct sales may outperform indirect sales.

Extensions

- Frictions under which double marginalization can still be avoided:
  - Multiplicative sales outcome: $x = \theta a + \epsilon$.
  - General effort costs: $\frac{1}{2k}a^2$.
  - Different timing: The market condition θ is observed before the manufacturer designs the contract.
  - Different contract form: Allowing the knowledgeable reseller to offer a menu or restricting the diligent reseller to offer a single contract.
- Frictions under which double marginalization arises:
  - The reseller's monitoring expertise is hidden.
  - The reseller's utility function is strictly concave.
  - The reseller cannot pay too much to the manufacturer.

Conclusions

- A problem with **both** adverse selection and moral hazard is studied.
- The impact of **indirect monitoring** is shown to be positive.
  - A three-layer supply chain is constructed and a cascade of contract design is analyzed.
- In our context, monitoring the salesperson (eliminating moral hazard) is more effective than monitoring the market (eliminating adverse selection).
- There are other kinds of mixture of adverse selection and moral hazard. It is not always unambiguously better to eliminate moral hazard!