<u>Question 1(Principal Agent)</u>

Information from the text:

- Principal= Cleanex
- Agent= Lawex
- Case: Dirtex should pay d to cleanex

- Damage (d)

- Costs for agent c(e)=e2

- Effort e(0;0,5d)

- Schadensersatz x vom Gericht zugesprochen x-U(0,2e)

- Contract: w(x)= a+bx, b (0,1)

- Liability constraint: w(x)>=0 für alle x

a)

Objective funtion (Principals): *e-(a+be)*

IC= e = B/2

PC= a+be-e2 >= 0
LL= a> = 0

b)

The liability constraint says that w(x) >=0, what means lawex can earn 0 but not less than that. X can be 0 if X is zero A must be >= 0 because if not Lawex would pay money, but the liability constraint doesn’t allow it

c)

IC= e=B/2 and LL = a= 0

In PC = 0+b*/(b/2)-(b/2)2

= **b2/4**

Π*P*=*e*−(*a*+*be*)=*e*−*be*=*e*(1−*b*) // e= B/2

P=B/2(1-b) = b/2-b2/2 //

Dp/db= ½-b=0 -> **b*=1/2**

e*= b*/2 = **1/4**

a*=0

d)

rent= überschuss zum minimum

rent=a+be-e

rent=0+(1/2*1/4) –(1/4)2

rent= 1/8-1/16

rent=1/16

e) The rent and effort cost are both 1/16.

Question 2

Text Information's:

Players:

- Principal(risk-neutral)
- Agent(risk-averse)

Effort and cost:

- $E>=0$ effort
- $c(e)=0,5*e^2$

Output:

- $Q=10e+u$
- Only Q is observable not e= moral hazard

Contract:

- $P=s+rQ$
- S= fixed salary, r= bonus rate

Agents expected utility:

- $EU= E(p)-0,5e^2-Kr^2$
- $E(p)$= expected payment
- $0,5e^2$ = effort cost
- Kr^2 = risk cost

Reservation utility:

- **U0**

Checklist to set up principal agent problem:

1**. Principal objective**

$\max(s,r)\ E(Q)- E(p)$ where $E(p)= s+rE(Q)$

$= \max(s,r)\ E(Q)-(s+rE(Q))$

2. **Agents expected utility:**

EU=E(p)-c(e)- (risk cost if risk-averse)

3**. Write the constraints**

IC(Anreiz): e maximizes EU

PC(Teilnahmebedingungen): EU>= u0

Principal objective:

Max(s,r) 10e-s-10re // Outcome= Outcome – Fixum – bonus%

IC= max(e) (s+10re^- 0,5^2-Kr^2)

Pc= s+10re- 0,5e^2-Kr^2 >= u0

b)

Agent is maximizing:

s+10re^-0,5e^2-Kr2

= 10re^-0,5e^2

=f(e^) = 10re^-0,5^2

=

Advanced Microeconomics, winter term 2025/26

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a) Set up the Principal-Agent problem.
b) Why does the liability constraint $w(x) \geq 0$ imply that $a \geq 0$?
c) Solve the Principal-Agent problem for the optimal contract elements (a, b, e).
d) Calculate the rent which Lawex receives due to the liability constraint.
e) Compare the size of this rent with the effort cost.

Question 2 (Risk and Incentives in Contracting)
Consider a principal–agent relationship where a risk-neutral principal hires an agent whose effort is not observable.

We make the following assumptions: The agent's effort level is $e \geq 0$ and effort costs are given by $c(e) = 0.5 \cdot e^2$. Output is $Q = 10 \cdot e + u$ where u is a random variable with $E[u] = 0$. Only output Q is observable. The principal offers a **linear incentive contract** $p = s + r \cdot Q$ where s is a fixed payment and r measures the strength of incentives. The agent is **risk-averse**. His expected utility (certainty-equivalent form) is $EU = E[p] - 0.5 \cdot e^2 - Kr^2$ where $K > 0$ measures the agent's degree of risk aversion. If the agent does not accept the contract, he obtains a reservation utility u_0.The principal maximizes expected profits.

a) Set up the Principal-Agent problem.
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Principal Cleanex
Agent Lawex

Cost of agent $C(e) = e^2$, $\in [0, \frac{1}{2} \cdot d]$

Court outcome x, $\in [0, 2 \cdot e]$

Payment to Agent $w(x) = a + bx$
$b \in [0, 1]$

Limited liability $w(x) \geq 0$

Given:

lawex is paid: $w(x) = a + bx$ where b is $(0 \leq b \leq 1)$

Effort costs $C(e) = e^2$ ⇒ efforts are costly!

Expected court compensation: $x \sim U[0, 2e] \rightarrow \mathbb{E}[x] = e$

a) should know ⇒ 1- Agent's utility function ⇒ "Payoff" $U_A = a + be - e^2$ → cost of effort

lawex's Payoff

fixed agreed payment "always paid"

→ expected performance based on payment
b: strength of جهد
e: effort level

2- Cleanex profit function: $\Pi_p = e - (a + be)$

$\underbrace{\text{profit} = \text{expected court compensation} - \text{expected wage paid}}$

cleanex expected profit

$e =$ expected court compensation
from $x \sim U[0, 2e] \rightarrow \mathbb{E}[x] = e$

$a + be =$ expected payment to Lawex

a) Agent Problem:
$\max_e E[w(x) - c(e)]$
$\Rightarrow \max_e a + be - e^2$
"incentive constrain"

Participation Constrain:
Agent must get at least income 0
$a + be - e^2 \geq 0$

3- Constraints in the problem: 1) Equation:- $\underbrace{e \in \arg\max_e \{a + be - e^2\}}$

was ist das? ← Incentive compatibility constraint

the contract must make the desired effort optimal for lawex ← Effort is unobservable ⇒ lawex must choose effort voluntarily.

2) Participation Constraint (PC) ⇒ $a + be - e^2 \geq 0$ → what? lawex can reject the contract & earn 0 elsewhere, so lawex must at least earn 0 €

3) limited liability constraint (LL)

$a + bx \geq 0$

Principle Problem
Gets court outcome but pays $w(x)$
$\max E[x] - E[w(x)]$

max $e - (a + b \cdot e)$

$w(x) \geq 0$ ⇒ lawer can't be forced to pay money to cleaner

b) why does $w(x) \geq 0$ imply $a \geq 0$?

If $x=0$ then "LL" would be violated for any $a<0$

wage function $w(x) = a + bx$ ⇒ performance based part

$w(x)$: wage lawer Receives, Court compensati

a: fixed payment

$w(x) \to x = 0$

$w(0) = a + b \cdot 0$

$w(0) = a \to a \geq 0$

worst Case outcome $w(0) = a$ ⇒ If the court gives 0, is the worst outcome, so $a \geq 0$

c) solving agent problem! lawer optimal effort ⇒ maximum effort

maximum? ⇒ is this derivative again? YES ☺

finding the maximum effort means finding the derivative with respect to e effort

Agent

$$\frac{d}{de} \Rightarrow \frac{\partial}{\partial e}(a + be - e^2) \longrightarrow (0 + b - 2e)$$

$4 \qquad 5x^4$

$6x \qquad 2e$

$$b - 2e = 0 \Rightarrow e = \frac{b}{2}$$

optimal effort

$\frac{\partial}{\partial x} 5x^n$

$n \cdot 5x^{n-1}$

$4x^3 \to 12x^2$

$2x^4 \to 8x^3$

Principal

Cleaner reduced problem:

$$\Pi_p = e - (a + be) \qquad b \cdot \frac{b}{2}$$

$$= \frac{b}{2} - \left(a + \frac{b^2}{2}\right)$$

$a + be - e^2 \geq 0$

$0 + b \cdot \frac{b}{2} - \left(\frac{b}{2}\right)^2 \geq 0$

$\frac{b^2}{2} - \frac{b^2}{4} \geq 0$

$\frac{b^2}{4} \geq 0$

fixed payment:-

$a \geq 0 \Rightarrow a = 0$

Zak adejmonde utamki:

$\frac{2b^2}{4} - \frac{b^2}{4}$

$$\Pi_P = \frac{b}{2} - \left(0 + \frac{b}{2}\right)$$

$$= \frac{b}{2} - \frac{b^2}{2}$$

$- \cdot + = -$

$- \cdot - = +$

$$\max_b \frac{\partial}{\partial b}\left(\frac{b}{2} - \frac{b^2}{2}\right)$$

$b^2 \to 2b$

$$\left(\frac{1}{2} - \frac{\cancel{2}b}{\cancel{2}}\right) = 0$$

$$\left(\frac{1}{2} - \right) b = 0$$

$$b = \frac{1}{2}$$

$$e = \frac{b}{2} \Rightarrow e = \frac{\frac{1}{2}}{2} \Rightarrow \frac{1}{4}$$

optimal contract terms $\Rightarrow a^* = 0,\ b^* = \frac{1}{2},\ e^* = \frac{1}{4}$

* means „optimal" value of a

d) Liability Constrain:-

$U_A = a + be - e^2$ ⇒ lower can't be punished for low outcomes.

$$= 0 + \frac{1}{2} \cdot \frac{1}{4} - \left(\frac{1}{4}\right)^2 \to \frac{1^2}{4^2}$$

$$= \frac{1}{8} - \frac{1}{16} = \frac{1}{16}$$

rent of the Agent $= \frac{b^2}{4}$

$$\hookrightarrow \frac{16-8}{8 \cdot 16} = \frac{8 \div 8}{128 \div 8} = \frac{1}{16} > 0$$

e) Effort

$\hookrightarrow C(e) = e^2 = \left(\frac{1}{4}\right)^2 = \frac{1}{16}$

Effort = Rent AKA lower rent due to limited liability.

cost = rent

Which means income is double the cost
(rent = income − cost)

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a)

Principal:

$Q = 10e + u$ $\left[\begin{matrix} E[u] = 0 \\ e \geq 0 \end{matrix}\right]$

payoff: $\underbrace{Q}_{\text{Average output}} - \underbrace{p}_{\text{Average pay}}$

$p = s + r \cdot Q$

Agent: Expected Utility

$$\underbrace{E(U)}_{\text{Happines (EU)}} = \underbrace{E[p]}_{\text{Averedge Pay}} - \underbrace{0{,}5e^2}_{\text{Work cost}} - \underbrace{Kr^2}_{\text{Stress cost}}$$

Rules:

- Agent say „yes" when their Happines is atleast U_0

- Principle offers $\underbrace{p}_{\text{contract}} = \underbrace{s}_{\text{Safety pay}} + \underbrace{r}_{\text{bonus strength}}Q$

since $E[u] = 0$
we can state
$E[Q] = 10e$
$E[p] = s + 10 \cdot r \cdot e$
$EU = s + 10 \cdot r \cdot e - 0{,}5 \cdot e^2 - r^2 \cdot K$ → Agents expected utility
$s + 10re - 0{,}5e^2 - r^2K \geq U_0$ → Participation Constrain

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b) How hard will Agent work? (incentive Constrain)

Agent's HAPPINES FORMULA :

$$EU = s + r(10e) - 0{,}5e^2 - Kr^2$$

Now we look where the „extra money" matches „extra pain" of working

We use Derivatives : with respect to e

2·0,5 = 1

$$\max_e \left(10re - 0{,}5e^2\right) \Rightarrow 10r - e = 0$$

$$10r = e$$

$$e^* = 10r$$

If the Principle gives the Agent bigger r, Agent works harder

c)

c) Show that the participation constraint binds in the optimal contract and derive the fixed payment $s(r)$.
~~d) Determine the optimal incentive parameter r^* chosen by the principal and the induced effort level e^*.~~
~~e) Calculate and discuss how the strength of incentives, r, depends on the agent's degree of risk aversion.~~

The Principal ofc wants to pay the Agent the min. amount that keeps the agent to work

Participation Constrain

using $e^* = 10r$

$$U_0 = s + 10r \cdot 10r - 0{,}5 \cdot (10r)^2 - r^2K$$

s → fixed payments

r → Measures the strenth of incentives

$$s + r(10e) - 0{,}5e^2 - Kr^2 = U_0$$

fixed payment

incentive straight

effort

Risk Aversion

Higher K means the Agent gets very stressed if their pay is uncertain

(Minimum bar) The amount of happines that keeps the Agent at work

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① The bonus pay for Agent:

Agent's bonus is based on output $r \cdot Q$
we know $Q = 10e$

Since Agent chooses to work $e = 10r$ then
the output is $10 \cdot 10r = 100r$

Bonus Pay: $r \cdot 100r = \underline{\underline{100r^2}}$

② Cost of working / Work pain

the cost of working: $0{,}5e \cdot e^2$

$e = 10r$

$$0{,}5 \times (10r)^2 = 0{,}5 \cdot 100r^2 = \underline{\underline{50r^2}}$$

③ Solving for „s" —> s is the safety pay

We have:

$100r^2$ $50r^2$ Kr^2

$$s + r(10e) - 0{,}5e^2 - Kr^2 = U_0$$

$$s + 50r^2 - Kr^2 = U_0$$

$$s = U_0 + Kr^2 - 50r^2 \;/= U_0 + r^2 \cdot (K - 50)$$

To keep the Agent happy (U_0) the Boss has to pay enough money (s) to cover the stress (Kr^2)

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d) Determine the optimal incentive parameter r^* chosen by the principal and the induced effort level e^*.

~~e) Calculate and discuss how the strength of incentives, r, depends on the agent's degree of risk aversion.~~

d)

Here the Principal pics the bonus streinght r that makes his profit the highest
And see how hard the Agent works bc of it - effords of Agent

The Principle wants to Maximize their Expected Profit
(value of product sold − payment to the Agent)

① What we have: $Q = 10e$

Average work: $10 \cdot (10r) = 100r$

from c)

Average Payment: $(E[p])$ → to keep Agent to work the Principal has to pay average

$$U_0 + Kr^2 + 50r^2$$

Profit equation: Principle Profits = work − payment to Agent

$$= 100r - [U_0 + Kr^2 + 50r^2] =$$

$$\underline{\underline{100r - U_0 - (K+50)r^2}}$$

② Finding the best Bonus:
- we look for value r that makes the equation max
- Expected Profit on max

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(income − costs)

d) $\max_{e} \; E[Q] - E[p]$

$= 10e - (s + 10re)$

using $e = 10r$, $s = U_0 + r^2 \cdot (K - 50)$

The income: $100r$

from b)

The Costs: $\underbrace{U_0}_{\text{minimum happines for the Agent to keep him working}} + (\underbrace{K}_{\text{Risk Premium}} + \underbrace{50}_{\text{work pain}})r^2$

$$\max_{r} = 10 \cdot 10r - (U_0 + r^2 \cdot (K-50) + 10r \cdot 10r)$$

$$100r - 100r^2 - U_0 - r^2 \cdot (K-50)$$

$$100r - 100r^2 - U_0 - r^2K + r^2 50$$

$$100r - 50r^2 - U_0 - r^2K$$

FOC: $100 - 100 \cdot r - 2 \cdot r \cdot K = 0$

$$r \cdot (100 + 2 \cdot K) = 100$$

$$r^* = \frac{100}{100+2K} = \frac{50}{50+K}$$

Profit Formula: $100r - U_0 - (K+50)r^2$

gain from "r" is 100

the increasing cost of the bonus: $2 \cdot (K+50)r$

We set them as equal to find the balance point

$$100 = 2(K+50)r$$

$$50 = (K+50)r$$

$$r = \frac{50}{K+50}$$

SAME

→ This shows that K Risk Aversion of the helper is the most important factor

Large K = bonus smaller

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e)

e) Calculate and discuss how the strength of incentives, r, depends on the agent's degree of risk aversion.

from d)

$$r = \frac{50}{50+K}$$

In any fraction, if the bottom number (determinator) gets larger while the top stay the same, the total value of the fraction decreases

Low K: The Brave Agent - The Principle gives high bonus bc the Agent doesn't need much "stress money" to stay happy

High K Scared Agent - The Principle gives low bonus and higher guaranteed salary to avoid paying a big expensive K risk premium

• **Incentives vs. Stress:** Higher bonuses (r) are good because they motivate the worker to put in more effort (e) 5 6. However, because the outcome is partly based on luck (u), a higher bonus makes the worker's paycheck "jump around" and become uncertain 6 7.

• **The Risk Premium:** A risk-averse worker hates this uncertainty. To get them to accept the contract, the Boss has to pay them a **risk premium**—basically "stress money"—to compensate them for the risk they are taking 4 8.

• **The Cost to the Boss:** The risk premium is calculated as Kr^2 6 8. If the worker is very risk-averse (high K), this "stress money" becomes very expensive for the Boss 5 8.

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e) $\tau^* = \frac{50}{50+K}$

$\Rightarrow$ τ is strictly decreasing in K.

$\Rightarrow$ Higer risk aversion means a contract with more insurance

$$\frac{d\tau^*}{dK} < 0$$

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a) Set up the Principal-Agent problem.
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Given:

fixed payment   compensation

Lowlex is payed: $w(x) = a + bx$ where $b = (0 \leq b \leq 1)$

Effort costs $C(e) = e^2$

Expected court compensation: $x_2 U[0, 2e] = E[x] e$

a) Agent's utility function:

$$U_A = a + \underbrace{be}_{\text{expected performance}} - e^2$$

Lowlex payoff   fixed agreed payment   cost of efford