Sixth Annual IIASA-DPRI Forum
Integrated Disaster Risk Management

Performance-Based Contract for Aseismic Retrofit of Buildings

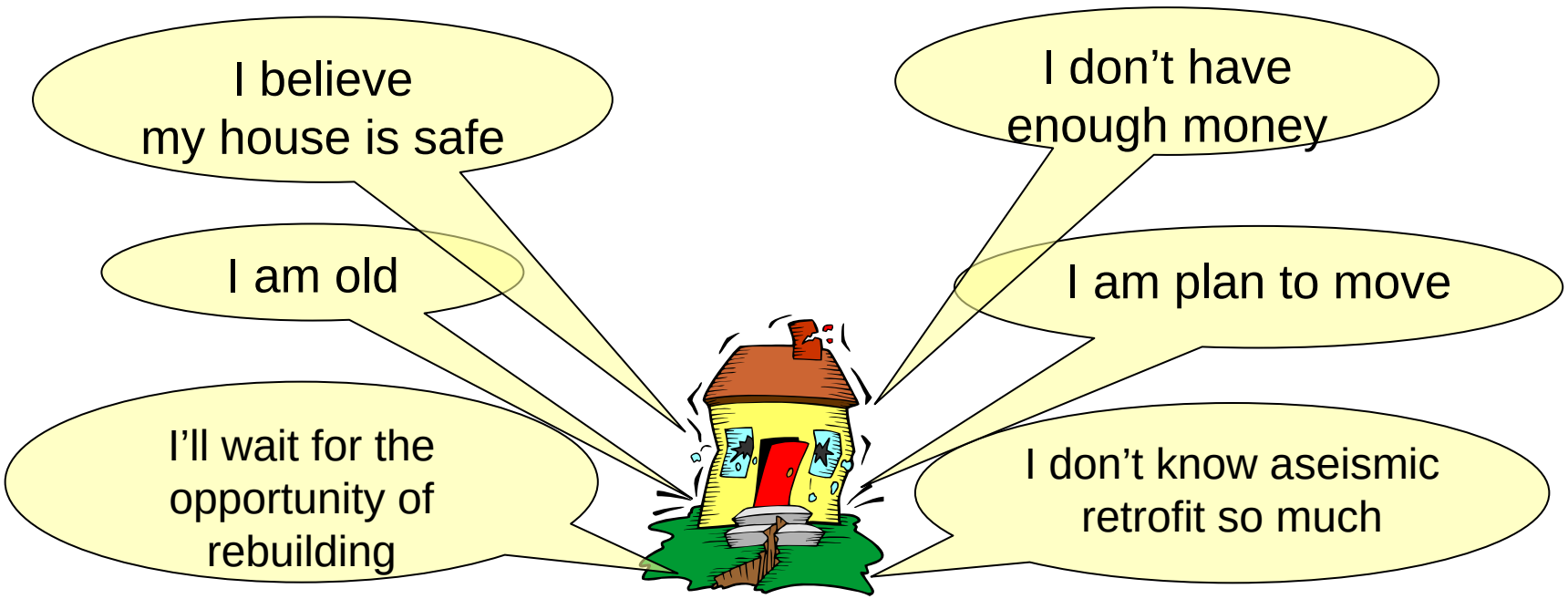
Mamoru Yoshida
DPRI, Kyoto University, Japan

Background(1)

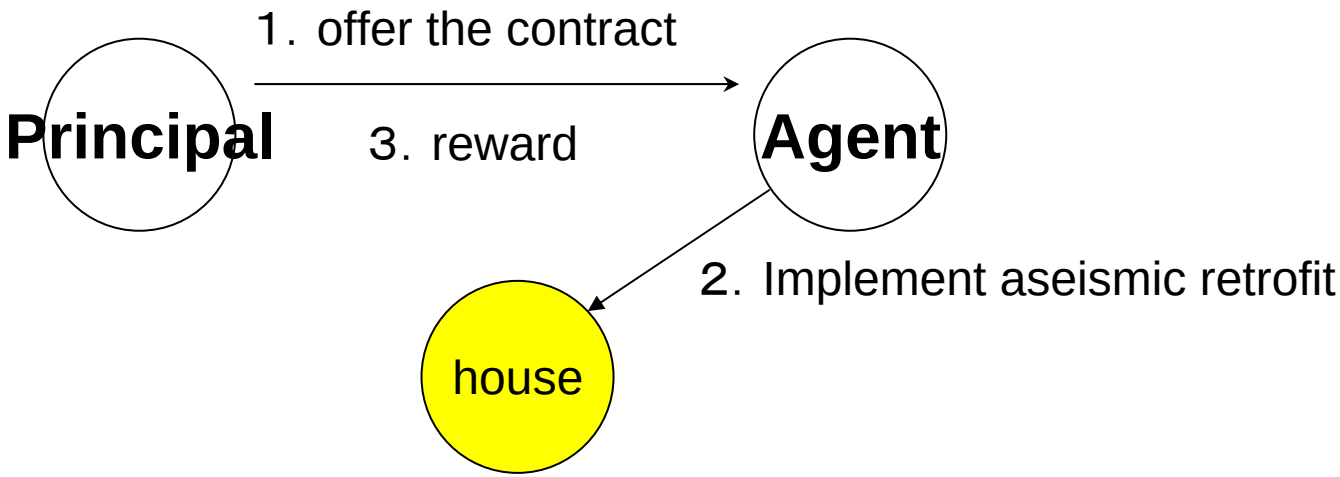
- Hanshin-Awaji earthquake in 1995 destroyed a large number of wooden houses.
- More than 80% death was crushing death
- Some local governments subsidize aseismic retrofit for house owners whose house was built before the Standard Building Law was revised.
- Central Prevention Disaster Council(2005) set up a target to raise the rate of quake-proof house from 75% to 90% over a decade.

Background(2)

I can not observe the quality of the agent's work
(unobservability of the agent's work)



Moral hazard and ex-post unobservability



– It is difficult for the principal to observe the quality of the agent's work (ex-post unobservability)

– The agent can take a opportunistic action（Moral Hazard）

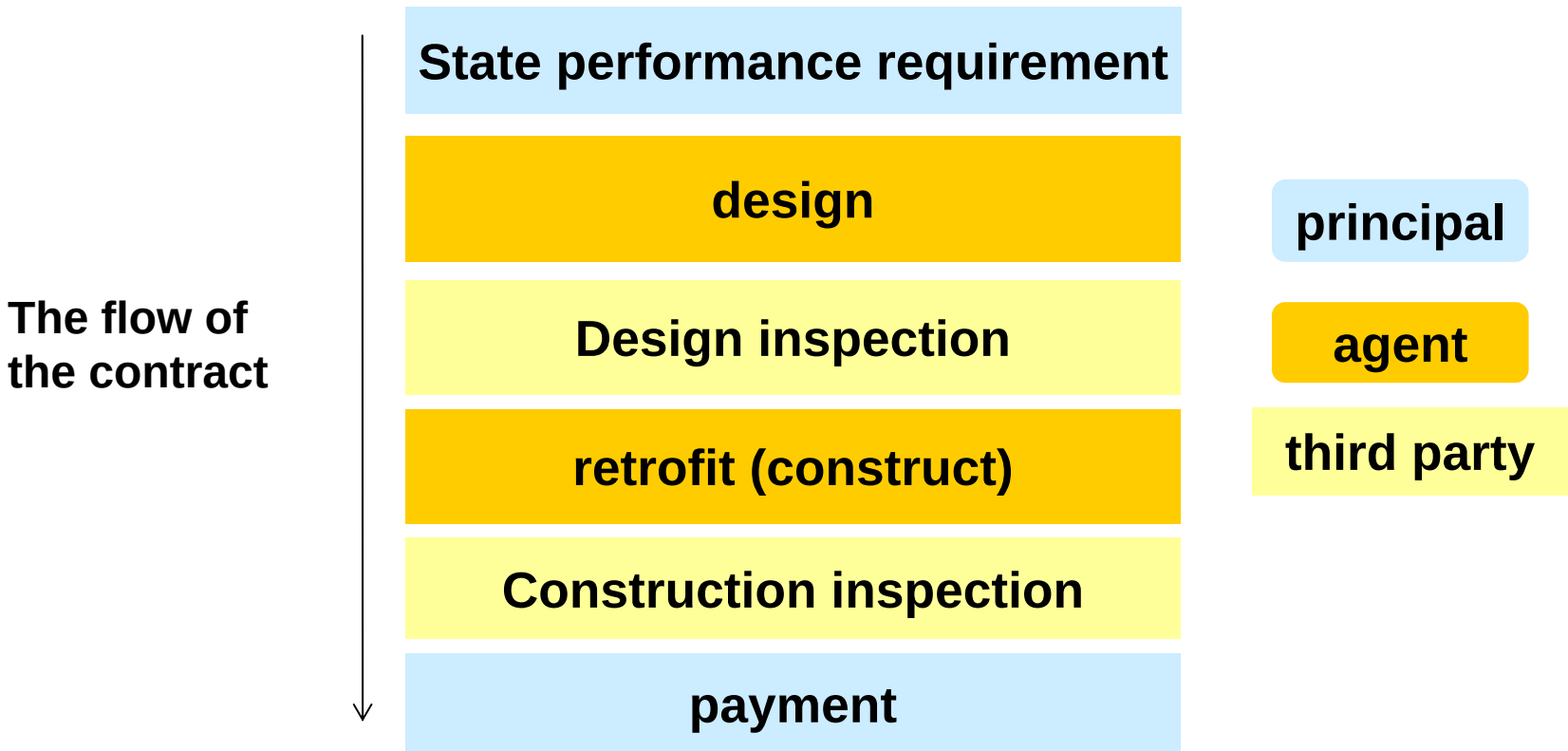
– The principal does not offer the contract in the first place if she expects that the agent take a opportunistic action

Framework(1)

- Performance-based design
  - The principal states her requirement for the vulnerability of her house.
  - The agent can use any construction method as long as the achieved vulnerability satisfies the principal's requirement.
- Performance verification
  - inspects the vulnerability directly after the agent's work
    ⇒ technically and financially difficult
  - Two-staged inspection
    - At first stage, inspects whether the design drawing has a potential to satisfy the principal's performance requirement
    - At second stage, inspects whether the retrofit is undertook in accordance with the final design drawing.

Framework(2)

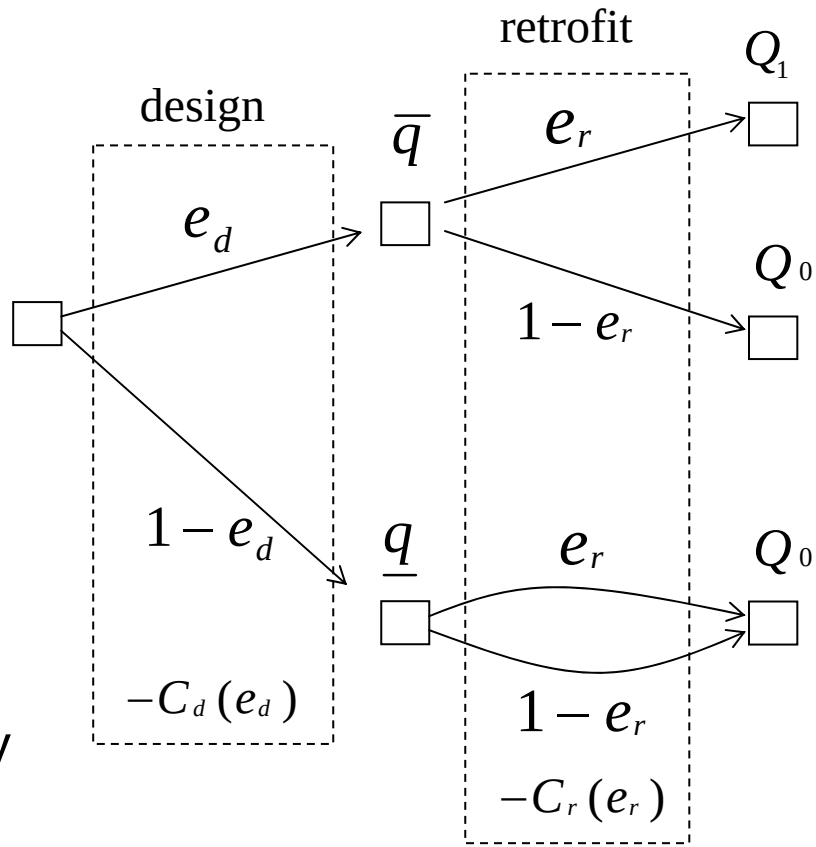
- Performance-based contract



Purpose of research

- the effect of the principal's ex-post unobservability of the agent's work
- the role of performance-based contract under the ex-post unobservability

Preliminary setting



designin, retrofit effort level $0 \le e_d, e_r \le 1$

quality of design drawing $q \in \{\overline{q}, \underline{q}\}$

the vulnerability of the house $Q \in \{Q_1, Q_0\}$

Q_1 : satisfies performance requirement of the principal

Q_0 : not satisfied the performance requirement (, which is same as the vulnerability before retrofitting)

$0 < Q_1 < Q_0 < 1$

$C_d(e_d)$ design cost function $C_d' > 0, C_d'' < 0, C_d'(1) = \infty, C_d'(1) = 0$

$C_r(e_r)$ retrofit cost function $C_r' > 0, C_r'' > 0, C_r'(0) = 0, C_r'(1) = \infty$

Principal and Agent are risk-neutral,

Principal obeys the rational expectation hypothesis

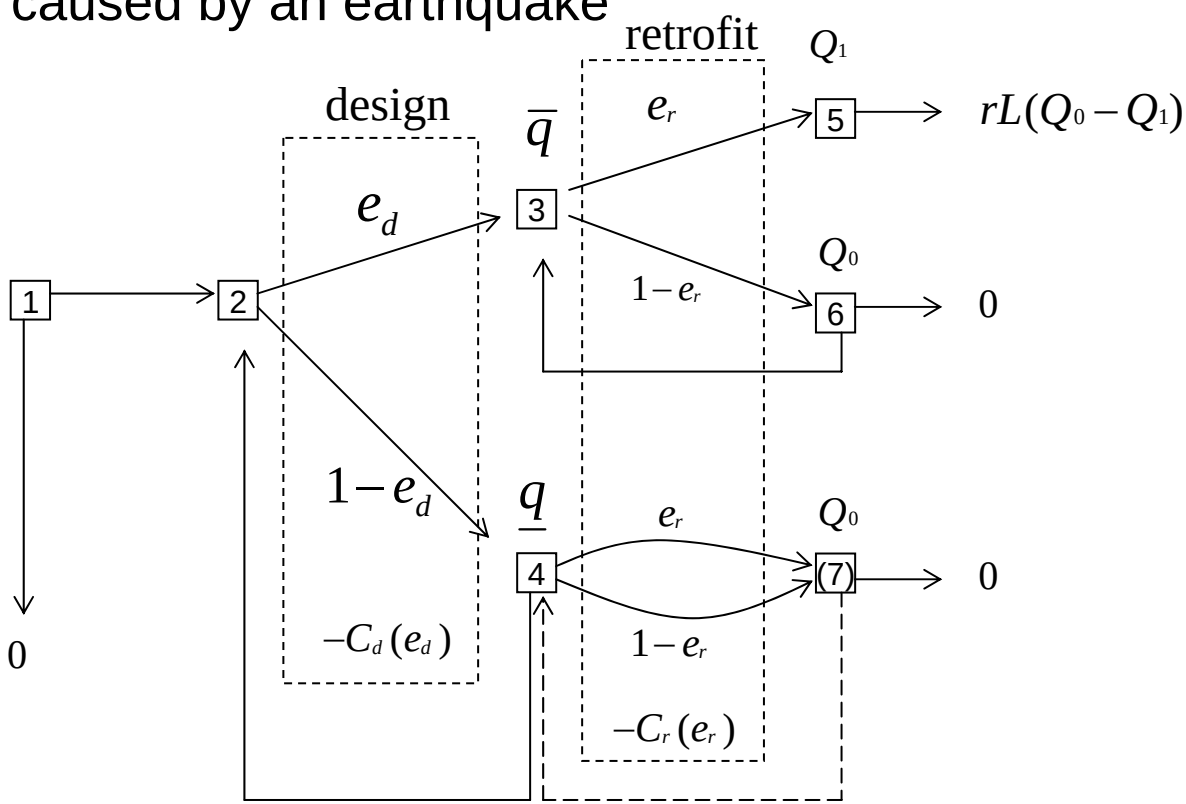
Social optimal contract

the principal designs and retrofits by herself

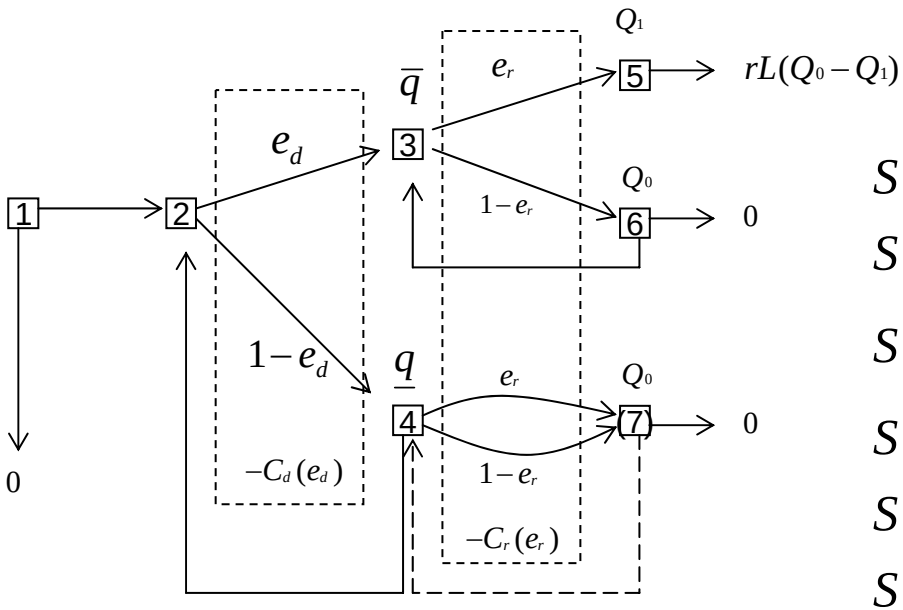
(can observe each effort level, the quality of design drawing and the vulnerability)

r : the probability of occurrence of an earthquake

L : the loss caused by an earthquake



Social optimal contract



each value function
at each decision-making node

$$S_1 = \max[S_2, 0]$$

$$S_2 = \max_{ed} e_d S_3 + (1-e_d) S_4 - C_d(e_d)$$

$$S_3 = \max_{er} e_r S_5 + (1-e_r) S_6 - C_r(e_r)$$

$$S_4 = \max[S_2, S_6 - C_r(e_r)]$$

$$S_5 = rL(Q_0 - Q_1)$$

$$S_6 = \max[S_3, 0]$$

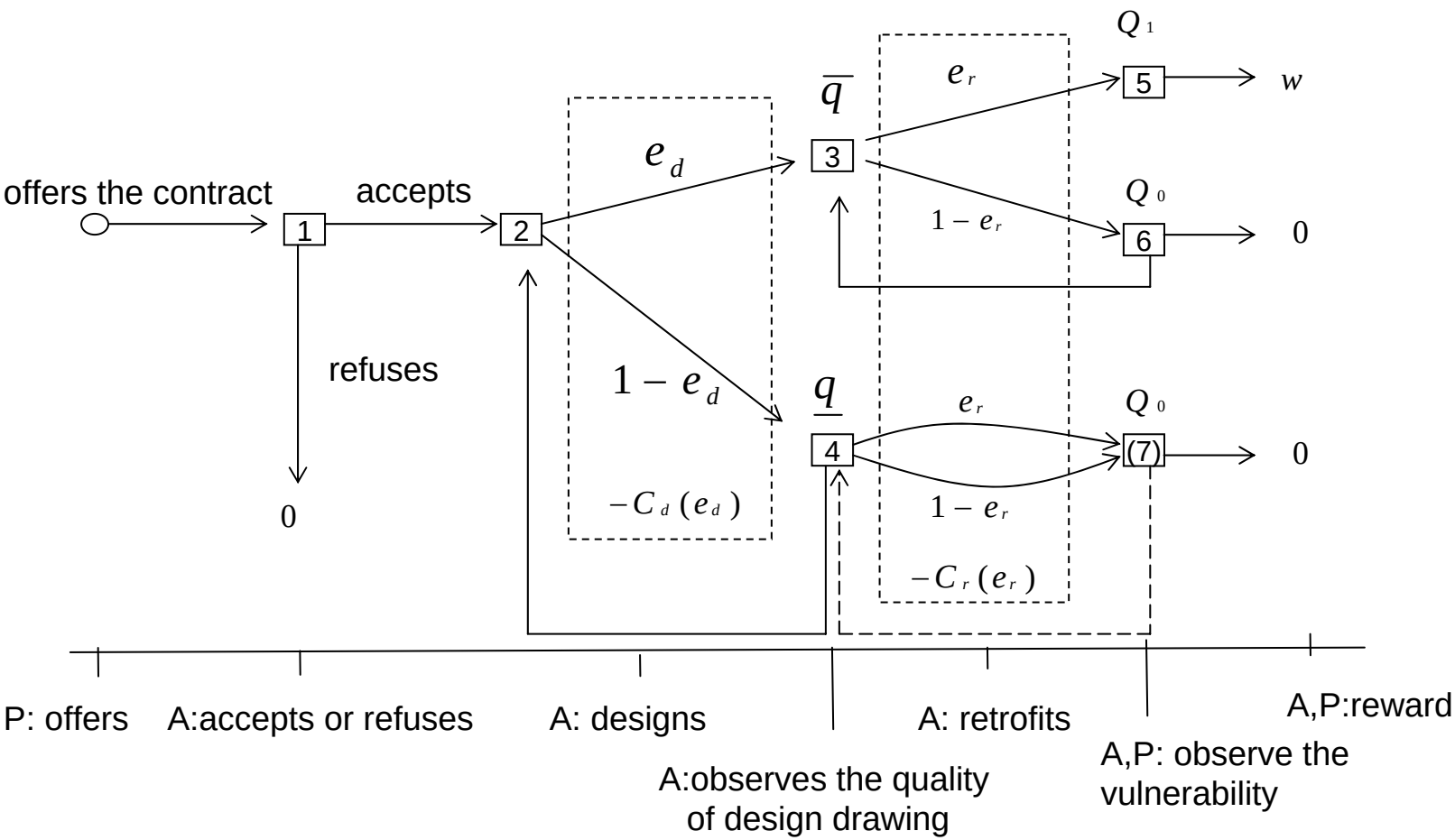
Design effort level $e_d^* = 1$

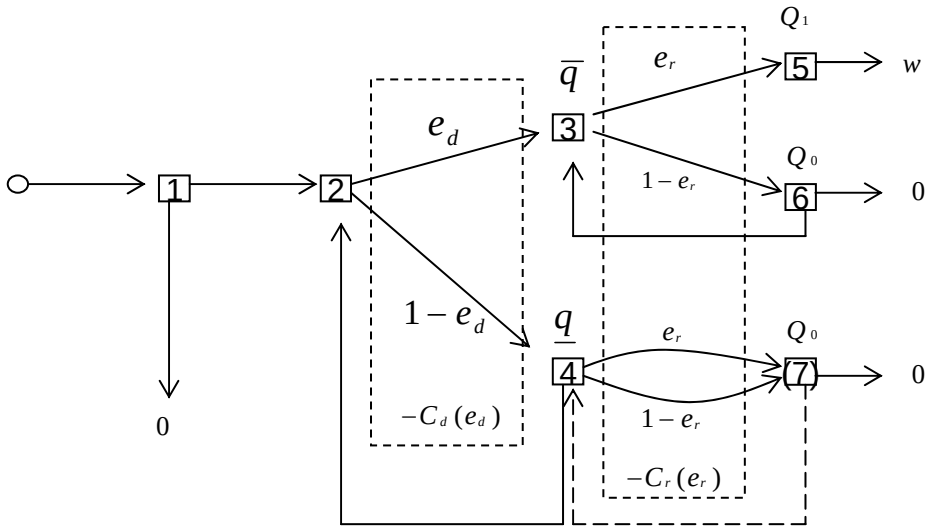
Retrofit effort level $C_r'(e_r^*) = C_r(e_r^*)/e_r^*$

The principal (the agent) repeats retrofitting until the low vulnerability is achieved

The contract under the ex-post observability

Assumption- the principal can observe the achieved vulnerability,
but cannot observe each effort level which is chosen by the agent





each value function for each decision-making node

$$V_1 = \max[V_2, 0]$$

$$V_2 = \max_{ed} e_d V_3 + (1-e_d)V_4 - C_d(e_d)$$

$$V_3 = \max_{er} e_r V_5 + (1-e_r)V_6 - C_r(e_r)$$

$$V_4 = \max[V_2, V_7 - C_c(e_c)]$$

$$V_5 = w$$

$$V_6 = \max[V_3, 0]$$

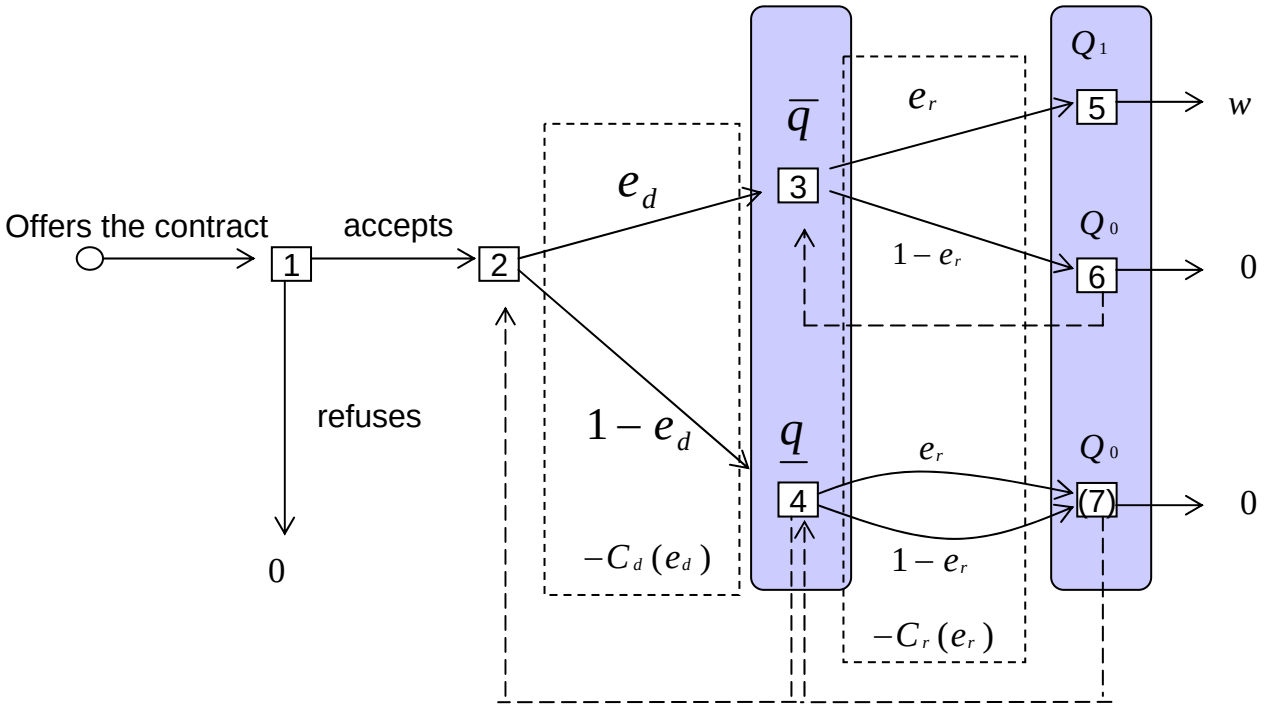
- Equilibrium solution A : reach agreement on the contract
  The agent continue to retrofit until the low vulnerability is achieved
- Equilibrium solution B : don't reach agreement on the contract

each effort level chosen by the agent = each social optimal effort level

Social optimal contract can be concluded
if and only if the principal can observe the vulnerability

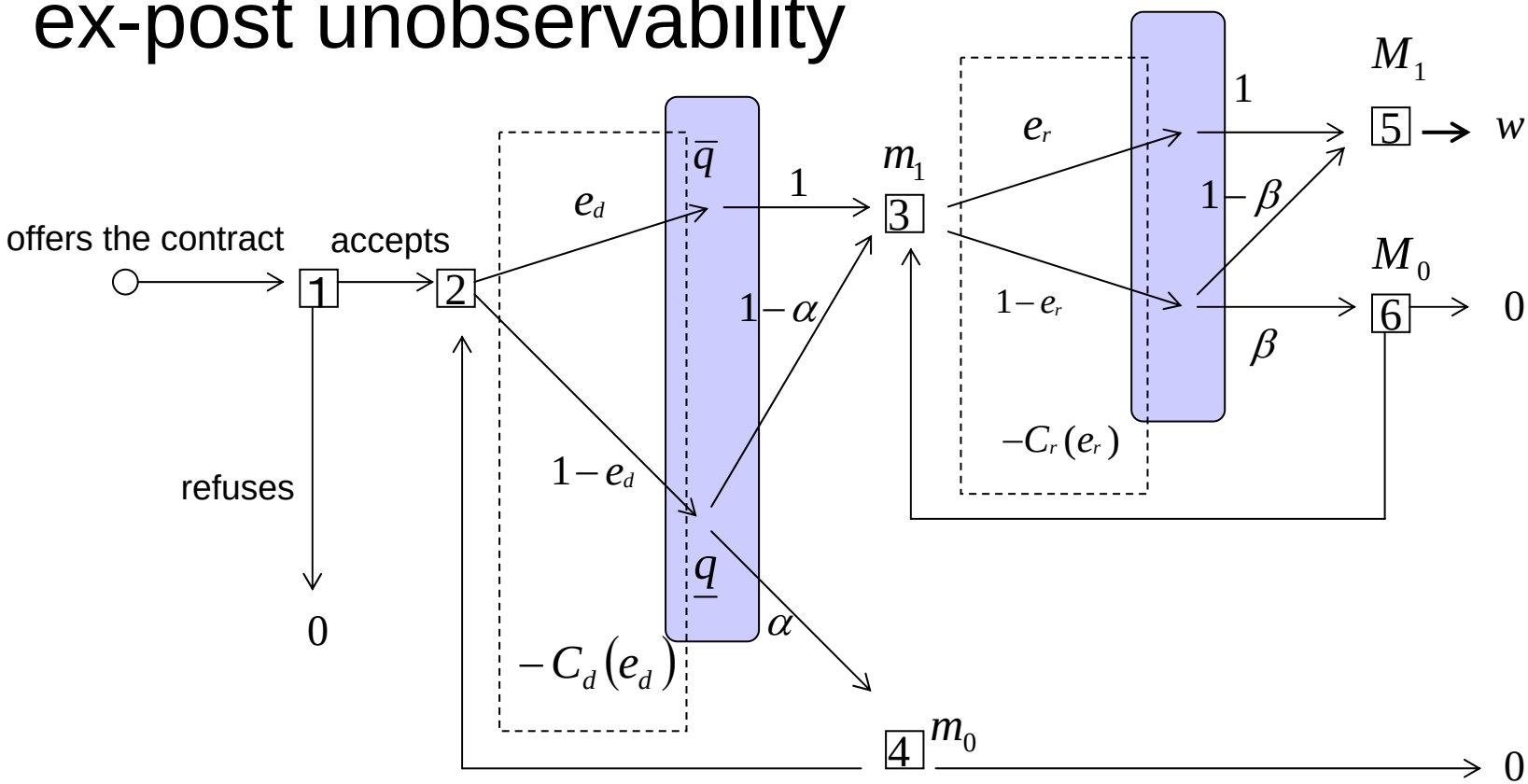
The contract under the ex-post unobservability

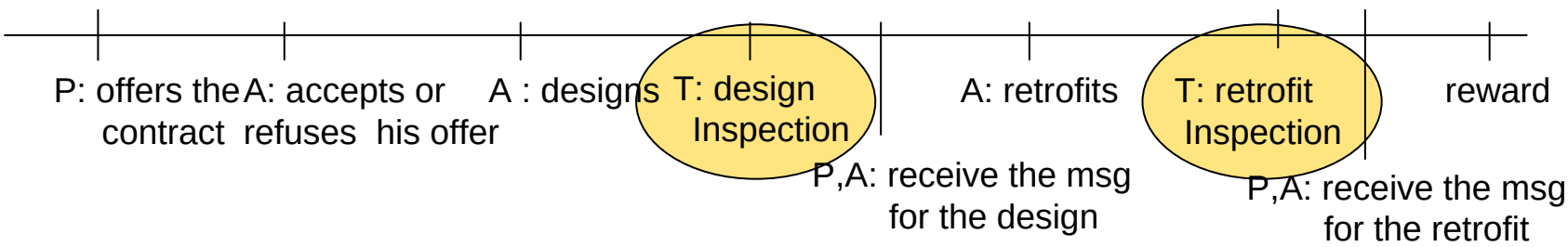
Assumption-the principal cannot observe each effort level,
the quality of design drawing, and the vulnerability

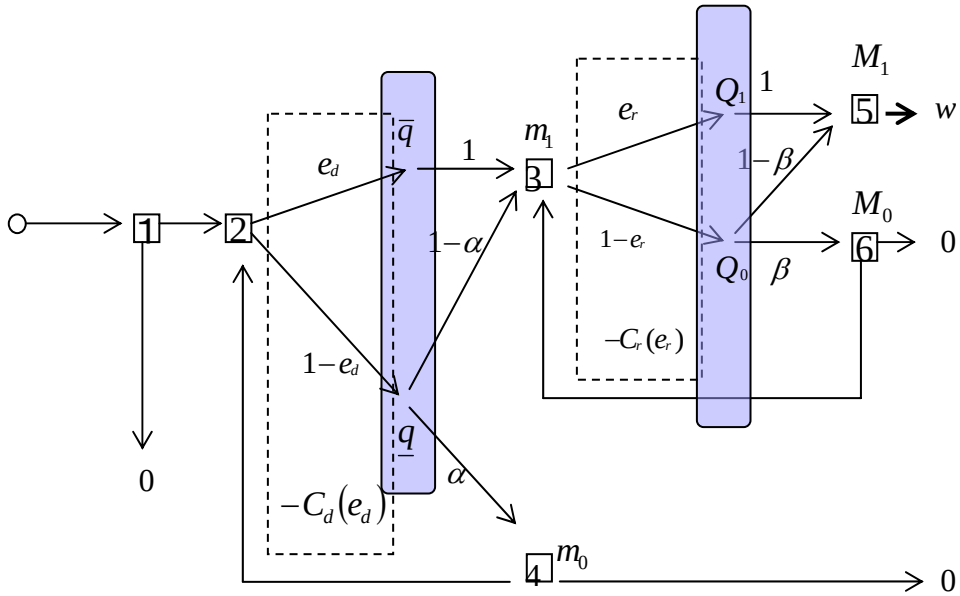


Minimum effort levels maximize the agent's profit
Principal ・・・rational expectation→does not offer the contract

Performance-based contract under the ex-post unobservability







each value function at each decision-making node

$$W_1 = \max[W_2, 0]$$

$$W_2 = \max_{ed} \tau_d(m_1 \mid e_d) W_3 + \tau_d(m_0 \mid e_d) W_4 - C_d(e_d)$$

$$W_3 = \max_{er} \tau_r(m_1 \mid e_r) W_5 + \tau_r(m_0 \mid e_r) W_6 - C_r(e_r)$$

$$W_4 = \max[W_2, 0]$$

$$W_5 = w$$

$$W_6 = [W_3, 0]$$

Main feature of performance-based contract

Equilibrium solution A: reach agreement on the contract
The agent repeats retrofitting until he receives the reward

Equilibrium solution B: do not reach agreement of the contract

1. the social optimal contract can be concluded
   if the proper inspection is conducted

2. Design inspection accuracy
   the threshold value
   new necessary condition to conclude a contract

$$\alpha \geq \frac{C_d(1) - C_d(0)}{C_d(1)}$$

3. Retrofit inspection accuracy
   – the higher it is, the closer it is to the social optimal level

Conclusion

- Performance-based contract can lead the principal and the agent to conclude a social optimal contract, if the third party inspects properly.
- As for the design inspection accuracy, there exists a threshold value. If the accuracy follow from the value, the principal does not offer the contract in the first place
- As for the retrofit inspection accuracy, the higher it is, the closer it is to the social optimal effort level.

Further Research

- Incentive design for third party
  - Moral hazard for intention and ability
  - Peer Review
  - Inspection cost

Thank you for your attention !!