Dynamic Moral Hazard with Manipulation of Output Reports

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Setting

- Multi-period moral hazard problem
- Agent produces successes – sales, breakthroughs, strategic deals, etc.
- Agent can delay report of success

Why Does Hiding Matter

- In a one-period setting, MLRP is sufficient to prevent hiding.
- In multi-period settings delaying reports is a common concern:
    - "Earnings Management" – delaying reports to shareholder, has been extensively studied empirically in accounting research
    - "Sales Gaming" – timing sales according to incentives

This Paper

- Simple model to identify the main underlying economics:
  - Private saving of outcomes *does not equal* private saving of income
  - Optimal contract is more responsive to outcomes
  - Informativeness principle (sufficient statistic) may not apply
  - Hiding matters less if agent is risk neutral
  - Increases cost (to the prinipal) of agent's risk averseness
  - Agent may be worse off
- General dynamic program framework

Related Literature

- Only paper in which agent can delay output reports we know of is Strulovici (2011). Very different focus.
- Zhu (2013) and Varas (2013) allow the agent to increase current productivity by sacrificing future productivity.
- Williams (2011) and Sannikov (2014) allow the agent's actions to have long term effects
- Fudenberg et al. (1990), Edmans et al. (2012), and others consider private savings
- Sales manipulation: Oyer (1998), Oyer (2000), Misra and Nair (2009), Larkin (2014)
- Earnings management: Healy (1985), Healy and Wahlen (1999), Bergstresser and Philippon (2006), Dechow et al. (2010),...

Model - Production

- Agent's effort $a \in A$, cost $c(a)$ increasing (convex)
- Discrete outcome $y \in \{0, 1, 2, ... Y\}$, density $p(a, y) > 0$
- Principal's value from outcome y is $v(y)$, increasing in y (concave)
- Higher effort yields higher expected outcome value
- Discrete time

Model - Contract and Utility

- Only positive payments to the agent
- Contract specifies for each history h_t the required effort a and output-dependent payments w_y
  - Dynamic problem also specifies continuation utility (or certainty equivalent) U^y
- Agent's utility value for period effort cost c, payment w and continuation utility (or certainty equivalent) U is $u(c, w, U)$
- Discount factors can be different $(\delta_a,\ \delta_p)$

Hiding

- At the end of period t with outcome y_t, the agent can report $y_t - 1$, the unreported unit is added to y_{t+1}
- Can be hidden again
- Only one output unit can be hidden at a time

Honest Reporting Incentive Compatibility (RIC)

- For any proposed contract, let:
  - $U(h_t)$ be the expected continuation utility for a complying agent
  - $\hat{U}(h_t)$ be the expected continuation utility for a "hiding" agent: an agent that started the current period with a stored success. Note: hiding agent may choose different actions
- Let $h' = \langle h, (a, y) \rangle$ be the history h followed by requested effort a and outcome y

Proposition

A contract is RIC iff for any history h with requested action a, for all $y > 0$: $U(\langle h, (a, y) \rangle) \geq \hat{U}(\langle h, (a, y-1) \rangle)$

Honest Reporting Incentive Compatibility (RIC) - proof

Proposition

A contract is RIC iff for any history h with requested action a, for all $y > 0$: $U(\langle h,(a,y)\rangle) \geq \hat{U}(\langle h,(a,y-1)\rangle)$

Proof

- Necessity: If the condition fails, the agent should hide
- Sufficiency: If the condition holds, lying reduces the agents' expected utility

Dynamic Problem:

$$V(U,\hat{U}) = \max_{a\in A, z\in A, U^y\geq 0, \hat{U}^y\geq 0} \sum_y \left[p(a,y)\left(v(y) - w_y + \delta_p V(U^y, \hat{U}^y) \right) \right] \quad s.t.$$

$$U = \sum_y p(a,y)\cdot u(c(a), w_y, \delta_a U^y)$$

$$a \in \arg\max_{\tilde{a}} \sum_y p(\tilde{a},y)\cdot u(c(\tilde{a}), w_y, \delta_a U^y)$$

$$\hat{U} \geq \sum_{y<Y} \left[p(z,y)\cdot u(c(z), w_{y+1}, \delta_a U^{y+1}) \right] + p(z,Y)\cdot u(c(z), w_Y, \delta_a \hat{U}^Y)$$

$$z \in \arg\max_{\tilde{z}} \sum_{y<Y} \left[p(\tilde{z},y)\cdot u(c(\tilde{z}), w_{y+1}, \delta_a U^{y+1}) \right] + p(\tilde{z},Y)\cdot u(c(\tilde{z}), w_Y, \delta_a \hat{U}^Y)$$

$$\forall y > 0 \quad U^y = U^{\hat{y-1}}$$

Dynamic Problem - Similar Parts

$$V(U,\hat{U}) = \max_{a\in A, z\in A, U^y\geq 0, \hat{U}^y\geq 0} \sum_y \left[p(a,y)\left(v(y) - w_y + \delta_p V(U^y, \hat{U}^y)\right)\right] \quad s.t.$$

$$U = \sum_y p(a,y)\cdot u(c(a), w_y, \delta_a U^y)$$

$$a \in \arg\max_{\tilde{a}} \sum_y p(\tilde{a},y)\cdot u(c(\tilde{a}), w_y, \delta_a U^y)$$

Dynamic Problem - Changed/New Parts

$$V(U,\hat{U}) = \max_{a\in A, z\in A, U^y\geq 0, \hat{U}^y\geq 0} \sum_y \left[p(a,y)\left(v(y) - w_y + \delta_p V(U^y, \hat{U}^y)\right)\right] \quad s.t.$$

$$\hat{U} \geq \sum_{y<Y} \left[p(z,y)\cdot u(c(z), w_{y+1}, \delta_a U^{y+1})\right] + p(z,Y)\cdot u(c(z), w_Y, \delta_a \hat{U}^Y)$$

$$z \in \arg\max_{\tilde{z}} \sum_{y<Y} \left[p(\tilde{z},y)\cdot u(c(\tilde{z}), w_{y+1}, \delta_a U^{y+1})\right]$$

$$+ p(\tilde{z},Y)\cdot u(c(\tilde{z}), w_Y, \delta_a \hat{U}^Y)$$

$$\forall y > 0 \quad U^y = U^{\hat{y}-1}$$

Dynamic Problem Simplifications / Observations

- Standard IC and regeneration constraint ($U = ...$) unaffected
- Period return not directly affected
- No need to choose $\hat{U}^y$ for $y < Y$
- Only two additional variables compared to the standard problem: hiding agent's action z and $\hat{U}^Y$
- Two additional constraints: $\hat{U} \geq ...$ and $z \in ...$
- If f.o.c. approach works without hiding, f.o.c. works with hiding
- Under some regularity conditions, the $\hat{U}$ is an equality
- Managable computational burden – if you can solve the problem without hiding, you can solve with hiding

Three Reasons to Hide

- Game the Rewards
  - Threshold contract: Rewards only when $y \geq y^{\star}$, hide when $y < y^{\star}$ (and maybe when $y > y^{\star}$)
  - Decreasing rewards within period: e.g. $y > y^{\star}$ is so unlikely that it isn't informative of action, rewards don't increase: hide when $y > y^{\star}$
- Game the Contract Dynamics
  - Contract expected to increase incentives
  - Value of marginal reward today lower than expected marginal value tomorrow
- Insure
  - Value of marginal reward today is lower than value of reducing variance tomorrow

Example 1 – Gaming the Rewards

- Two periods, no discounting
- Risk neutral agent: $u(c, w, U) = w - c + U$
- Two actions: $a \in \{L, H\}$
- $c(L) = 0, c(H) = c$
- Three outcomes $y \in \{0, 1, 2\}$, $v(y) = y$
- $p(a, 1) = p_a \cdot (1 - \lambda), \quad p(a, 2) = p_a \lambda, \quad p(a, 0) = 1 - p_a$
- $p_H > p_L$
- Note: outcomes 1 and 2 provide the same indication of the agent's effort

Example 1 – Optimal Contract

- Assume contract without hiding sets $a_1 = a_2 = H, w(0) = 0$
- Optimal contract problem is to choose $w(1)$ and $w(2)$
- Without hiding, infinitely many stationary contracts

$$(1-\lambda)w(1) + \lambda w(2) = \frac{c}{p_H - p_L}$$

- Easier to write $b(2) \equiv w(2) - w(1)$

$$w(1) + \lambda b(2) = \frac{c}{p_H - p_L}$$

Example 1 – Contract to Prevent Reward Gaming

1. Will a hiding agent work?

$$w(1) + p_H b(2) - c \geq w(1) + p_L b(2) \iff b(2) \geq \frac{c}{p_H - p_L}$$

2. RIC if hiding agent works:

$$w(1) \geq w(1) + p_H b(2) - c - (p_H(w(1) + \lambda b(2) - c)$$
$$\iff w(1) \geq (1-\lambda) b(2)$$
$$b(2) \geq w(1) + p_H b(2) - c - (p_H(w(1) + \lambda b(2) - c)$$
$$\iff b(2)(1 - p_H(1-\lambda)) \geq w(1)(1 - p_H)$$

3. Solution: $b(2) = \frac{c}{p_H - p_L}$, $w(1) = (1-\lambda)\frac{c}{p_H - p_L}$

Reward Gaming – Observations

1. Optimal contract is as profitable to the principal and agent
2. Optimal contract is unique
3. Optimal stationary rewards violate "sufficient statistic principle" ($w(2) \neq w(1)$)
4. Optimal stationary contract is *convex*: $w(2) - w(1) > w(1) - w(0)$
5. Agent is rewarded even more for something completely out of his control

Insurance

- Same problem, but with risk averse agent (CARA)

$$u = -e^{c(a_1)+c(a_2)-w(y_1)-w(y_2)}$$

- Unique optimal contract without hiding is stationary, sets $w(1) = w(2) = w^\star$
- Unique optimal stationary contract with hiding:

$$b(2) \equiv w(2) - w(1) = w^\star$$

$$e^{-w(1)} = \frac{e^{-w^\star}}{1 - \lambda + \lambda e^{-w^\star}}$$

Insurance Observations

- Optimal stationary contract is less profitable to the principal
- Same reward structure as for the risk neutral agent
  - Reward for second success in period higher than reward for first success
- Agent can only be worse off
  - IC still binds so certainty equivalent didn't change
  - Increased cost may sway the principal to avoid work altogether
- Optimal rewards are not stationary (didn't show here)
  - In second period, can set $w(2) \approx w(1)$
  - Stationary contract more indicative of longer horizons with fixed actions

Gaming Contract Dynamics

- Three actions ($a \in L, M, H$), same outcome structure ($p_M \in (p_L, p_H)$)
- Optimal contract without hiding starts with $a_1 = M$ and moves to $a_2 = H$ if there is a success
    - Second period rewards are stronger
    - Hiding the second success is a bigger problem
- Optimal contract without hiding starts with $a_1 = M$ and moves to $a_2 = L$ if there is no success
    - Second period rewards are higher
    - Reward gaming only

Conclusion - Output Report Manipulation

- Interesting and important problem
- Many variations, similar structure
- Simplest models to flush out the economics:
  - Gaming the rewards
  - Insurance
  - Gaming the dynamics
- Storing output is NOT like storing payments