Managerial Incentives, Financial Innovation, and Risk-Management Policy

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Motivations

- A lot of literatures on risk-management of an individual firm and how each corporation's imprudent risk-taking adds to systemic risks on the financial market and the real economy
  - Global financial crisis (GFC) and the subsequent Great Recession

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  1. Bernanke (2009): "compensation practices at some banking organizations have led to misaligned incentives and excessive risk-taking, contributing to bank losses and financial instability"
  2. How do we operationalize the above claim in general?
  3. How do innovations in financial markets affect the value of corporations?
     - Derivative instruments allow managers to engage in hedging, thus completely eliminating risk-exposures of the firm (which are unobserved by shareholders)
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     - If managers speculate (as in GFC) instead of hedging, compensation contract must be altered, incurring additional agency cost
- Our contribution: provide a neat framework where compensation contracts, innovations in the financial markets, and risk-choices of corporations are intertwined, jointly affecting a value of corporation

Findings

- When ∃ effort and project-choice (non-hedgeable risk-choice) by managers
  - If ∃ moral hazard only in effort (project-choice is observed)
    1. Shareholders want less risk than the case where there is no moral hazard at all
    2. Why? A lower risk level makes output a sharper signal in inducing effort
  - If ∃ moral hazard in effort and project-choice
    1. Compensation contract rewards or punishes the output 'variation' depending on whether shareholders want managers to raise the risk level or not.

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  1. A derivative market brings an informational benefit if managers hedge and eliminate the firm's risk exposures voluntarily
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  3. Financial innovation thus might hurt the efficiency
- Following prior theoretical and empirical literatures including Hirshleifer and Suh (1992), Sung (1995), Guay (1999), Rajgopal and Shevlin (2002), Palomino and Prat (2003), DeMarzo et al. (2013), Makarov and Plantin (2015), Hébert (2018), Barron et al. (2020)

Outline

1. Environment
   - Action, non-hedgeable risk-choice, and hedgeable risk-choice
2. Without derivative market
   - When non-hedgeable risk-choice can be enforced
   - When $\exists$ moral hazard in non-hedgeable risk-choice
   - When R is not observed
3. With derivative market (a_3 is freely chosen)
   - Hedging
   - Speculation and the new contract
   - Costless communication

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$$\text{Output } x = \underbrace{\phi(a_1, a_2)}_{\text{Expected output}} + \underbrace{a_2\theta}_{\text{Project risk}} + \underbrace{(R - a_3)\eta}_{\text{Hedgeable risk}} \tag{1}$$

1. $\theta \sim N(0, 1)$ non-hedgeable risk, $\eta \sim N(0, 1)$ hedgeable risk (market variable)

2. Contract can be written on x (output) and η (market variable)

3. R: firm's exposure to hedgeable risks, only observable to manager

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- If $|R - a_3| < |R|$, manager is hedging. $|R - a_3| > |R|$ means he's speculating in financial markets

- Manager is risk-averse with $u(\cdot)$, shareholders are risk-neutral

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Benchmark: R is observed by principal and no derivative market ($a_3 = 0$) and a_2 is enforceable (no moral hazard in a_2)

- Then principal can write contract on $y = x - R\eta = \phi(a_1, a_2) + a_2\theta$

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- Then principal can write contract on $y = x - R\eta = \phi(a_1, a_2) + a_2\theta$
- <u>Fix actions a_1, a_2</u> and find optimal $w^P(y|a_1, a_2)$ that induces a_1

$$\max_{a_1, a_2, w(\cdot)} \underbrace{\phi(a_1, a_2)}_{\text{Expected output}} - \underbrace{\int w(y) f(y|a_1, a_2, a_3 = 0) dy}_{\text{Payment to manager}}$$

$$+ \underbrace{\lambda}_{\text{Fixed weight}} \underbrace{\left[\int u(w(y)) f(y|a_1, a_2, a_3 = 0) dy - v(a_1) \right]}_{\text{Manager's utility}} \quad \text{s.t.} \tag{2}$$

$$(i) \quad a_1 \in \arg\max_{a_1'} \int u(w(y)) f(y|a_1', a_2, a_3 = 0) dy - v(a_1'), \quad \forall a_1'$$

$$(ii) \quad w(y) \geq k, \quad \forall y,$$

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- For solution $w^P(y|a_1, a_2)$, social welfare is defined:

$$SW(a_1, a_2) \equiv \phi(a_1, a_2) - \underbrace{C(a_1, a_2)}_{\text{Agency cost}} - \lambda v(a_1), \tag{3}$$

  - $C(a_1, a_2) \equiv \int [w^P(y|a_1, a_2) - \lambda u(w^P(y|a_1, a_2))] f(y|a_1, a_2, a_3 = 0) dy$

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Lemma

$C(a_1, a_2^0) < C(a_1, a_2^1)$ for any given a_1 if $a_2^0 < a_2^1$.

- A lower a_2 gives a sharper information of how a_1 affects y, lowering $C(a_1, a_2)$, but due to risk-return tradeoff it also lowers $\phi(a_1, a_2)$: thus trade-off

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- Let $\underline{a_1^P, a_2^P, w^P(y|a_1^P, a_2^P)}$ be the solution of the above problem
  1. If a_2 is not enforceable, would manager choose a_2^P voluntarily given $w^P(y|a_1^P, a_2^P)$?
  2. In other words, with
  $$a_2^A(a_2^P) \in \arg\max_{a_2} \int u(w^P(y|a_1^P, a_2^P)) f(y|a_1^P, a_2, a_3 = 0) dy. \qquad (4)$$
  3. Generally $a_2^A(a_2^P) \neq a_2^P$

Benchmark: R is observed by principal and no derivative market ($a_3 = 0$) and a_2 is NOT enforceable (moral hazard in a_2)

- Then shareholders solve the following problem

$$\max_{a_1, a_2, w(\cdot)} \underbrace{\phi(a_1, a_2)}_{\text{Expected output}} - \underbrace{\int w(y) f(y|a_1, a_2, a_3 = 0) dy}_{\text{Payment to manager}}$$

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$$(i) \quad a_1 \in \arg\max_{a_1'} \int u(w(y)) f(y|a_1', a_2, a_3 = 0) dy - v(a_1'), \quad \forall a_1'$$

$$(ii) \quad a_2 \in \arg\max_{a_2'} \int u(w(y)) f(y|a_1, a_2', a_3 = 0) dy - v(a_1), \quad \forall a_2'$$

$$(iii) \quad w(y) \geq k, \quad \forall y,$$

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- Optimum $\underline{(a_1^*, a_2^*, w^*(y))}$ satisfies:

$$\frac{1}{u'(w^*(y))} = \lambda + \underbrace{(\mu_1^* \phi_1^* + \mu_2^* \phi_2^*)}_{>0:\ \text{Proved}} \frac{y - \phi^*}{(a_2^*)^2} + \underbrace{\mu_2^*}_{\lesseqgtr 0(?)} \frac{1}{a_2^*} \left(\underbrace{\frac{(y - \phi^*)^2}{(a_2^*)^2}}_{\text{Output variation}} - 1 \right) \tag{6}$$

Benchmark: R is observed by principal and no derivative market ($a_3 = 0$) and a_2 is NOT enforceable (moral hazard in a_2)

Proposition

If $a_2^P < a_2^A(a_2^P)$, $w^*(y)$ penalizes the agent for having unusual output deviation from the expected level, i.e., $\mu_2^* < 0$. If $a_2^P > a_2^A(a_2^P)$, then $w^*(y)$ rewards the agent for having unusual output deviation, i.e., $\mu_2^* > 0$.

- Define similarly the welfare in this case

$$SW(a_1^*, a_2^*, a_3 = 0) \equiv \phi(a_1^*, a_2^*) - \underbrace{C(a_1^*, a_2^*)}_{\text{Agency cost}} - \lambda v(a_1^*), \tag{7}$$

- $C(a_1^*, a_2^*) \equiv \int [w^*(y) - \lambda u(w^*(y))] f(y|a_1^*, a_2^*, a_3 = 0) dy$

When R is NOT observed by principal and no derivative market ($a_3 = 0$) and a_2 is NOT enforceable (moral hazard in a_2)

- Principal knows manager with different R chooses different $(a_1(R), a_2(R))$

$$\max_{a_1(\cdot),a_2(\cdot),w(\cdot)} \mathbb{E}_R \int_{x,\eta} [x - w(x,\eta)] g(x,\eta|a_1(R), a_2(R), R) dx d\eta$$
$$+ \lambda \mathbb{E}_R \left(\int_{x,\eta} u(w(x,\eta)) g(x,\eta|a_1(R), a_2(R), R) dx d\eta - v(a_1(R)) \right) \text{ s.t.}$$
$$(i) \quad a_1(R) \in \arg\max_{a_1} \int_{x,\eta} u(w(x,\eta)) g(x,\eta|a_1, a_2(R), R) dx d\eta - v(a_1), \forall R,$$
$$(ii) \quad a_2(R) \in \arg\max_{a_2} \int_{x,\eta} u(w(x,\eta)) g(x,\eta|a_1(R), a_2, R) dx d\eta, \forall R,$$
$$(iii) \quad w(x,\eta) \geq k, \quad \forall (x,\eta), \tag{8}$$

- Define similarly the welfare in this case

$$SW^N \equiv \int_R [\phi(a_1^N(R), a_2^N(R)) - \underbrace{C^N(a_1^N(R), a_2^N(R))}_{\text{Agency cost for } \forall R} - \lambda v(a_1^N(R))] h(R) dR, \tag{9}$$

- $C^N(a_1^N(R), a_2^N(R)) \equiv \int_{x,\eta} [w^N(x,\eta) - \lambda u(w^N(x,\eta))] g(x,\eta|a_1^N(R), a_2^N(R), R) dx d\eta$

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When R is NOT observed by principal and there is a derivative market

- Imagine principal designs a contract that is optimal in the absence of derivative market with x instead of $y \equiv x - (R - a_3)\eta$

$$\frac{1}{u'(w^*(x))} = \lambda + \underbrace{(\mu_1^*\phi_1^* + \mu_2^*\phi_2^*)}_{>0} \frac{x-\phi^*}{(a_2^*)^2} + \underbrace{\mu_2^*}_{\lesseqgtr 0(?)} \frac{1}{a_2^*}\Bigg(\underbrace{\frac{(x-\phi^*)^2}{(a_2^*)^2}}_{\text{Output variation}} - 1\Bigg) \quad (10)$$

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Lemma

When $\mu_2^* < 0$, then manager voluntarily chooses $a_3 = R$ (complete hedging). If $\mu_2^* > 0$, manager chooses $|R - a_3| = \infty$ (speculation).

- Thus with $\mu_2^* < 0$, agent voluntarily eliminates $(R - a_3)\eta$ as he dislikes additional risk on output x, thus achieving $SW(a_1^*, a_2^*, a_3 = 0)$: informational gain of financial market innovation
- With $\mu_2^* > 0$, principal must alter the contract to make sure manager hedges
  - It brings additional cost, as contract must change from $w^*(x)$ to $w^o(x, \underbrace{\eta}_{\text{Additional risk}})$
  - To induce hedging, contract must depend on η. How?

When R is NOT observed by principal and there is a derivative market

- With $\mu_2^* > 0$, principal solves the following problem

$$\max_{a_1, a_2, w(\cdot)} \underbrace{\phi(a_1, a_2)}_{\text{Expected output}} - \underbrace{\int w(x,\eta) g(x,\eta | a_1, a_2, a_3 = R) dx d\eta}_{\text{Payment to manager}}$$

$$+ \underbrace{\lambda}_{\text{Fixed weight}} \underbrace{\left[\int u(w(x,\eta)) g(x,\eta | a_1, a_2, a_3 = R) dx d\eta - v(a_1) \right]}_{\text{Manager's utility}} \quad \text{s.t.}$$

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$$(ii) \quad a_2 \in \arg\max_{a_2'} \int u(w(x,\eta)) g(x,\eta | a_1, a_2', a_3 = R) dx d\eta - v(a_1), \quad \forall a_2'$$

$$(iii) \quad R \in \arg\max_{a_3'} \int u(w(x,\eta)) g(x,\eta | a_1, a_2, a_3') dx d\eta - v(a_1), \quad \forall a_3'$$

$$(iv) \quad w(y) \geq k, \quad \forall y, \tag{11}$$

- Cannot rely on the famous first-order approach for (iii). Mathematical difficulty (indirect utility becomes convex if we use the first-order approach)

When R is NOT observed by principal and there is a derivative market

- A little more about the first-order approach
  1. $w^*(x)$ in equation (10): the optimal contract without (iii) (IC for $a_3 = R$)
     - $w^*(x)$ does not include η as an argument
  2. Manager's indirect utility as a function of a_3: symmetric around $a_3 = R$
     - Why? As η is symmetrically distributed around 0
     - Remember $x = \phi(a_1, a_2) + a_2\theta + (R - a_3)\eta$
  3. Thus for $w^*(x)$, we have:

$$\int u(w^*(x))g_3(x, \eta | a_1, a_2, a_3 = R)dxd\eta = 0 \tag{12}$$

  4. Thus if we rely on the first-order approach for IC for $a_3 = R$, we get $w^*(x)$ as an optimal contract, which induces manager to choose $|R - a_3| = \infty$

When R is NOT observed by principal and there is a derivative market

Proposition

Optimal $w^o(x, \eta)$ satisfies:

1. $w^o(x, \eta) = w^o(x, -\eta)$ *for* $\forall x, \eta$

2. *It penalizes the manager for having any (both positive and negative) sample covariance between the output, x, and market observables, η, i.e., penalizing manager for having high $(x - \phi)^2\eta^2$*
   - *Given η, a higher sample covariance $(x - \phi)^2\eta^2$ yields a lower wage $w^o(x, \eta)$, while given a fixed value of sample covariance $(x - \phi)^2\eta^2$, a higher η raises the wage $w^o(x, \eta)$*

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- Intuition: $R - a_3 = \mathbb{E}((x - \phi(a_1, a_2))\eta)$, thus punish its sample version
  1. With $a_3 = R$, x is not correlated with η, thus $w^o(x, \eta) = w^o(x, -\eta)$ to minimize risks imposed on risk-averse agent
- Welfare can go below SW^N, the one when there is no derivative market
  1. When $\sigma_R \to 0$: no informational gain but still $\exists$ incentive problem
  2. Then shareholders are better-off by not allowing any access to derivative market

When R is NOT observed by principal and there is a derivative market

- Optimal contract $w^o(x,\eta)$ is given as:

$$
\begin{aligned}
\frac{1}{u'(w^o(x,\eta))} =& \lambda + (\mu_1^o \phi_1^o + \mu_2^o \phi_2^o) \frac{x - \phi(a_1^o, a_2^o)}{(a_2^o)^2} + \frac{\mu_2^o}{a_2^o} \left(\frac{(x - \phi(a_1^o, a_2^o))^2}{(a_2^o)^2} - 1 \right) \\
& \underbrace{- 2 \sum_{k:\text{even}}^{\infty} \frac{1}{k!} \frac{1}{(a_2^o)^{2k}} \underbrace{\left(\int_{b \geq 0} \mu_4^o(b) b^k \exp\left[- \frac{b^2 \eta^2}{2(a_2^o)^2} \right] db \right)}_{\equiv C_{k:\text{even}}(\eta) > 0} \widehat{Cov}^k}_{\equiv D_{k:\text{even}}(\eta) > 0} \\
& + \underbrace{\int \mu_4^o(b) db}_{>0}
\end{aligned}
\tag{13}
$$

- With sample covariance $\widehat{Cov} \equiv (x - \phi(a_1^o, a_2^o))\eta$
  1. $\mu_4^o(b) \geq 0$: multiplier function for the following (IC) for $b = R - a_3$

$$
\int u(w(x,\eta))[g(x,\eta | a_1^o, a_2^o, b = 0) - g(x, \eta | a_1^o, a_2^o, b)] dx d\eta \geq 0 \tag{14}
$$

  2. μ_1^o and μ_2^o are multipliers for (IC) for a_1^o and a_2^o respectively

Other issues: costless communication

- What if manager can report his observation of R to shareholders?
  1. Truth-telling mechanism is possible in the case where agent voluntarily does not like additional risk (making a side-bet to agent)
  2. With $\mu_2^* < 0$, truth-telling contract can substitute the derivative market (for informational gain)
     - Risk management group at Disney would ask business unit heads to disclose all of their risks at the beginning of each quarter. Business unit profits were calculated assuming the risks were hedged, whether or not they actually were hedged
     - Then what is the additional benefit financial innovations bring about? (Big question)
  3. With $\mu_2^* > 0$, again truth-telling contract becomes much more complicated

Thank You!