

# Managerial Incentives, Financial Innovation, and Risk-Management Policy

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∃ Many stories about:

- Risk-management (or cash-management) of an individual firm
- How each corporation's imprudent risk-taking contributes to the systemic risk of the financial market and the Main Street economy
- The Global Financial Crisis (GFC) and the subsequent Great Recession

## Big Question (Main Topic)

**Managerial incentive**  $\iff$  the development of financial markets (e.g., derivative market) and risk-choices of corporations

**Bernanke (2009)**: “compensation practices at some banking organizations have led to misaligned incentives and excessive risk-taking, contributing to bank losses and financial instability”

- How do we operationalize his claim in relation to the agency literature?

## Big Question (Main Topic)

How do innovations in financial markets affect the value of corporations?

### Pros:

- Derivative instruments allow managers to HEDGE against hedgeable risks, thus eliminating the firm's original risk-exposures (which are unobserved by shareholders)

### Cons:

- If managers SPECULATE (as in usual financial crises) instead of HEDGE in the derivative market, their compensation contracts must be altered to make them HEDGE
- The shareholders would incur additional agency cost in twisting the comps

### **Our contribution:**

- A framework where incentive contracts, financial market innovations (e.g., introduction of derivative markets), and firms' risk-choices are intertwined, jointly affecting a value of corporation

When  $\exists$  effort and project-choice (non-hedgeable risk-choice) by managers

- ① If  $\exists$  moral hazard only in effort (project-choice is observed)
  - Shareholders: generally prefers the project's risk $\downarrow$
  - Why?: risk $\downarrow$  means output is a sharper signal in inferring the hidden effort (agency cost $\downarrow$ )
- ② If  $\exists$  moral hazard in both effort and project-choice
  - The optimal contract rewards or punishes the output's **sample variance**
  - When shareholders want the manager to raise the project's risk $\uparrow$ 
    - Then output's **sample variance** $\uparrow \rightarrow$  comps $\uparrow$
  - When shareholders want the manager to lower the project's risk $\downarrow$ 
    - Then output's **sample variance** $\uparrow \rightarrow$  comps $\downarrow$

When  $\exists$  hedgeable risk-choice (in addition to action and project choice) by managers

- ① Derivative market  $\Rightarrow$  informational benefit
  - When managers HEDGE and eliminate the firm's risk exposures voluntarily
- ② When managers SPECULATE,
  - Shareholders must alter the manager's compensation contract to make him HEDGE instead of SPECULATE
  - $\exists$  Additional cost from altering the contract
  - How shareholders change the comps to induce the manager to HEDGING is a very tricky question we answer
- ③ Financial innovation thus might hurt the efficiency of the firm
  - When the additional agency cost (for inducing HEDGING)  $>$  the informational gain from the introduction of derivative markets

Related prior theoretical and empirical works:

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)

# The Economic Environment

**Single period agency setting:** principal (shareholders) and agent (manager)

**Actions:**  $a_1$  action,  $a_2$  project choice,  $a_3$  transaction in derivative market

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

- ①  $\theta \sim N(0, 1)$ : NON-HEDGEABLE risk (project risk)
- ②  $\eta \sim N(0, 1)$ : HEDGEABLE risk (market's random variables: e.g., monetary policy, oil price, war, etc)
- ③ The contract can be written on  $x$  (output) and  $\eta$  (market variables)
- ④  $R$ : firm's exposure to HEDGEABLE risks, only observable to manager
  - Information asymmetry between shareholders and the manager

Transaction in the derivative market:  $a_3$

$$\text{Output } x = \underbrace{\phi(a_1, a_2)}_{\text{Expected output}} + \underbrace{a_2 \theta}_{\text{Project risk}} + \underbrace{(R - a_3) \eta}_{\text{Hedgeable risk}} \quad (2)$$

If  $|R - a_3| < |R|$ :

- The manager is HEDGING in the derivative market

If  $|R - a_3| > |R|$ :

- The manager is SPECULATING in the derivative market

Preference:

The manager is risk-averse with  $u(\cdot)$ , and shareholders are risk-neutral



## Without Derivative Markets ( $a_3 = 0$ )

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  $y = x - \underbrace{R}_{\text{Observed}} \eta = \phi(a_1, a_2) + a_2\theta$

Fix actions  $a_1, a_2$  and find optimal  $w^P(y|a_1, a_2)$  that induces  $a_1$

$$\begin{aligned} \max_{a_1, a_2, w(\cdot)} \quad & \underbrace{\phi(a_1, a_2)}_{\text{Expected output}} - \underbrace{\int w(y)f(y|a_1, a_2)dy}_{\text{Payment to manager}} \\ & + \underbrace{\lambda}_{\text{Fixed weight}} \underbrace{\left[ \int u(w(y))f(y|a_1, a_2)dy - v(a_1) \right]}_{\text{Manager's utility}} \quad \text{s.t.} \end{aligned} \quad (3)$$

$$(i) \quad a_1 \in \arg \max_{a'_1} \int u(w(y))f(y|a'_1, a_2)dy - v(a'_1), \quad \forall a'_1$$

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

→ Respect (IC) for  $a_1$  (NOT  $a_2$ ) and (LL)

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

For the optimal contract  $w^P(y|a_1^P, a_2^P)$ , social welfare is defined:

$$SW^P(a_1^P, a_2^P) \equiv \phi(a_1^P, a_2^P) - \underbrace{C^P(a_1^P, a_2^P)}_{\text{Agency cost}} - \lambda v(a_1^P) \quad (4)$$

where:

$$C^P(a_1^P, a_2^P) \equiv \int \left[ \boxed{w^P(y|a_1^P, a_2^P)} - \boxed{\lambda u(w^P(y|a_1^P, a_2^P))} \right] f(y|a_1^P, a_2^P) dy$$

Payment to the agent      Agent utility to SW

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

Lemma (Agency Cost: Kim (1995))

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

Low  $a_2$ : value of signal  $y \uparrow$

- $a_2 \downarrow \rightarrow$  a sharper information of how  $a_1$  affects  $y$ , thus  $C(a_1, a_2) \downarrow$
- $a_2 \downarrow \rightarrow \phi(a_1, a_2) \downarrow$  (risk-return tradeoff)

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

Given  $a_1^P, a_2^P, w^P(y|a_1^P, a_2^P)$ : solution of (3)

Question ((IC) for  $a_2$ )

Given  $w^P(y|a_1^P, a_2^P)$ , would the manager choose  $a_2 = a_2^P$  voluntarily if  $a_2$  is NOT enforceable?

In other words, with

$$a_2^A(a_2^P) \in \arg \max_{a_2} \int u(w^P(y|a_1^P, a_2^P)) f(y|a_1^P, a_2) dy \quad (5)$$

Would we have  $a_2^A(a_2^P) = a_2^P$ ?

$\Rightarrow$  Generically  $\underline{a_2^A(a_2^P)} \neq a_2^P$

Then what happens if  $a_2$  is NOT enforceable?: considering (IC) for  $a_2$

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:

$$\begin{aligned}
 \max_{a_1, a_2, w(\cdot)} & \underbrace{\phi(a_1, a_2)}_{\text{Expected output}} - \underbrace{\int w(y)f(y|a_1, a_2)dy}_{\text{Payment to manager}} \\
 & + \underbrace{\lambda}_{\text{Fixed weight}} \underbrace{\left[ \int u(w(y))f(y|a_1, a_2)dy - v(a_1) \right]}_{\text{Manager's utility}} \quad \text{s.t.}
 \end{aligned} \tag{6}$$

$$\begin{aligned}
 (i) \quad & a_1 \in \arg \max_{a'_1} \int u(w(y))f(y|a'_1, a_2)dy - v(a'_1), \quad \forall a'_1 \\
 (ii) \quad & a_2 \in \arg \max_{a'_2} \int u(w(y))f(y|a_1, a'_2)dy - v(a_1), \quad \forall a'_2 \\
 (iii) \quad & w(y) \geq k, \quad \forall y,
 \end{aligned}$$

→ Now (ii) is (IC) for  $a_2$

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

Optimum solution  $(a_1^*, a_2^*, w^*(y))$  of (6) satisfies:

$$\frac{1}{u'(w^*(y))} = \lambda + \underbrace{(\mu_1^* \phi_1^* + \mu_2^* \phi_2^*)}_{>0} \underbrace{\frac{y - \phi^*}{(a_2^*)^2}}_{\text{Output mean}} + \underbrace{\mu_2^*}_{\leq 0} \frac{1}{a_2^*} \left( \underbrace{\frac{(y - \phi^*)^2}{(a_2^*)^2}}_{\text{Output variance}} - 1 \right) \quad (7)$$

when  $w^*(y) \geq k$ , and otherwise  $w^*(y) = k$

- We can prove  $\mu_1^* \phi_1^* + \mu_2^* \phi_2^* > 0$ : incentive in  $a_1$  (mean-shifting)
- $\mu_2^* > 0$  or  $\mu_2^* < 0$ :
  - Depends on the relative indirect risk-preferences of principal and agent

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 (Penalizing or Rewarding Risk through the Contract)

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.,  $\mu_2^* > 0$ .

$a_2^P < a_2^A(a_2^P)$ :

- The manager wants to raise the project risk ( $a_2^A(a_2^P)$ ) from the stipulated level ( $a_2^P$ )
- Thus penalizing the sample output variance: i.e.,  $\mu_2^* < 0$

$a_2^P > a_2^A(a_2^P)$ :

- The manager wants to reduce the project risk ( $a_2^A(a_2^P)$ ) from the stipulated level ( $a_2^P$ )
- Thus rewarding the sample output variance: i.e.,  $\mu_2^* > 0$



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

For the optimal contract  $w^*(y|a_1^*, a_2^*)$ , social welfare is defined similarly:

$$SW^*(a_1^*, a_2^*) \equiv \phi(a_1^*, a_2^*) - \underbrace{C^*(a_1^*, a_2^*)}_{\text{Agency cost}} - \lambda v(a_1^*) \quad (9)$$

where:

$$C^*(a_1^*, a_2^*) \equiv \int \left[ \boxed{w^*(y)} - \boxed{\lambda u(w^*(y))} \right] f(y|a_1^*, a_2^*) dy$$

Payment to the agent      Agent utility to SW

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

Now, the contract  $w(x, \eta)$  CANNOT depend on  $y \equiv x - \underbrace{R}_{\text{Not observed}} \eta$

$g(x, \eta | a_1, a_2, R) \equiv$  conditional distribution of  $(x, \eta)$  given  $(a_1, a_2, R)$

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

$$\begin{aligned} \max_{a_1(\cdot), a_2(\cdot), w(\cdot)} \mathbb{E}_R \left( \int_{x, \eta} (x - w(x, \eta)) g(x, \eta | a_1(R), a_2(R), R) dx d\eta \right) \\ + \lambda \mathbb{E}_R \left( \int_{x, \eta} u(w(x, \eta)) g(x, \eta | a_1(R), a_2(R), R) dx d\eta - v(a_1(R)) \right) \text{ s.t.} \end{aligned}$$

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

$$(ii) \quad a_2(R) \in \arg \max_{a_2} \int_{x, \eta} u(w(x, \eta)) g(x, \eta | a_1(R), a_2, R) dx d\eta, \forall R,$$

$$(iii) \quad w(x, \eta) \geq k, \quad \forall (x, \eta),$$

(10)

$\rightarrow$  (IC) for  $a_1$  and (IC) for  $a_2$  for all different  $R$ s

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

For the optimal contract  $w^N(x, \eta)$ , social welfare is defined similarly:

$$SW^N \equiv \int_R [\phi(a_1^N(R), a_2^N(R)) - \underbrace{C^N(a_1^N(R), a_2^N(R))}_{\text{Agency cost for } \forall R} - \lambda v(a_1^N(R))] h(R) dR \quad (11)$$

where:

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

Payment to the agent      Agent utility to SW

# With Derivative Markets (Free $a_3$ )

Imagine principal designs a contract that is optimal in the absence of derivative market (i.e., (7)), with  $x$  instead of  $y \equiv x - (R - a_3)\eta$

$$\frac{1}{u'(w^*(x))} = \lambda + \underbrace{(\mu_1^* \phi_1^* + \mu_2^* \phi_2^*)}_{>0} \underbrace{\frac{x - \phi^*}{(a_2^*)^2}}_{\text{Output mean}} + \underbrace{\mu_2^*}_{\leq 0} \frac{1}{a_2^*} \left( \underbrace{\frac{(x - \phi^*)^2}{(a_2^*)^2}}_{\text{Output variance}} - 1 \right) \quad (12)$$

**Lemma (HEDGING and SPECULATION depending on the sign of  $\mu_2^*$ )**

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

With  $\mu_2^* < 0$ :

- The manager voluntarily eliminates  $(R - a_3)\eta$  as he dislikes additional risk on output  $x$
- Eliminates the **information asymmetry** about  $R$ : informational gain of financial market innovations
- The social welfare becomes  $SW^*(a_1^*, a_2^*)$

With  $\mu_2^* > 0$ :

- Shareholders must alter the contract to make sure the manager HEDGES (i.e.,  $a_3 = R$ )
- Must change from  $w^*(x)$  to  $w^o(x, \underbrace{\eta}_{\text{Additional risk}})$
- To induce HEDGING, the new contract must depend on  $\eta$ . **How exactly?**

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

$$\begin{aligned}
 \max_{a_1, a_2, w(\cdot)} & \underbrace{\phi(a_1, a_2)}_{\text{Expected output}} - \underbrace{\int w(x, \eta) g(x, \eta | a_1, a_2, a_3 = R) dx d\eta}_{\text{Payment to manager}} \\
 & + \underbrace{\lambda}_{\text{Fixed weight}} \underbrace{\left[ \int u(w(x, \eta)) g(x, \eta | a_1, a_2, a_3 = R) dx d\eta - v(a_1) \right]}_{\text{Manager's utility}} \quad \text{s.t.} \\
 (i) \quad & a_1 \in \arg \max_{a'_1} \int u(w(x, \eta)) g(x, \eta | a'_1, a_2, a_3 = R) dx d\eta - v(a'_1), \quad \forall a'_1 \\
 (ii) \quad & a_2 \in \arg \max_{a'_2} \int u(w(x, \eta)) g(x, \eta | a_1, a'_2, a_3 = R) dx d\eta - v(a_1), \quad \forall a'_2 \\
 (iii) \quad & R \in \arg \max_{a'_3} \int u(w(x, \eta)) g(x, \eta | a_1, a_2, a'_3) dx d\eta - v(a_1), \quad \forall a'_3 \\
 (iv) \quad & w(y) \geq k, \quad \forall y,
 \end{aligned} \tag{13}$$

→ Now we add (iii), (IC) for  $a_3 = R$

### Problem (The First-Order Approach)

Cannot rely on the famous first-order approach for (iii), (IC) for  $a_3 = R$

Mathematical difficulty:

- The indirect value function becomes convex if we use the first-order approach about  $a_3 = R$

### Question (The First-Order Approach)

How can we solve the above optimization problem without relying on 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:

$w^*(x)$  in (12): the optimal contract without (iii), (IC) for  $a_3 = R$

- $w^*(x)$  does not include  $\eta$  as an argument

The manager's indirect utility given  $w^*(x)$ , as a function of  $a_3$ :

- Symmetric around  $a_3 = R$
- Why? As  $\eta \sim N(0, 1)$  is symmetrically distributed around 0
- Remember  $x = \phi(a_1, a_2) + a_2\theta + (R - a_3)\eta$

Thus for  $w^*(x)$ , we have:

$$\int u(w^*(x))g_3(x, \eta|a_1, a_2, a_3 = R)dx d\eta = 0 \quad (14)$$

→ 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  $|R - a_3| = \infty$  (infinite SPECULATION)

### Proposition (The New Optimal Contract)

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,  $\eta$ , i.e., penalizing manager for having high realized  $(x - \phi)^2 \eta^2$

Given  $\eta$ :

- Sample covariance<sup>2</sup> =  $\widehat{Cov}^2 \equiv (x - \phi)^2 \eta^2 \uparrow \rightarrow w^o(x, \eta) \downarrow$

Given  $(x - \phi)^2 \eta^2$ :

- $|\eta| \uparrow \rightarrow w^o(x, \eta) \uparrow$

## Intuition:

$$R - a_3 = \mathbb{E}((x - \phi(a_1, a_2))\eta) = \text{Cov}(x, \eta)$$

To induce  $a_3 = R$  (which leads to  $\text{Cov}(x, \eta) = 0$ ):

Let's punish its SAMPLE version (SAMPLE COVARIANCE) =  $|\widehat{\text{Cov}}|$

With  $a_3 = R$ :

- $x$  is not correlated with  $\eta$
- $w^o(x, \eta) = w^o(x, -\eta)$  to minimize risks imposed on risk-averse agent
- Given realized sample covariance  $|\widehat{\text{Cov}}|$ , the principal becomes more lenient when it is coming from a high  $\eta$  realization, since it's out of control of the manager, which explains

$$|\eta| \uparrow \rightarrow w^o(x, \eta) \uparrow$$

Welfare can go below  $SW^N$  in (11), the one when there is no derivative market

When  $\sigma_R \rightarrow 0$  (Informational asymmetry  $\rightarrow 0$ )

- ① No informational gain but still  $\exists$  incentive problem around  $a_3$
- ② Shareholders are better-off by shutting down any access to derivative markets

## Financial innovation can hurt the efficiency!

The optimal contract  $w^o(x, \eta)$ :

$$\begin{aligned} \frac{1}{u'(w^o(x, \eta))} = & \lambda + (\mu_1^o \phi_1^o + \mu_2^o \phi_2^o) \frac{x - \phi(a_1^o, a_2^o)}{(a_2^o)^2} + \underbrace{\frac{\mu_2^o}{a_2^o}}_{>0} \left( \frac{(x - \phi(a_1^o, a_2^o))^2}{(a_2^o)^2} - 1 \right) \\ & - 2 \sum_{k:\text{even}}^{\infty} \frac{1}{k!} \frac{1}{(a_2^o)^{2k}} \underbrace{\left( \int_{b \geq 0} \mu_4^o(b) b^k \exp \left[ -\frac{b^2 \eta^2}{2(a_2^o)^2} \right] db \right)}_{\substack{\equiv C_{k:\text{even}}(\eta) > 0 \\ \equiv D_{k:\text{even}}(\eta) > 0}} \widehat{\text{Cov}}^k \\ & + \underbrace{\int \mu_4^o(b) db}_{>0} \end{aligned} \quad (15)$$

With sample covariance  $\widehat{\text{Cov}} \equiv (x - \phi(a_1^o, a_2^o))\eta$

- ①  $\mu_4^o(b) \geq 0$ : multiplier function for the following (IC) for  $b = R - a_3$

$$\int u(w(x, \eta)) [g(x, \eta | a_1^o, a_2^o, b = 0) - g(x, \eta | a_1^o, a_2^o, b)] dx d\eta \geq 0 \quad (16)$$

- ②  $\mu_1^o$  and  $\mu_2^o$  are multipliers for (IC) for  $a_1^o$  and  $a_2^o$  respectively

## Question (Communication between shareholders and the manager)

What if manager can report his observation of  $R$  to shareholders?

Truth-telling mechanism is possible in the case where agent voluntarily does not like additional risk (making a side-bet to agent)

With  $\mu_2^* < 0$ :

- Truth-telling contract can substitute the derivative market (for informational gain)

### Example:

- 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

## Big Question

*Then what is the additional benefit financial innovations bring about?*

With  $\mu_2^* > 0$ , again truth-telling contract becomes much more complicated