Interest Rates and Investment Under Competitive Screening and Moral Hazard

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Motivation

- The precise relationship between interest rates and investment is fundamental in financial economics and has intrigued economists at least since Fisher (1930) and Keynes (1936).
- **Neoclassical theory:** Interest rates affect the opportunity cost of capital (e.g., Haavelmo (1960), Jorgenson (1936), etc.)
- **Tobin's q:** Interest rates affect stock prices (Tobin (1969))
- **Bank-Lending and Balance Sheet channels**: Financial frictions exacerbate the effect of interest rate changes on investment (e.g., Bernanke and Blinder (1988), Gertler and Hubbard (1988), Bernanke and Gertler (1989), etc.)
- Main lesson: Investment is inversely related to interest rates

Motivation

- Following the recent financial crisis, Central banks (e.g., the Fed and ECB) responded by decreasing interest rates to unprecedendently low levels (ZIRP)
- Nonetheless, the effect of such low rates on investment and growth has been weaker than expected
- This very fact constitutes a puzzle for academic economists and policy makers alike as described by the Economist:

  "IT'S ONE of the fundamental lessons of any introductory economics course: lower interest rates, when all else remains equal, leads to higher levels of investment. But today, after several years of near-zero interest rates and only modest increases in investment to show for it, some economists are claiming just the opposite...".

Motivation

- I examine the effect of interest rates changes on investment under (banks) competitive screening and (entrepreneurial) moral hazard
- Investment might be hump-shaped
- Competitive screening and moral hazard combined provide fruitful insights

Structure

- Model
- Numerical Example
- Implications

The Model

- Continuum of entrepreneurs
- An entrepreneur is characterised by a type $i \in \{H, L\}$ and a wealth level $W \in [0, +\infty]$ (independent)
- $\lambda_i > 0$ is the probability of i and $F(W)$ the cdf of wealth, with $\int_0^{+\infty} W dF(W) < +\infty$
- Each entrepreneur has a project
- By investing I, an entrepreneur of type-i can realise payoff X_i with probability π_i
- The real net risk-free interest rate (or market rate) is $r \geq 0$

Assumptions

Assumption

(i) $X_H < X_L$,
(ii) $X_H > \max\{\frac{\pi_L X_L}{\pi_H}, \frac{I(1+r)}{\pi_H}\}$, *and,*
(iii) $X_L < \frac{I(1+r)}{\overline{\pi}}$

- $\Delta X = X_L - X_H$
- $\overline{\pi} = \lambda_H \pi_H + \lambda_L \pi_L$

Banks and Loan Contracts

- Wealth is observable
- Free-entry of banks
- Assumptions:
  1. Limited liability
  2. Wealth is non-pledgeable
- Risky debt contract: $\psi = (S, R)$
  - S: the share (i.e., equity) of the entrepreneur in the project
  - $I - S$: the share of the bank in the project
  - R: the share of the projects return (if this succeeds) that is pledged as a repayment for the loan

Timing of Events

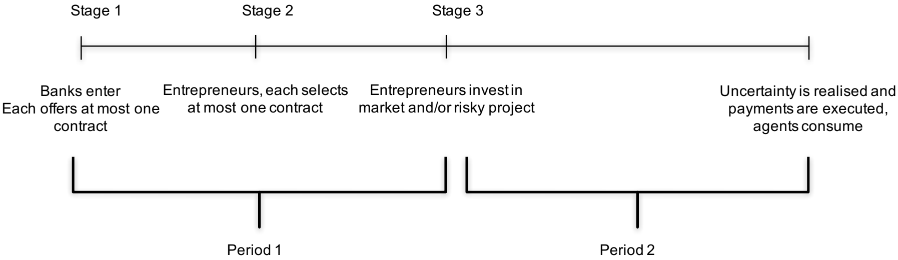


Figure: Timing of events

Definition of Equilibrium

- **Menu of contracts**: A set of contracts for each possible wealth level
- **Optimal allocation**: An allocation of entrepreneurs to either a contract or the market rate

Definition

An equilibrium consists of a menu of contracts and an optimal allocation such that (i) given the optimal allocation, no contract in the menu of contracts makes negative expected profits, and, (ii) there exists no wealth and contract that, given the optimal allocation, if is included in the menu of contracts, it will yield strictly positive profits.

Definition of Equilibrium with Notation

- **Menu of contracts**: $\mu : [0, +\infty] \twoheadrightarrow [0, I] \times [0, X_H]$
- **Optimal allocation**: $\alpha|\mu : [0, +\infty] \times \{L, H\} \times \mathcal{M} \to \mu(W) \cup \{\emptyset\}$

$$\alpha_i(W|\mu) \in \underset{\psi \in \mu(W)}{\arg\max} \{\pi_i(X_i - R) + (W - S)(1 + r) : \pi_i(X_i - R) - S(1 + r) \geq 0\}$$

Definition

An equilibrium consists of a menu of contracts and an optimal allocation $(\hat{\mu}, \hat{\alpha})$ such that (i) given $\hat{\alpha}$, no contract in the menu μ makes negative expected profits, and, (ii) there exists no W and $\tilde{\psi}$ that, given $\hat{\alpha}$, if $\tilde{\psi}$ is included in $\hat{\mu}(W)$, it will make strictly positive profits.

Characterisation of Equilibrium

Proposition

There exists no equilibrium in which type L borrows and invests.

Characterisation of Equilibrium

- There are two possibilities: (i) Separating, or (ii) pooling
- Neither is possible!
- Only possibility: type L invests in the market and type H invests in the risk project by using her wealth as "skin-in-the-game"
- Wealth introduces an implicit cost for type L who holds a negative NPV project
- Implicit cost allows banks to use wealth as a screening device
- The cost is increasing in wealth

Least-Costly Separating Equilibrium

Proposition

A decision for type H with wealth W is an equilibirum decision if and only if it belongs to

$$\underset{\psi \in [0,W]\times[0,X_H]}{\arg\max} \quad \pi_H(X_H - R) + (W - S)(1 + r) \ \ \textit{subject to}$$

$$\pi_H R - (I - S)(1 + r) \geq 0 \tag{2.1}$$

$$\pi_L(X_L - R) - S(1 + r) \leq 0 \tag{2.2}$$

$$\pi_H(X_H - R) - S(1 + r) \geq 0 \tag{2.3}$$

Solving the Linear Program

Proposition

Type H invests if and only if

$$W \geq \overline{W}(r) \equiv \frac{\Delta X}{\left(\frac{1}{\pi_L} - \frac{1}{\pi_H}\right)(1+r)} \tag{2.4}$$

Comparative Statics

$$AI(r) = \lambda_H I[1 - F(\overline{W}(r))] \tag{2.5}$$

- Strictly increasing in r
- Increase in λ_H, π_H or a shift of the wealth cdf in FOSD sense, all shift investment curve to the left
- Increase in ΔX or π_L, all shift investment curve to the right

Project Choice and Moral Hazard

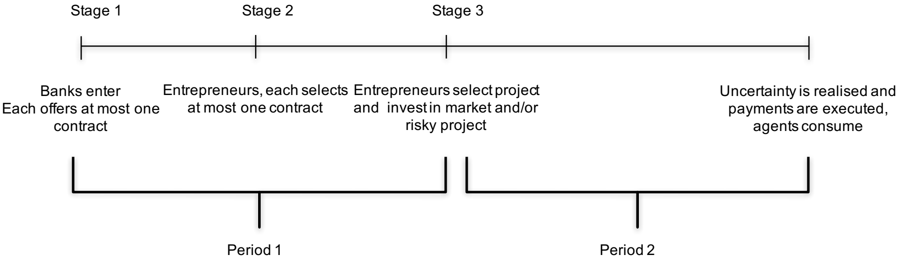
- Type i has two projects $j \in \{a, b\}$ (*advanced* and *baseline*)
- Cost of operation c_i^j, where $c_L^a = c_L^b = c_H^b = 0$ and $c_H^a = c > 0$
- Project j requires I and returns X_i with probability π_i^j, whereas with probability $1 - \pi_i^j$ it returns zero
- Let $\Delta\pi_i = \pi_i^a - \pi_i^b$.

Assumption

Assumption

(i) $\pi_L^b = \pi_L^a = \pi_L$,
(ii) $X_L > X_H$,
(iii) $\pi_L X_L < \pi_H^b X_H < \pi_H^a X_H$,
(iv) $X_H > \max\left\{\frac{I(1+r)}{\pi_H^a} + \frac{c}{\pi_H^a}, \frac{c}{\Delta\pi_H}\right\}$, *and,*
(v) $X_L < \min\{\frac{I(1+r)}{\lambda_L\pi_L+\lambda_H\pi_H^a}, X_H + \left(\frac{\pi_H^a}{\pi_L} - 1\right)\frac{c}{\Delta\pi_H}\}$

Timing of Events



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$$\alpha_i(W|\mu) \in \underset{(\psi,j)\in\{\mu(W)\}\times\{b,a\}}{\arg\max} \{\pi_i^j(X_i - R) + (W - S)(1 + r) - c_i^j : \pi_i^j(X_i - R) - S(1 +$$

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Characterisation of Equilibrium

Proposition

There exists no equilibrium in which type L borrows and invests.

Characterisation of Equilibrium

- Intuition (and proof) similar to the competitive screening case
- Banks need to (i) discourage type-L from borrowing and, (ii) provide incentives to type-H to invest in the advanced project
- Interplay between screening, moral hazard and type-H's participation constraints

Least-Costly Separating Equilibrium (with moral hazard)

Proposition

A decision for type H with wealth W is an equilibirum decision if and only if it belongs to

$$\underset{(\psi,j)\in[0,W]\times[0,X_H]\times\{b,a\}}{\arg\max} \pi_H^j(X_H - R) + (W - S)(1 + r) - c_i^j \quad \textit{subject to}$$

$$\pi_H^j R - (I - S)(1 + r) \geq 0 \tag{3.1}$$

$$\pi_L(X_L - R) - S(1 + r) \leq 0 \tag{3.2}$$

$$\pi_H^j(X_H - R) - S(1 + r) - c_H^j \geq 0 \tag{3.3}$$

Solving the Linear Program I

Proposition (Severe Adverse Selection)

Suppose that $X_L > \frac{I(1+r)}{\pi_L} - \left(\frac{\pi_H^a}{\pi_L} - 1\right)\left(X_H - \frac{c}{\Delta\pi_H}\right)$.

If $X_H \geq \frac{I(1+r)}{\pi_H^b}$, *then in the unique equilibrium type H with wealth:*

(i) $W < W_1(r) \equiv \frac{\Delta X}{(\frac{1}{\pi_L} - \frac{1}{\pi_H^b})(1+r)}$ *invests in the market rate*

(ii) $W_1(r) \leq W \leq W_2(r) \equiv \frac{\Delta X + \frac{c}{\Delta\pi_H}}{\frac{1+r}{\pi_L}}$ *invests in the baseline project*

(iii) $W_2(r) \leq W \leq +\infty$ *invests in the advanced project*

If $X_H < \frac{I(1+r)}{\pi_H^b}$, *then in the unique equilibrium type H with wealth:*

(i) $W < W_2(r)$ *invests in the market rate*

(ii) $W_2(r) \leq W \leq +\infty$ *invests in the advanced project*

Solving the Linear Program II

Proposition (Severe Moral Hazard)

Suppose that $X_L \leq \frac{I(1+r)}{\pi_L} - \left(\frac{\pi_H^a}{\pi_L} - 1\right)\left(X_H - \frac{c}{\Delta\pi_H}\right)$.

If $X_H \geq \frac{I(1+r)}{\pi_H^b}$, *then in the unique equilibrium type H with wealth:*

(i) $W < W_1(r) \equiv \frac{\Delta X}{(\frac{1}{\pi_L} - \frac{1}{\pi_H^b})(1+r)}$ *invests in the market rate*

(ii) $W_1(r) \leq W \leq W_3(r) \equiv I - \frac{\pi_H^a}{1+r}\left(X_H - \frac{c}{\Delta\pi_H}\right)$ *invests in the baseline project*

(iii) $W_3(r) \leq W \leq +\infty$ *invests in the advanced project*

If $X_H < \frac{I(1+r)}{\pi_H^b}$, *then in the unique equilibrium type H with wealth:*

(i) $W < W_3(r)$ *invests in the market rate*

(ii) $W_3(r) \leq W \leq +\infty$ *invests in the advanced project*

Comparative Statics

Let $AI(r)$, $I^b(r)$ and $I^a(r)$ denote respectively the aggregate, baseline and advanced investment correspondences.

Corollary

(i) If $X_L > \frac{I(1+r)}{\pi_L} - \left(\frac{\pi_H^a}{\pi_L} - 1\right)\left(X_H - \frac{c}{\Delta\pi_H}\right)$ *and* $X_H \geq \frac{I(1+r)}{\pi_H^b}$*, then*

$$\frac{\partial AI(r)}{\partial r} > 0$$

$$\frac{\partial I^b(r)}{\partial r} \text{ ambiguous}$$

$$\frac{\partial I^a(r)}{\partial r} > 0$$

Comparative Statics

Corollary

(ii) If $X_L > \frac{I(1+r)}{\pi_L} - \left(\frac{\pi_H^a}{\pi_L} - 1\right)\left(X_H - \frac{c}{\Delta\pi_H}\right)$ *and* $X_H < \frac{I(1+r)}{\pi_H^b}$*, then*

$$\frac{\partial AI(r)}{\partial r} > 0$$

$$\frac{\partial I^b(r)}{\partial r} = 0$$

$$\frac{\partial I^a(r)}{\partial r} > 0$$

Comparative Statics

Corollary

(iii) If $X_L \leq \frac{I(1+r)}{\pi_L} - \left(\frac{\pi_H^a}{\pi_L} - 1\right)\left(X_H - \frac{c}{\Delta\pi_H}\right)$ *and* $X_H \geq \frac{I(1+r)}{\pi_H^b}$, *then*

$$\frac{\partial AI(r)}{\partial r} > 0$$

$$\frac{\partial I^b(r)}{\partial r} > 0$$

$$\frac{\partial I^a(r)}{\partial r} < 0$$

Comparative Statics

Corollary

(iv) If $X_L \leq \frac{I(1+r)}{\pi_L} - \left(\frac{\pi_H^a}{\pi_L} - 1\right)\left(X_H - \frac{c}{\Delta\pi_H}\right)$ *and* $X_H < \frac{I(1+r)}{\pi_H^b}$, *then*

$$\frac{\partial AI(r)}{\partial r} < 0$$

$$\frac{\partial I^b(r)}{\partial r} = 0$$

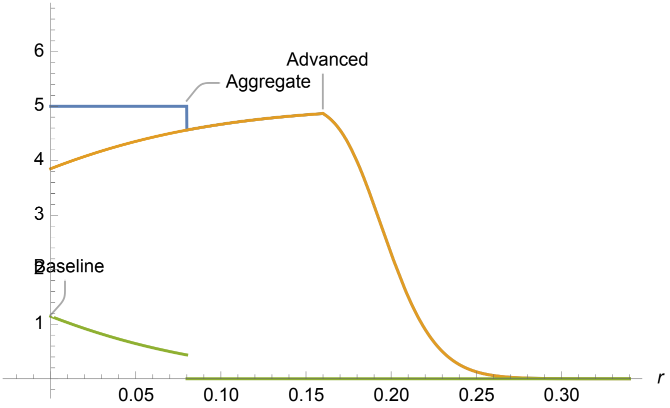
$$\frac{\partial I^a(r)}{\partial r} < 0$$

A Numerical Example

$c = 1$
$I = 10$
$X_H = 18$
$X_L = 19$
$\pi_H^b = 0.6$
$\pi_H^a = 0.8$
$\pi_L = 0.2$
$\lambda_H = 0.5$
$W \sim \text{LN}(0.275, 0.125)$

Table

Investment Curves



Figure

Implication 1

Ultra-low interest rates might have an adverse impact on investment.

- Rajan (2005), Taylor (2007), Borio and Zhu (2012), Summers (2014)
- Prolonged period ofZIRP can lead to market distortions and asset price inflation
- Empirical evidence: during the period that preceded the financial crisis there was indeed a deterioration of lending standards and over-leverage by large financial institutions (Keys et al (2012), Adrian and Shin (2010))
- This argument fails to explain why interest rates have not forced banks to expand credit

Interest Rates

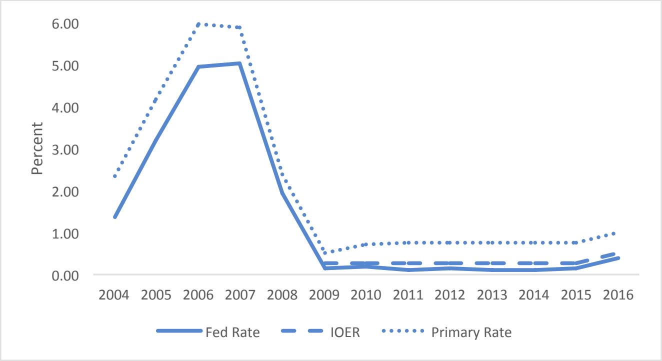


Figure: Interest Rates

Source: Federal Reserve Bank of St. Louis (FRED)

Excess Reserves

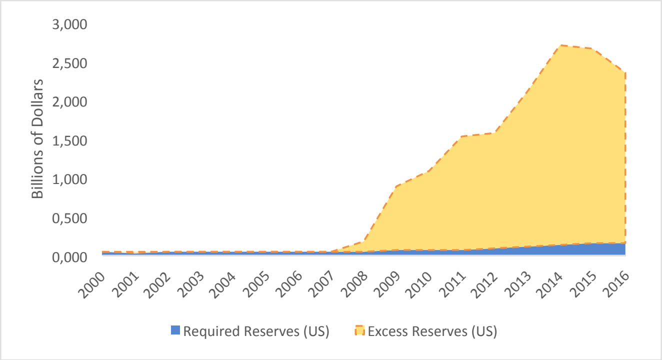


Figure: Interest Rates

Source: Federal Reserve Bank of St. Louis (FRED)

Some Further Evidence

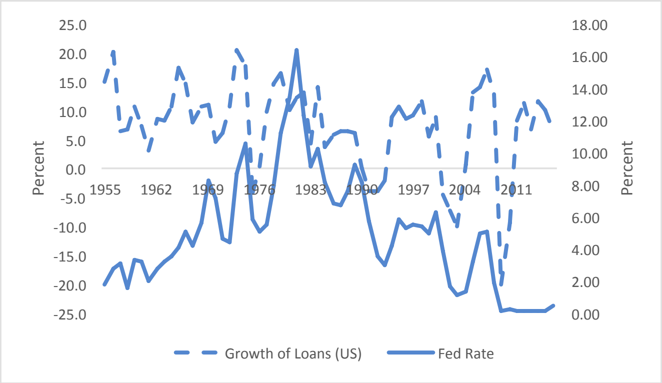


Figure: The Fed Funds rate and the growth of Commercial and Industrial Loans granted by US financial institutions. The left vertical axis depicts the Fed fund rate and the right one the growth of Commercial and Industrial Loans.

Source: Federal Reserve Bank of St. Louis (FRED)

Japanese Interest Rates

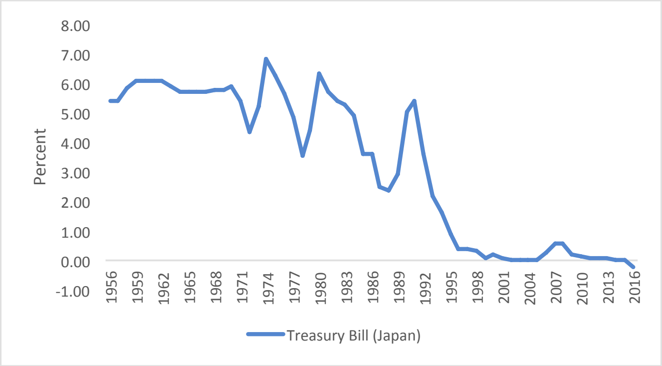


Figure: T-Bill Rate in Japan.

Source: Federal Reserve Bank of St. Louis (FRED)

Japanese Reserve Balances

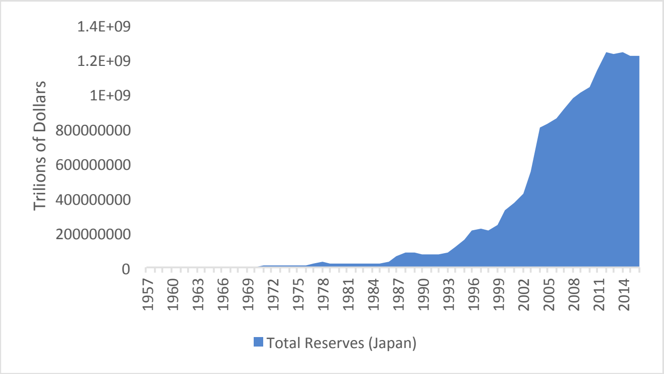


Figure: Reserves Balances in Japan.

Source: Federal Reserve Bank of St. Louis (FRED)

Japanese Credit to GDP ratio

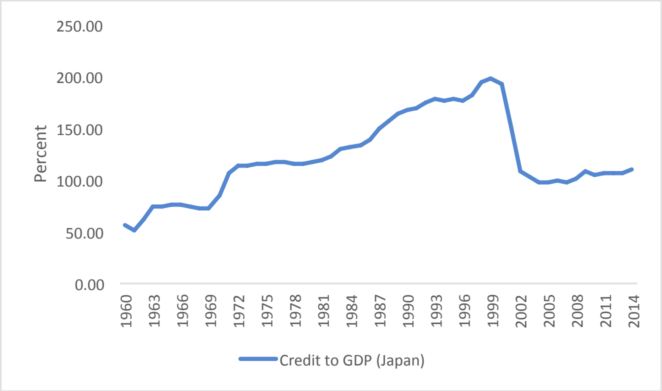


Figure: Credit to GDP ratio in Japan

Source: Federal Reserve Bank of St. Louis (FRED)

Euro Area Crisis

- The ECB considerably decreased its discount window rate (i.e., the marginal lending rate) and expanded monetary policy
- As in Japan and the US, these actions led to an explosion of the monetary base and excess reserves by depository institutions
- To discourage cash hoarding and encourage lending, the ECB, unlike the Fed, adopted another unconventional policy: it now charges a negative interest rate on excess reserves, which basically means that depository institutions are penalised for holding reserves above the regulatory standards.

Implication 2

More investment is not necessarily better.

- The prevalent viewpoint is that financial market friction lead to insufficient investment.(Jaffee and Russell (1976), Stiglitz and Weiss (1981), Myers and Majluf (1984), Holmstrom and Tirole (1987), etc.)
- DeMeza and Webb (1987) challenge that
- Model prediction: Not all entrepreneurs who acqurie funds invest in high-quality projects

Implication 3

Lower interest rates might result to riskier pool of funded projects.

- "Too-lax-for-too-long" monetary policy contributed to the financial crisis (Taylor (2007), Greenspan (2009), Bernanke (2010), etc.)
- Empirical evidence: Jimenez et al (2014), Dell'Ariccia etal (2017)
- Model prediction: interest rates may indeed affect the composition of investment by inducing more lending to baseline projects

Implication 4

Among firms with similar observable characteristics, the (loan) repayment to debt ratio is increasing in firm's indebtedness.

- *Limit pricing* leaves rents to banks which are decreasing in entrepreneurial wealth
- This might create an inverse relationship between the ratio of the repayment rate and indebtedness

Implication 5

When interest rates are low, among firms with similar observable characteristics, the share of defaulting firms is increasing in firm's indebtedness.

- Screening hinders the ability of banks to provide incentives to entrepreneurs to undertake superior projects
- More indebted firms have higher probability of default

Related Literature

- **Credit Markets with Adverse Selection:** Stiglitz and Weiss (1981), DeMeza and Webb (1987), etc.
- **Collateral:** Bester (1985,1987), Kiyotaki and Moore (1997), etc.
- **Net Worth:** Bernanke and Gertler (1989), Holmstrom and Tirole (1997), etc.
- **Skin in the Game:** Leland and Pyle (1977), De Marzo and Duffie (1999), Bias and Mariotti (2005), Chemla and Hennessy (2014), Vanasco (2016), etc.
- **Interest rates and risk-taking:** Rajan (2005), Taylor (2007), Borio and Zhu (2012), Summers (2014), Bolton et al (2016), Martinez Repullo (2017), etc.
- **Most closely related:** Dell'Ariccia and Marquez (2006) and Nenov (2016)

Conclusion

- Low interest rates may have an adverse impact on investment because they hinder competitive screening
- Low interest rates hinder the adoption of superior projects (exacerbate mora hazard)
- This might be more severe in the aftermath of crises