Peer Effect and the Structure of Teams

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Introduction

- To team or not to team?

  Benefit positive peer effect: peer pressure & knowledge spillover

  Cost free-riding/moral hazard

- If team, how?

Introduction: Empirics

- Small peer effect due to knowledge transfer; large peer effect due to **social pressure**.
  - Cornelissen, Dustmann, and Schönberg (2017)
- (Positive) peer effect is larger and more significant in teams composed of members with **more heterogenous productivities** (holding the average constant).
  - Hamilton, Nickerson and Owan (2003), Chan, Li and Pierce (2014)
- Social pressure works through **peer monitoring**.
  - Knez and Simester (2001), Mas and Moretti (2009)

Introduction: Model Ingredients

- A principal has hired a number of agents with **different (known) productivities**.
- The principal decides the assignment of agents into teams (of two), or independent production.
- Within a team, members can **monitor** each other and **impose sanction if shirking is detected**.
  - Che and Yoo (2001)

Introduction: Tradeoffs

- Peer monitoring mechanism is more effective with **negative assortative matching**.
- Free-riding incentives are lower with **positive assortative matching.**
  - Kaya and Vereshchagina (2014)
- Implications:

1. Ability heterogeneity and teamwork are complementary through peer monitoring.
2. Factors that makes peer monitoring effective (e.g., high discount factor) favor negative matching.

Roadmap

- Baseline model
    - illustrates peer monitoring mechanism is more effective with worker heterogeneity
- Endogenous job design
    - individual vs team production as a tradeoff between eliminating free-riding and utilizing peer monitoring

Baseline Model: Production

- One principal and n agents in a firm; all risk-neutral.
- Time is discrete and infinite. Common discount factor is $\delta \in (0, 1)$.
- In each period, agent i can work on a task, which has an outcome $y_i \in \{0, 1\}$ (received by the principal).
- Effort choice is binary $e_i \in \{0, 1\}$ with cost ce_i.
- Ability of agent i is $\lambda_i \in [\underline{\lambda}, \overline{\lambda}]$.
- Probability of task success:

$$\Pr(y_i = 1) = r + \lambda_i e_i.$$

  - Effort and ability are complementary.
  - Production is serially independent.

Baseline Model: Team

- The principal can put two agents in a team.
- Members can **perfectly observe** each others' effort at the end of each period.
  - But they cannot communicate these observations to the principal.
  - And they cannot make side-payments between themselves.
  - Che and Yoo (2001)

Baseline Model: Contract Space and Principal's Problem

- Principal can commit to a stationary long-term contract.
- The contract stipulates agent i's wage $w^i_{y_i,y_j}$, if the team outcome profile is (y_i, y_j).
- Agents are protected from limited liability: $w^i_{y_i,y_j} \geq 0$.
- Principal would like all the agents to work: c is small relative to r and $\underline{\lambda}$.
- Principal's problem is designing **agent assortment into teams**, as well as the **contract** offered to each agent with the objective of **minimizing the total agency cost**.

Solving the Baseline Model

- Step 1: fixing (λ_i, λ_j), compute the optimal contract
- Step 2: identify matching pattern that minimizes overall agency cost

Solving the Baseline Model: Step 1

- In a static game, motivating agent i to work requires a "bonus" w such that $(r+\lambda_i)\,w - c \geq rw$.
  - Implied agency cost is $(r+\lambda_i)\underbrace{\frac{c}{\lambda_i}}_{w}$.
- Mutual monitoring can be exploited to lower agency cost.
  - Wages can be positively linked (JPE) such that agents in a team play a **prisoners' dilemma** in each period.
  - Grim-trigger strategy: exert effort iff no one shirks in the past.
  - $w_{11}^i > 0 = w_{10}^i = w_{01}^i = w_{00}^i$.

Solving the Baseline Model: Step 1

- IC for agent i's effort (in the normal phase)

$$\begin{aligned} & (r+\lambda_i)(r+\lambda_j)\, w_{11}^i - c \geq (1-\delta)\, r\,(r+\lambda_j)\, w_{11}^i + \delta r^2 w_{11}^i \\ \Leftrightarrow \quad & w_{11}^i \geq \frac{c}{(r+\lambda_j)\,\lambda_i + \delta r \lambda_j}. \end{aligned}$$

- IC for agent i's shirking (in the punishment phase)

$$(r+\lambda_i)\, r w_{11}^i - c < r^2 w_{11}^i \Leftrightarrow w_{11}^i < \frac{c}{r\lambda_i}.$$

Summary Given ability profile (λ_i, λ_j) of a team, the optimal contract is $w_{11}^i = \frac{c}{(r+\lambda_j)\lambda_i+\delta r\lambda_j}$ and $w_{11}^j = \frac{c}{(r+\lambda_i)\lambda_j+\delta r\lambda_i}$.

Solving the Baseline Model: Step 2

- Agency cost of a team with ability profile (λ_i, λ_j) is

$$\begin{aligned} & W(\lambda_i, \lambda_j) \\ \equiv \; & (r+\lambda_i)(r+\lambda_j)\left[\frac{c}{(r+\lambda_j)\lambda_i + \delta r \lambda_j} + \frac{c}{(r+\lambda_i)\lambda_j + \delta r \lambda_i}\right]. \end{aligned}$$

Proposition

(i) Team agency cost is decreasing in either agent's ability.
(ii) Saving in team agency cost due to an increase in an agent's ability is greater if the partner has a lower ability, i.e., $-\frac{\partial W(\lambda_i, \lambda_j')}{\partial \lambda_i}$ *is greater than* $-\frac{\partial W(\lambda_i, \lambda_j)}{\partial \lambda_i}$ *if* $\lambda_j' < \lambda_j$*. Consequently, negative assortative matching is optimal in team formation.*

Intuition

- Effectiveness of peer monitoring mechanism depends on the magnitude of punishment for shirking, which in turn depends on
  1. the magnitude of the team bonus;
  2. the reduction in the probability of getting the team bonus.
- Increase in λ_i lowers w^i_{11}; and strengthens the peer-monitoring mechanism by increasing item 2, which lowers w^j_{11}.
- This effect is particularly strong if λ_j is small, as w^j_{11} (item 1) is large to begin with.

Remark: JPE does not imply NAM

- Adopting a JPE scheme without the peer monitoring mechanism, team agency cost is independent of matching pattern.
- Static optimal wages without peer-monitoring:

$$w_{11}^{i} = \frac{c}{\lambda_i \left(r + \lambda_j\right)} \text{ and } w_{11}^{j} = \frac{c}{\lambda_j \left(r + \lambda_i\right)}.$$

- Implied agency cost is identical that of independent evaluations:

$$\begin{aligned} & \left(r + \lambda_i\right)\left(r + \lambda_j\right)\left(w_{11}^{i} + w_{11}^{j}\right) \\ = \; & \left(r + \lambda_i\right)\frac{c}{\lambda_i} + \left(r + \lambda_j\right)\frac{c}{\lambda_j}. \end{aligned}$$

Implications

- Fixing team agency cost, the team's output weakly improves if
  - members' abilities increase, or
  - members' abilities become more heterogeneous, holding the average ability constant.
- Mas and Moretti (2009): supermarket cashiers work harder if he/she is in the line of vision of high-ability coworkers
  - "*the optimal mix of workers in a given shift is the one that maximizes skill diversity*"
- Chan, Li and Pierce (2014): worker heterogeneity and team performance are positively related at cosmetics counters that offer team-based sales commission.

Endogenous Job Design

- Principal has available a pool of agents with potentially different abilities.
- Principal can choose between two job designs:

1. Individual production: $\Pr(y_i = 1 | e_i, \lambda_i) = r + \lambda_i e_i$.
   - Effort is unobservable to anyone.
2. Team production: $\Pr(y_{ij} = 1 | e_i, e_j, \lambda_i, \lambda_j) = 2r + \lambda_i e_i + \lambda_j e_j$.
   - Members perfectly observe each others' effort at the end of a period.

- Individual effort cost ce_i is common for both designs.
- Absent moral hazard problem, the two designs are equally efficient.
  - No team synergy in the language of Che and Yoo (2001)
- Assume effort is always induced in the optimal arrangement.

Free-riding in Teams

- Consider a static setting.
- Whether agent i is assigned to individual or team production, a wage $w_1^i = \frac{c}{\lambda_i}$ is needed to induce his effort.
- Cost of free-riding:

$$
\begin{aligned}
f(\lambda_i, \lambda_j) &\equiv \underbrace{(2r + \lambda_i + \lambda_j) \times \frac{c}{\lambda_i}}_{\text{agency cost in a team}} - \underbrace{(r + \lambda_i) \times \frac{c}{\lambda_i}}_{\text{agency cost in individual production}} \\
&= (r + \lambda_j) \frac{c}{\lambda_i}.
\end{aligned}
$$

  - As $\frac{\partial^2}{\partial \lambda_i \partial \lambda_j} f(\lambda_i, \lambda_j) < 0$, positive sorting mitigates the free-riding cost (Kaya and Vereshchagina, 2014).
- In a static setting, individual production dominates team production.
  - Intuition: individual production has a higher likelihood ratio $\frac{\Pr(y_i=1|e_i=1)}{\Pr(y_i=1|e_i=0)}$.

Peer Monitoring in Teams

- Return to dynamic setting and consider a team with ability profile (λ_i, λ_j).
- Following similar derivations, IC for effort exertion:

$$\begin{aligned} & \left(2r + \lambda_i e_i + \lambda_j e_j\right) w_1^i - c \geq (1-\delta)\left(2r + \lambda_j\right) w_1^i + \delta\,(2r)\, w_1^i \\ \Leftrightarrow \quad & w_1^i \geq \frac{c}{\lambda_i + \delta \lambda_j}. \end{aligned}$$

- By setting $\left(w_1^i, w_1^j\right) = \left(\frac{c}{\lambda_i + \delta\lambda_j}, \frac{c}{\lambda_j + \delta\lambda_i}\right)$, team agency cost is

$$W_T\left(\lambda_i, \lambda_j\right) = \left(2r + \lambda_i + \lambda_j\right)\left(\frac{c}{\lambda_i + \delta\lambda_j} + \frac{c}{\lambda_j + \delta\lambda_i}\right).$$

- If δ is sufficiently large, $\frac{\partial^2}{\partial\lambda_i \partial\lambda_j} W_T\left(\lambda_i, \lambda_j\right) > 0$, so negative sorting is optimal.

Optimal Assortment into Teams

Proposition

(i) Negative sorting of agents into teams minimizes total agency cost if δ is sufficiently large.
(ii) Positive sorting of agents into teams minimizes total agency cost if δ is sufficiently small.

Corollary

Introducing agent heterogeneity and teamwork are complementary, provided that peer monitoring-and-sanction is effective.

- Hamilton, Nickerson and Owan (2003): Heterogeneity in teams help.
  - Mutual monitoring and social pressure is effective
- Meidinger, Rulliere and Villeval (2003): Heterogeneity in teams hurt.
  - No peer monitoring and sanction found.

Optimal Workplace Design: Two Agents

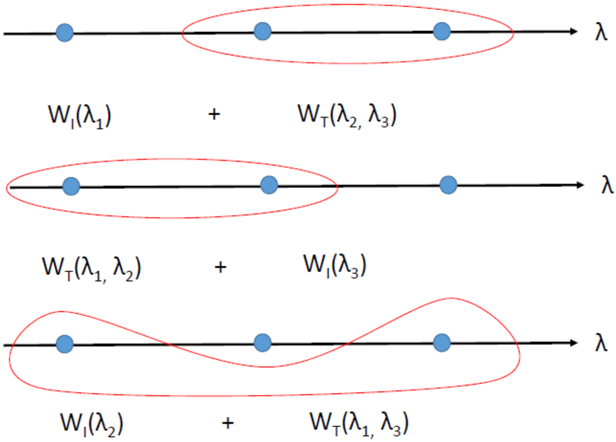
- Given a pair of agents, team is adopted if and only if

$$W_T\left(\lambda_i, \lambda_j\right) \leq W_I\left(\lambda_i\right) + W_I\left(\lambda_j\right).$$

- As $W_T\left(\lambda_i, \lambda_i\right) > 2W_I\left(\lambda_i\right)$, individual production should be adopted if agent abilities are homogeneous.
  - Che and Yoo (2001): team synergy is a necessary condition for team production (even taking peer monitoring and sanction into account).
- If λ_i and λ_j are sufficiently different, team production can be less costly.

Optimal Workplace Design: 3 Agents

- Given 3 agents, how should production be arranged?

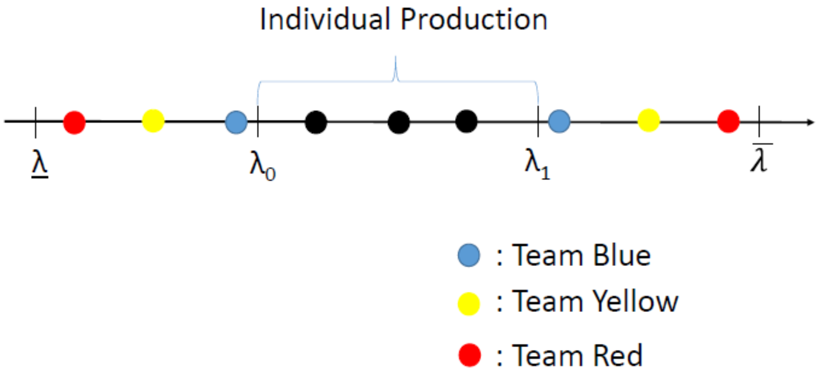


Optimal Workplace Design: Many Agents

Proposition

Suppose δ is sufficiently large. Then in the optimal job design and assignment, there is a pair of cutoffs λ_0 and λ_1 with $\underline{\lambda} \leq \lambda_0 \leq \lambda_1 \leq \bar{\lambda}$ such that
(i) agents with abilities in the interval $[\lambda_0, \lambda_1]$ are assigned to work independently, whereas
(ii) each agent with ability in the interval $[\underline{\lambda}, \lambda_0)$ is assigned into a team with another agent with ability in the interval $(\lambda_1, \bar{\lambda}]$.
Moreover, teams are formed in a negative-assortative manner.

Optimal Workplace Design: Many Agents



Optimal Workplace Design: Many Agents

- Algorithm

1. Match agents into pairs in a negative assortative manner
2. Compare $W_T(\lambda_i, \lambda_j)$ and $W_I(\lambda_i) + W_I(\lambda_j)$; pick the cheaper one.

- Simultaneous adoption of both individual-based and team-based production has been documented.
  - Hamilton, Nickerson and Owan (2003), Knez and Simester (2001), Chan, Li and Pierce (2014).

Robustness

- Sequential tasks
- Substitutable effort and ability
- Common shock

Summary

- Agent heterogeneity in a team makes the peer-monitoring mechanism more effective.
- Agent heterogeneity improves team performance if and only if peer monitoring and sanction is in place.
- Optimal workplace design involves
  - matching agents with very high and very low abilities into teams, while
  - leaving agents with intermediate abilities to work independently.