

공급사슬의 거래관계 구조에 따른 성과에 대한 연구 (work in progress)

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개요

1. **Research Objective**
:effect of supply chain network structure on performance?
2. **Framework**
:research models
3. **Network Level: Structure and Performance**
:structural feature of network (information entropy)
4. **Node Level: Structure and Behavioral Bias**
:structural feature of node (bargaining power)
5. **Summary and Implication**
6. **Limitation and Future Work**

1. Research Objective

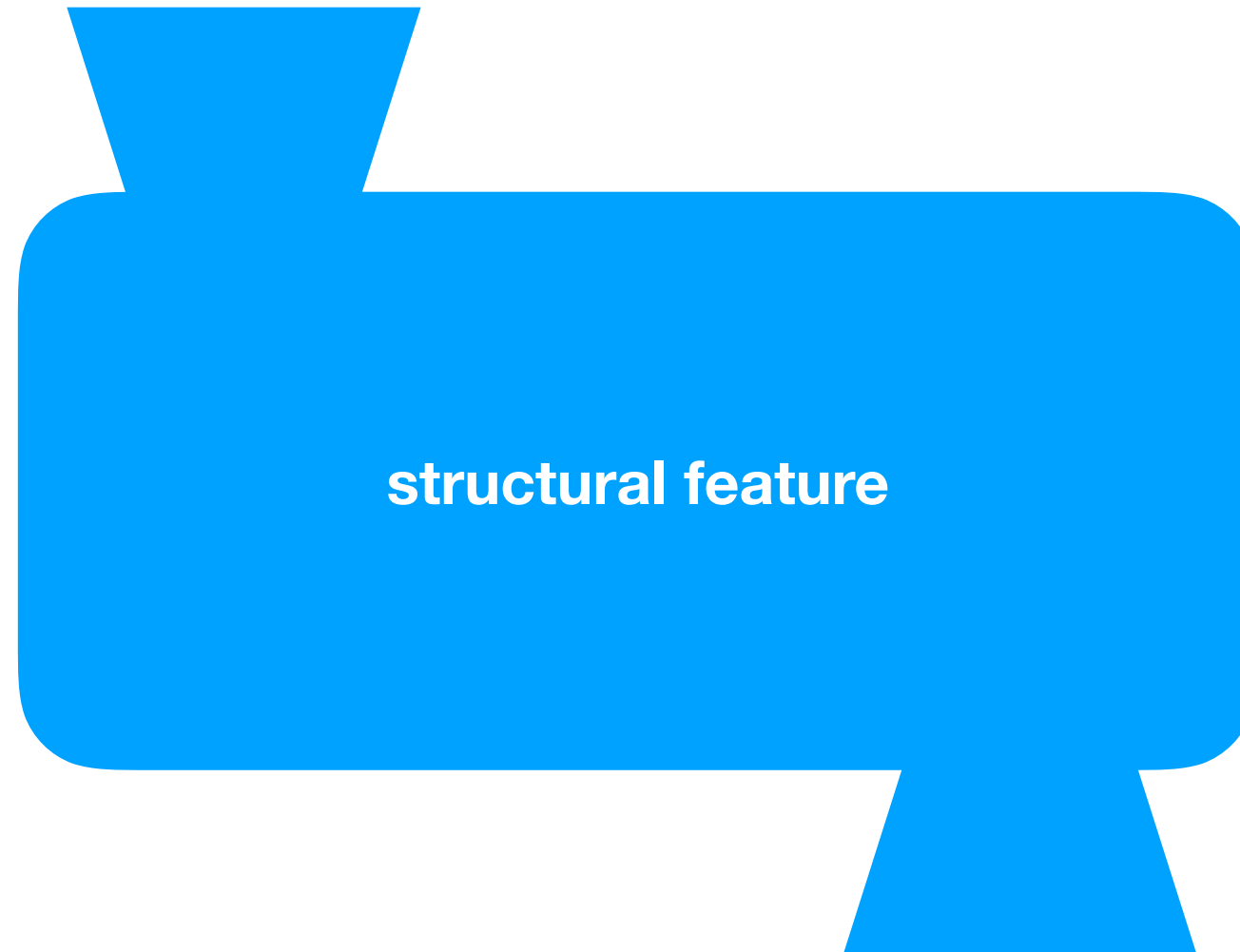
supply chain network



supply chain performance

1. Research Objective

supply chain network



supply chain performance

1. Research Objective

- While each decision-maker in supply chain network seek to maximize its own profit

- **How structure affects performance?**

1. Structural difference between networks on performance (network level)

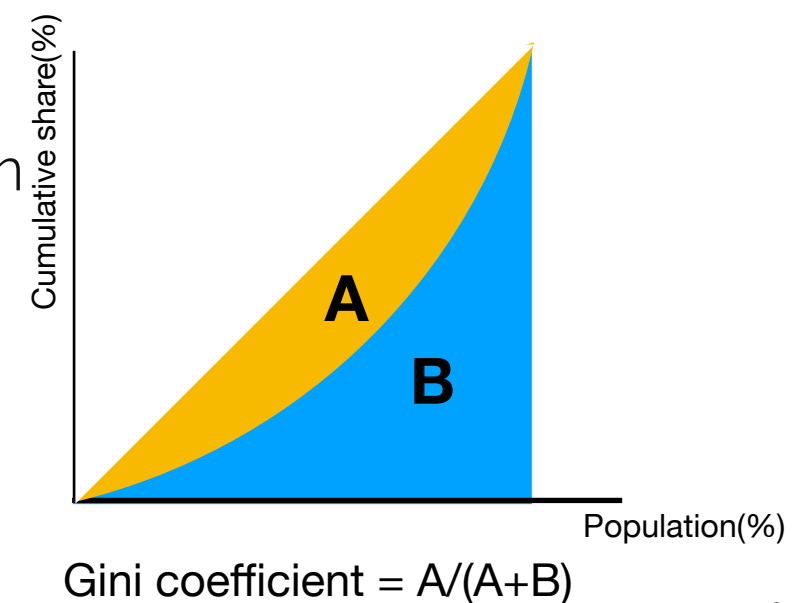
- What is structure of network?
- How do you quantify the structure?
- What is performance?
- How do you measure the performance?

2. Structural difference between nodes on performance (node level)

- Behavioral bias based on structural feature

2. Framework: operationalization of concept

- **Supply chain performance: How evenly total profit is distributed ?**
 - Amount of global profit & Distribution within network
- Importance on sustainability and fairness of supply chain network has increased in SCM(Searcy; 2011, Varsei et al; 2014, Schaltegger and Burritt; 2014, Ho et al.; 2014)
- Sustainability is considered as a measure of supply chain performance(Hutchins and Sutherland; 2008)
- Gini index can be used to measure social fairness(Vachon and Mao;2008, Mihai; 2014)
- Use Gini index as measure for the degree of even distribution

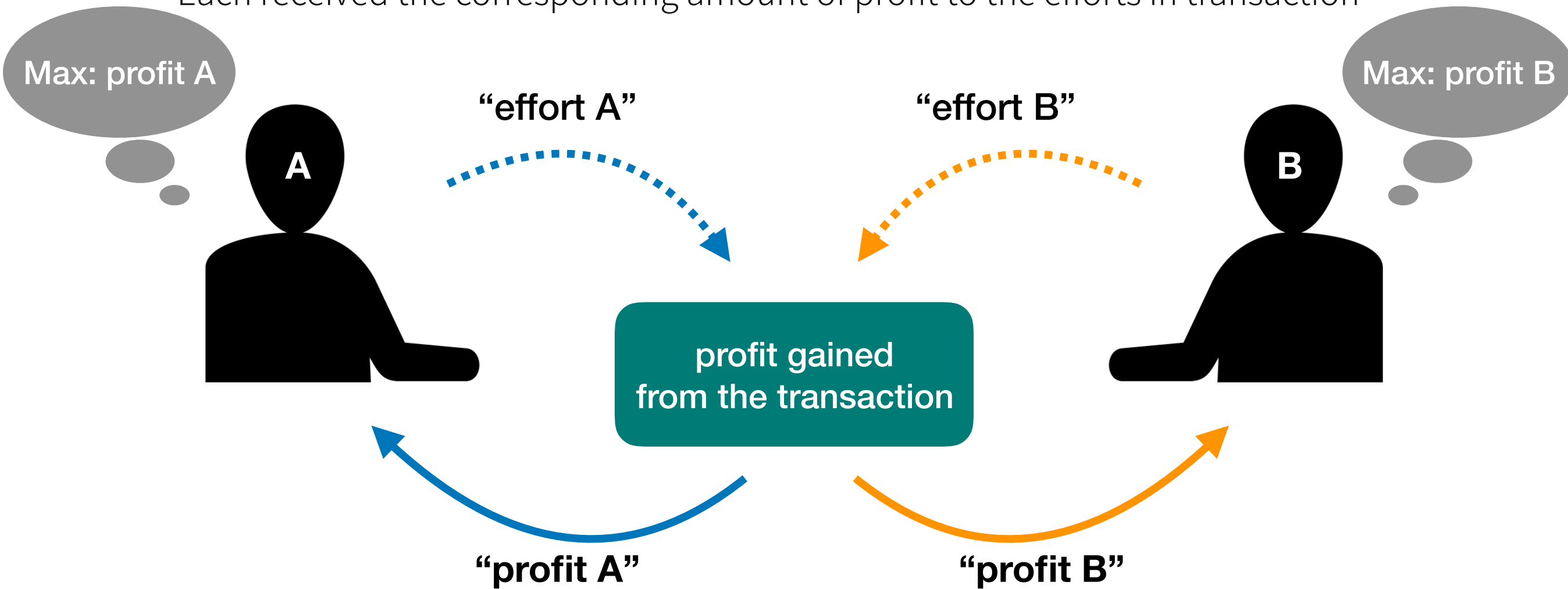


2. Framework: operationalization of concept

- **Supply chain structure: How individual nodes are connected in the network?**
- Position in a supply chain network can affect bargaining power and profitability (Cook and Emerson, 1978; Borgatti and Li, 2009)
- Relation to supply chain performance, many focused on specific individual network
- Information structure can measure network complexity (Siclen; 1997, Isik; 2009, Cheng et al.; 2014)
- Use information entropy as index to measure how evenly connections are distributed

2.1. Framework: decision-making process

- Indirected (not labeled as seller/buyer)
- Each decides effort level to maximize one's own profit
- Each received the corresponding amount of profit to the efforts in transaction

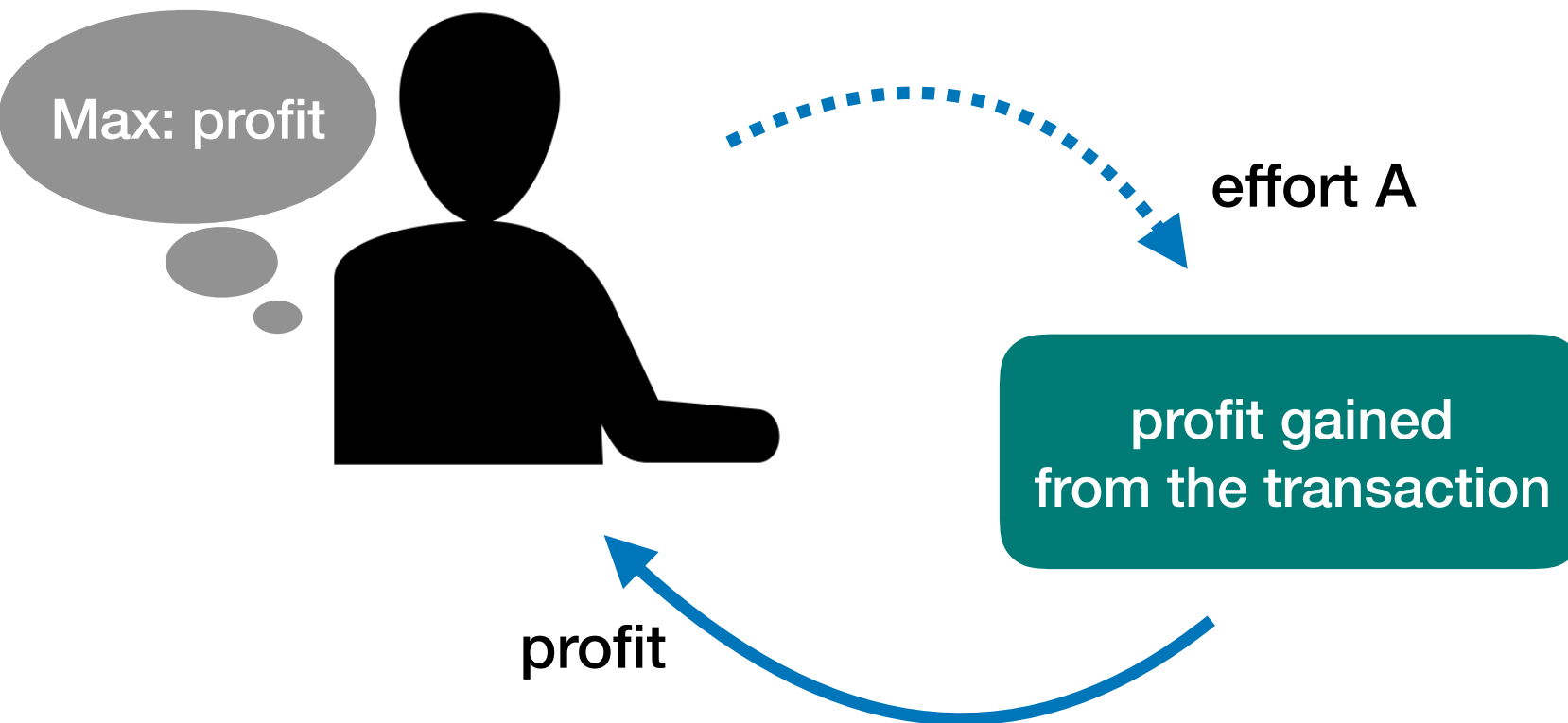


2.1. Framework: decision-making process

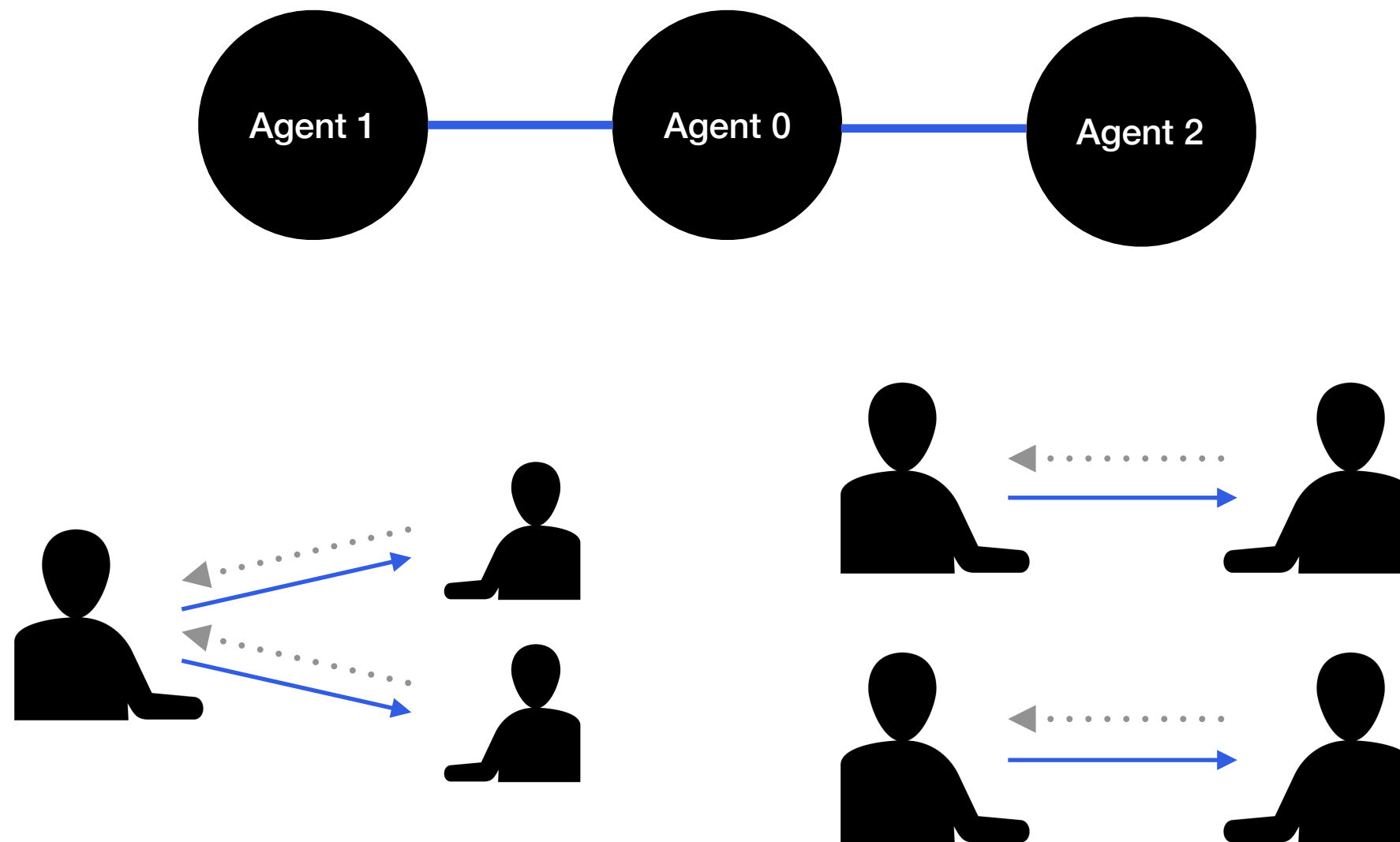
- For more efficient profit:

- Less effort input
- More synergy effect
- Bigger demand

$$\left. \begin{array}{l} \text{Less effort input} \\ \text{More synergy effect} \\ \text{Bigger demand} \end{array} \right\} \Rightarrow \Pi_i(e_{ij}; e_{ji}) = \left(1 - e_{ij} + \frac{e_{ij} \cdot e_{ji}}{4} \right) (e_{ij} + e_{ji})$$



2.2. Framework: supply chain network model-serial 3-agent case



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- When an agent has one transactional partner:

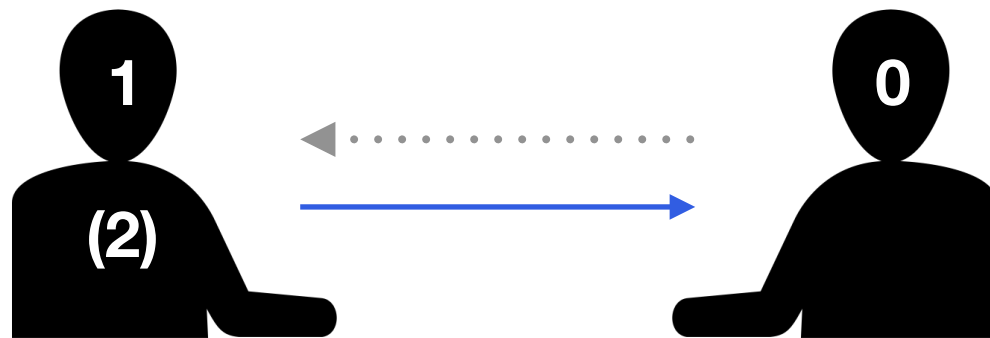
$$\Pi_i(e_{ij}; e_{ji}) = \left(1 - e_{ij} + \frac{e_{ij} \cdot e_{ji}}{4} \right) (e_{ij} + e_{ji})$$

- When an agent has two transactional partners:

$$\begin{aligned} & \Pi_i(e_{i,n_1}, e_{i,n_2}; e_{n_1,i}, e_{n_2,i}) \\ &= \frac{1}{2} \left(2 - \sum_{j=1}^2 e_{ij} + \frac{1}{4} \sum_{j=1}^2 e_{ij} e_{ji} \right) \left(\sum_{j=1}^2 e_{ij} + \sum_{j=1}^2 e_{ji} \right) \end{aligned}$$

2.2. Framework: supply chain network model-serial 3-agent case

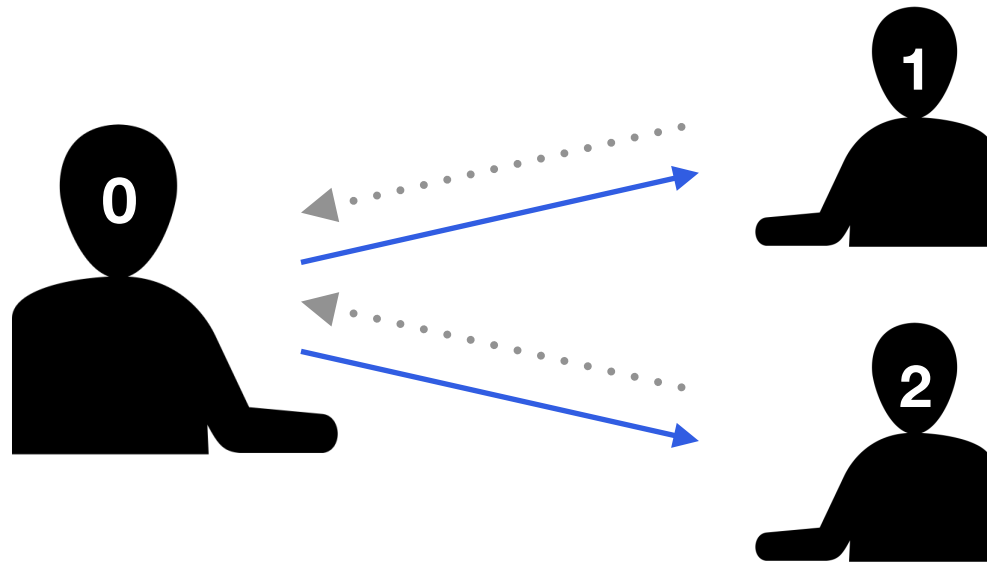
- Agent 1 (Agent 2)



$$e_{10}^*(e_{01}) = \frac{2 - e_{01}}{2} + \frac{2}{4 - e_{01}} - 1$$
$$e_{20}^*(e_{02}) = \frac{2 - e_{02}}{2} + \frac{2}{4 - e_{02}} - 1$$

2.2. Framework: supply chain network model-serial 3-agent case

- Agent 0



given $e_{10} = e_{20} = s$,

$$\forall (e_{01}^*(e_{10}, e_{20}), e_{02}^*(e_{10}, e_{20})), (e_{01} + e_{02}) = -\frac{(s-2)^2}{s-4}$$

given $e_{10} > e_{20}$,

$$e_{01}^* = \frac{8 - (4 - e_{10})(e_{10} + e_{20})}{8 - 2e_{10}}, e_{02}^* = 0$$

2.2. Framework: supply chain network model-serial 3-agent case

- Under stable status, result values are the recurrence of 4 points.
- → each effort level (decision variable) and profit gained (dependent variable) can be found

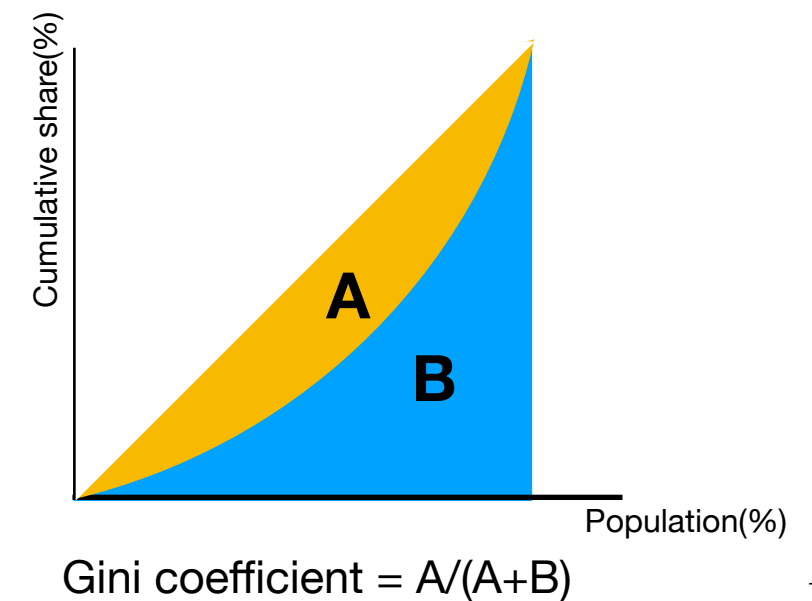
| | Π_0 | Π_1 | Π_2 | Π_s |
|---|---------|---------|---------|---------|
| $\left(\frac{25}{28} - \frac{s}{2}, 0, \frac{1}{2}, s\right)$ | 0.9961 | 0.7624 | 0.1782 | 1.9367 |
| $\left(\frac{25}{28} - \frac{s}{2}, 0, s, \frac{1}{2}\right)$ | 0.9568 | 0.8202 | 0.2500 | 2.0271 |
| $\left(0, \frac{25}{28} - \frac{s}{2}, s, \frac{1}{2}\right)$ | 0.9961 | 0.1782 | 0.7624 | 1.9367 |
| $\left(0, \frac{25}{28} - \frac{s}{2}, \frac{1}{2}, s\right)$ | 0.9568 | 0.2500 | 0.8202 | 2.0271 |
| average | 0.9765 | 0.5027 | 0.5027 | 1.9819 |

* where $s=0.232$

Network Level Structure and Performance

3. Network structure and Performance

- Supply chain performance
 - Global profit
 - Distribution
- Importance on sustainability and fairness of supply chain network has increased in SCM(Searcy; 2011, Varsei et al; 2014, Schaltegger and Burritt; 2014, Ho et al.; 2014)
- Sustainability is considered as a measure of supply chain performance(Hutchins and Sutherland; 2008)
- Gini index can be used to measure social fairness(Vachon and Mao;2008, Mihai; 2014)



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3. Network structure and Performance

- Position in a supply chain network can affect bargaining power and profitability (Cook and Emerson, 1978; Borgatti and Li, 2009)
- Relation to supply chain performance, many focused on specific focal networks
- Information structure can measure network complexity (Siclen; 1997, Isik; 2009, Cheng et al.; 2014) usually to measure the flow of information
- Adapting information entropy as index to measure how much connections are every distributed can be considered

3.1. Network Level: Network Structure and Performance -numerical analysis

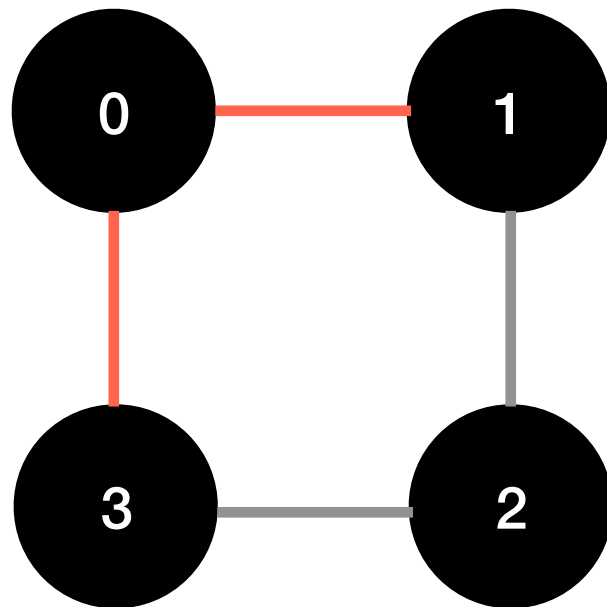
- Proportion of connection per node?

$$p_i = \frac{\sum_{j=1}^k e_{ij}}{\sum_{i=1}^k \sum_{j=1}^k e_{ij}}$$

- How much widely dispersed throughout the network?

$$H(X) = - \sum_{i=1}^k p_i \cdot \log_2(p_i)$$

- e.g.)

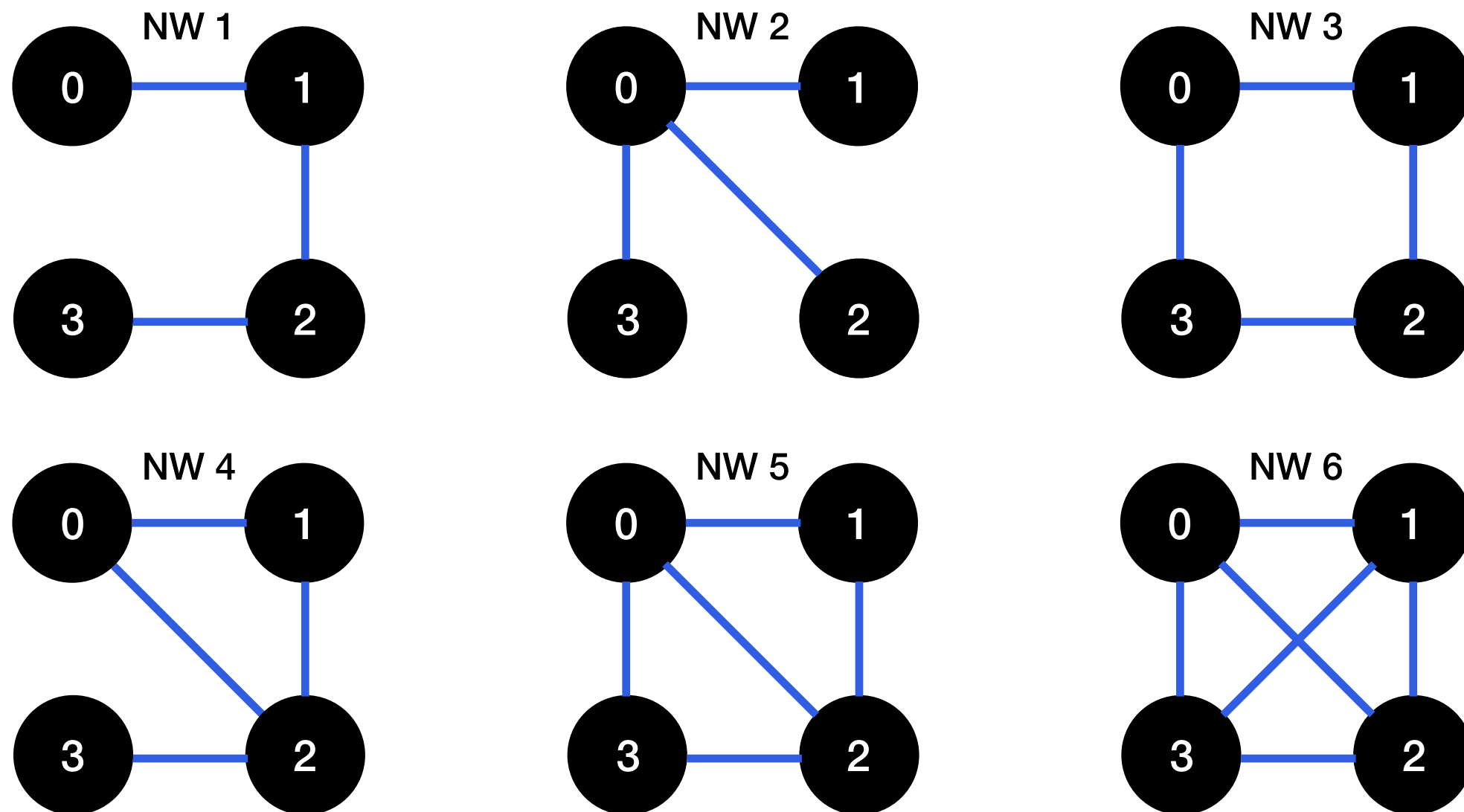


$$\begin{aligned} p_i &= \frac{2}{2 + 2 + 2 + 2} \\ &= \frac{1}{4} \\ H(X) &= - \frac{1}{4} \cdot \log_2\left(\frac{1}{4}\right) \cdot 4 \\ &= - \log_2\left(\frac{1}{4}\right) \\ &= 2 \end{aligned}$$

3.1. Network Level: Network Structure and Performance

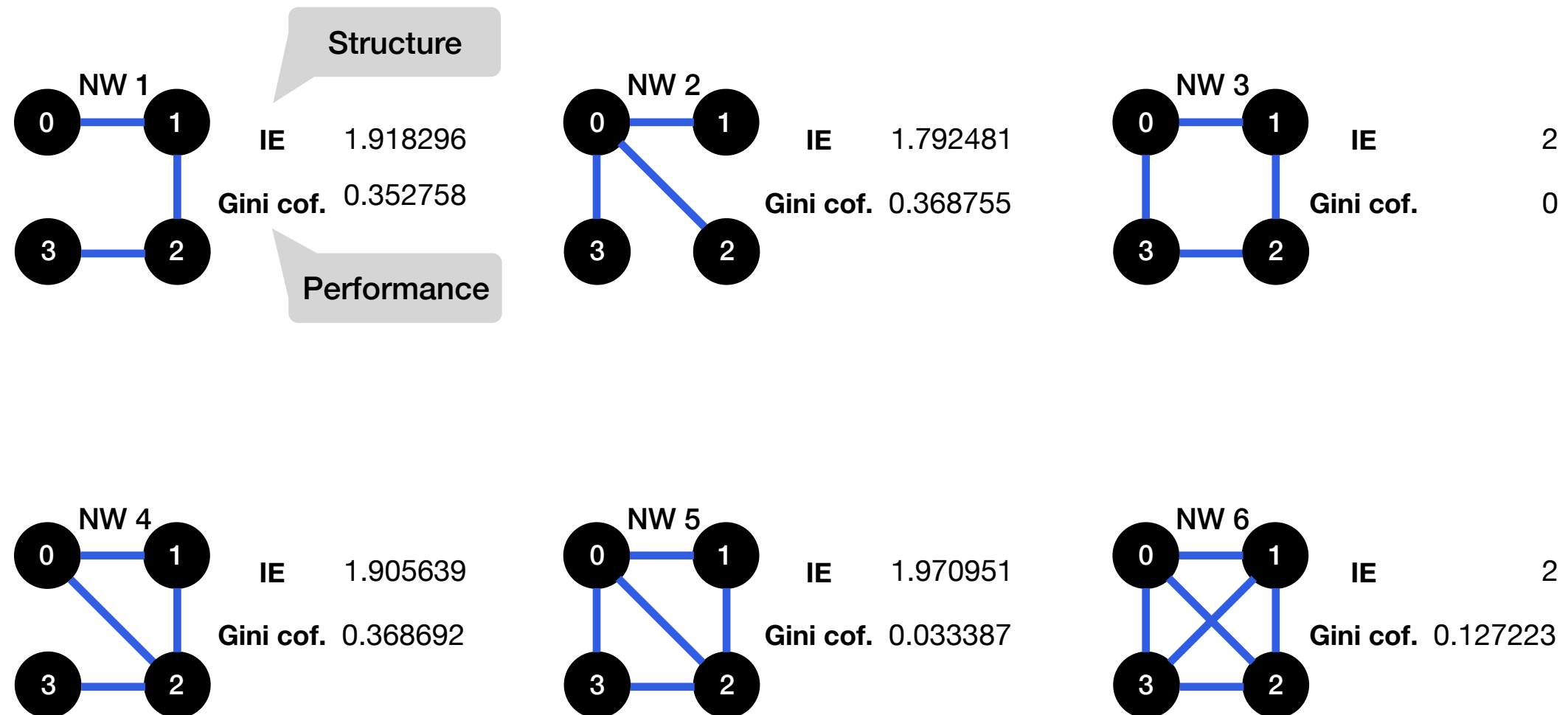
-numerical analysis

- Analyzed networks consist of 4 decision makers
- All possible structure without isolating any of them from initial setting : 6 structures

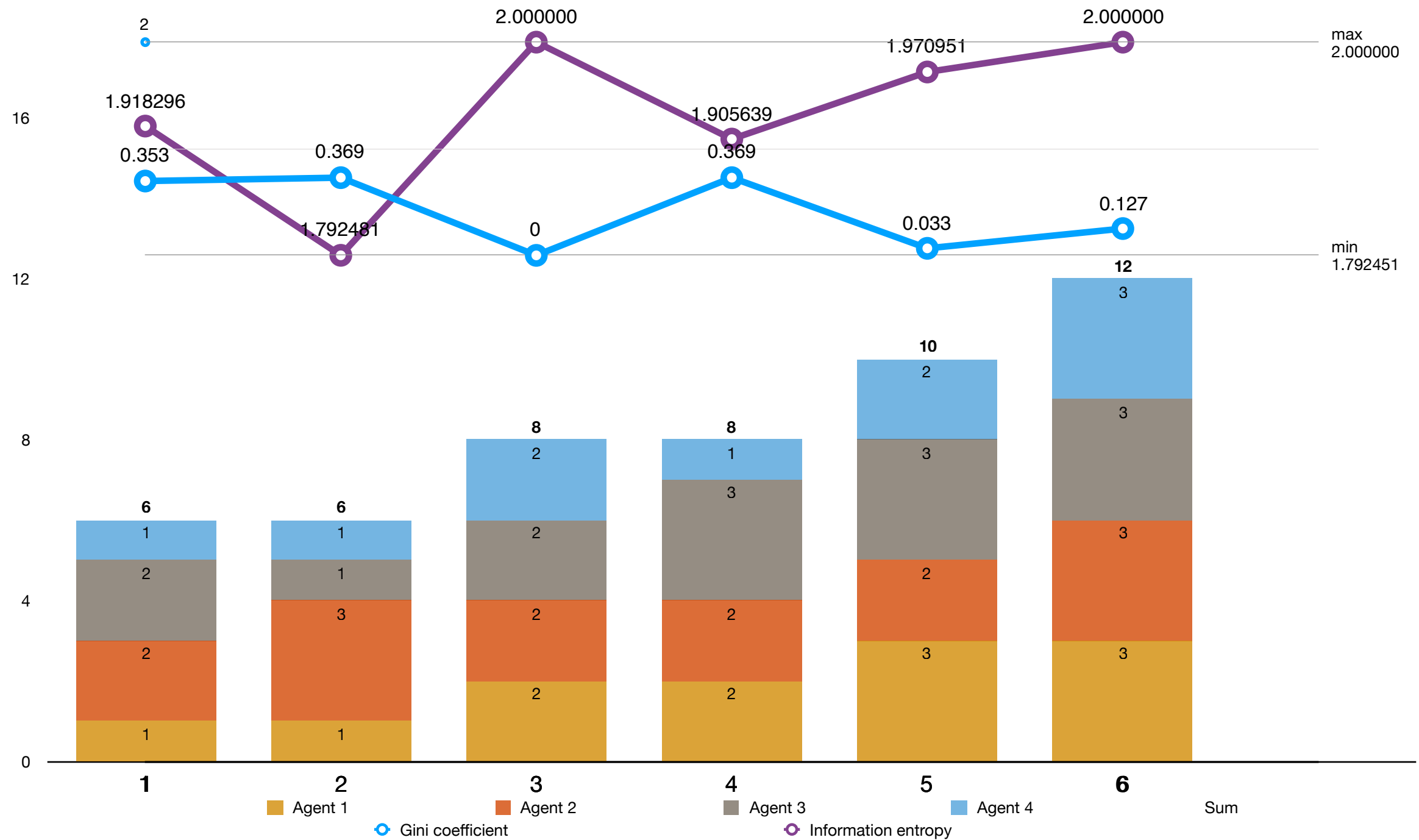


3.1. Network Level: Network Structure and Performance -numerical analysis

- Simulation programmed by java
- Until it reached stable status



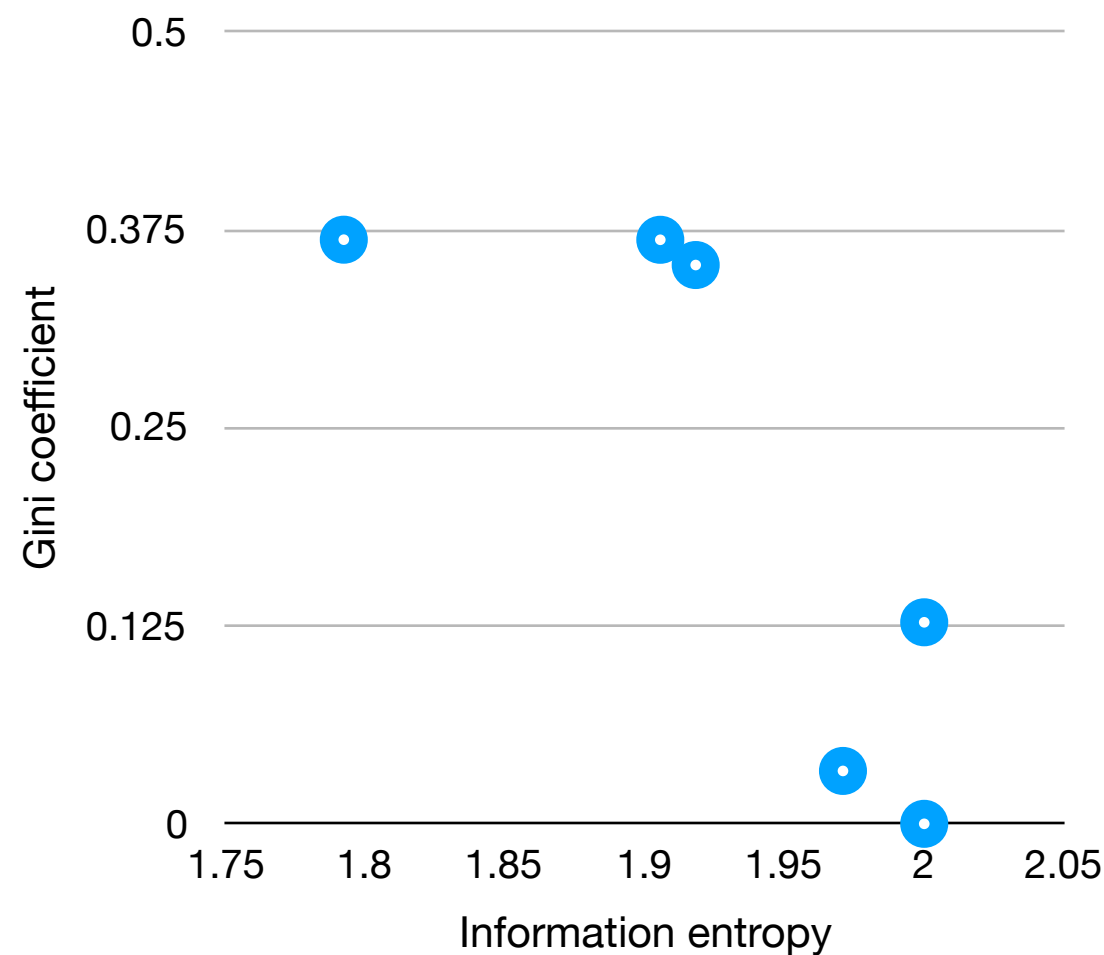
3.1. Network Level: Network Structure and Performance -numerical analysis



3.1. Network Level: Network Structure and Performance

-numerical analysis

- Information entropy and Gini index are negatively related
- How much connections are centralized indicates how much total flow is unevenly distributed throughout the network
- It suggests that proportion of degree of a individual node in supply chain network affects the proportion of profit the node gains

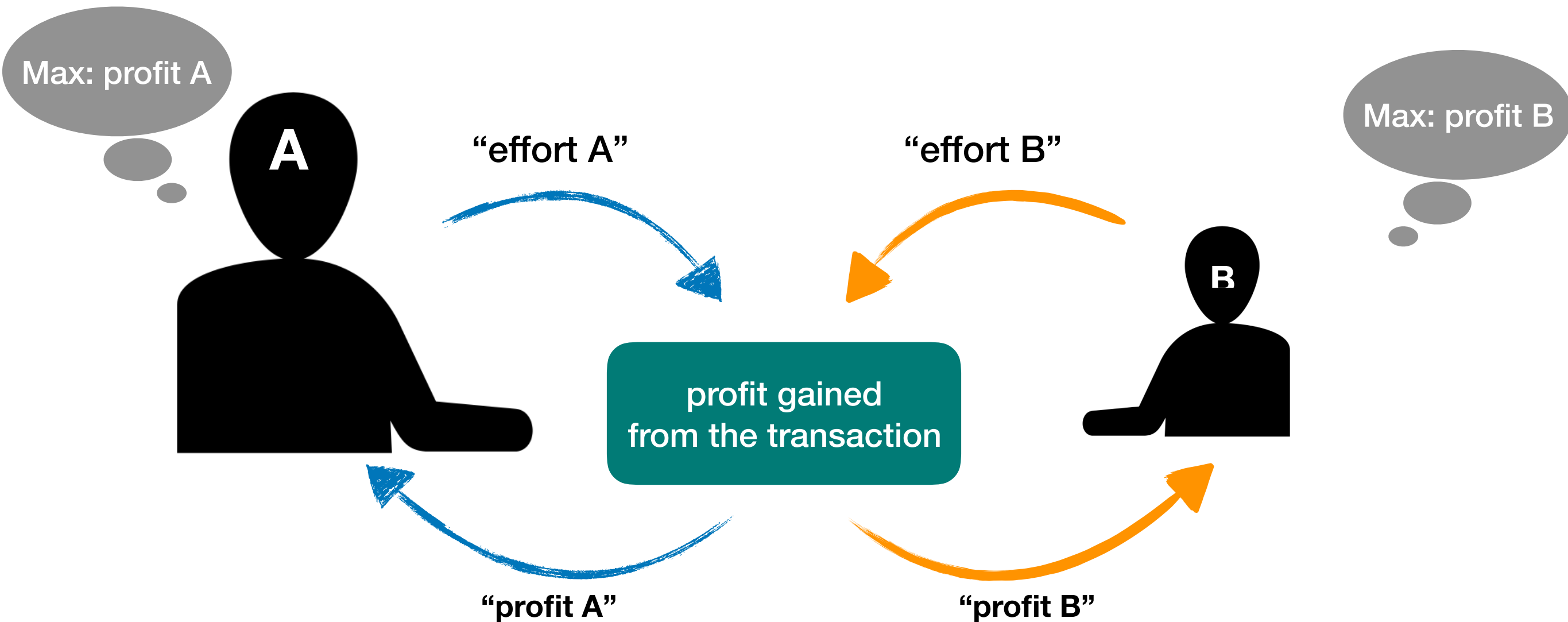


Node Level

Structure and Behavioral Bias

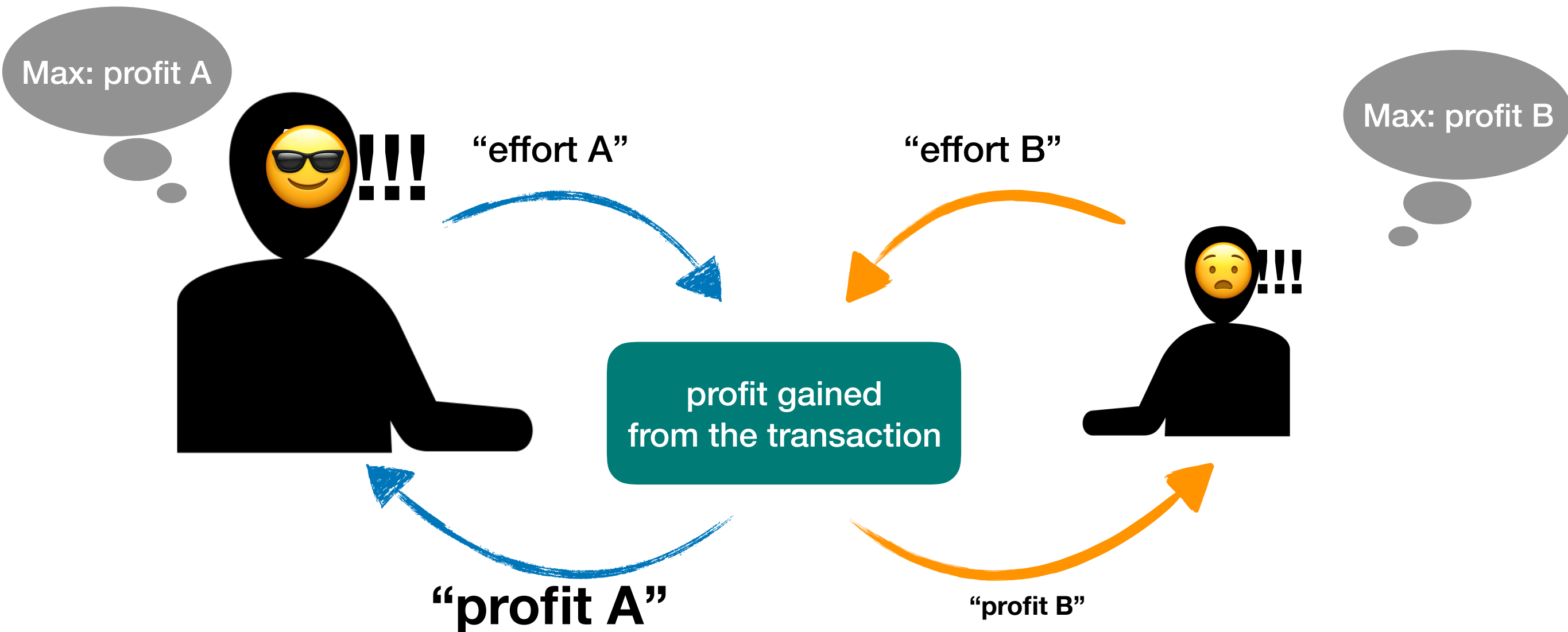
4. Node Level: Structure and Behavioral Bias

- Now we may say that based on the linkage status, decision makers have different level of bargaining power



4. Node Level: Structure and Behavioral Bias

- Difference in network structure → network level performance
- Difference in decision-maker → node level performance



4. Node Level: Structure and Behavioral Bias

- Position in a supply chain network can affect bargaining power and profitability (Cook and Emerson, 1978; Borgatti and Li, 2009)
- Power status affects one's propensity in decision-making behavior (Keltner et al., 2003; Anderson and Berdahl, 2002; Katok and Pavlov, 2013)

| | High status | Low status |
|--------------|--------------------|-----------------|
| Sensitive to | Reward Opportunity | Penalty Threats |

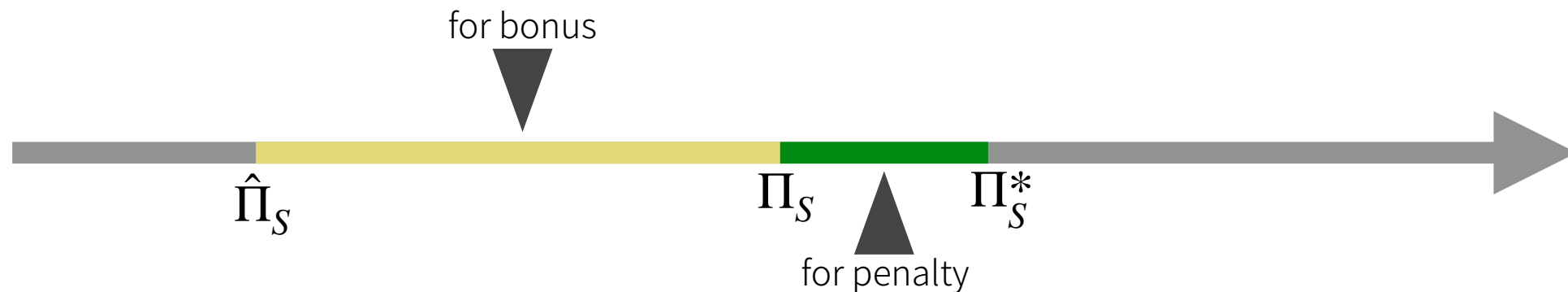
4.1. Node Level: Structure and Behavioral Bias

-incorporating bias in model

- Bonus
 - How much improved from free competition ?

$$V(e_{01}, e_{02}, e_{10}, e_{20}) = v \cdot \{ \Pi_S(e_{01}, e_{02}, e_{10}, e_{20}) - \hat{\Pi}_S \}$$

where $\hat{\Pi}_S$ is average of profit under free competition



- Penalty
 - How far behind the optimal?

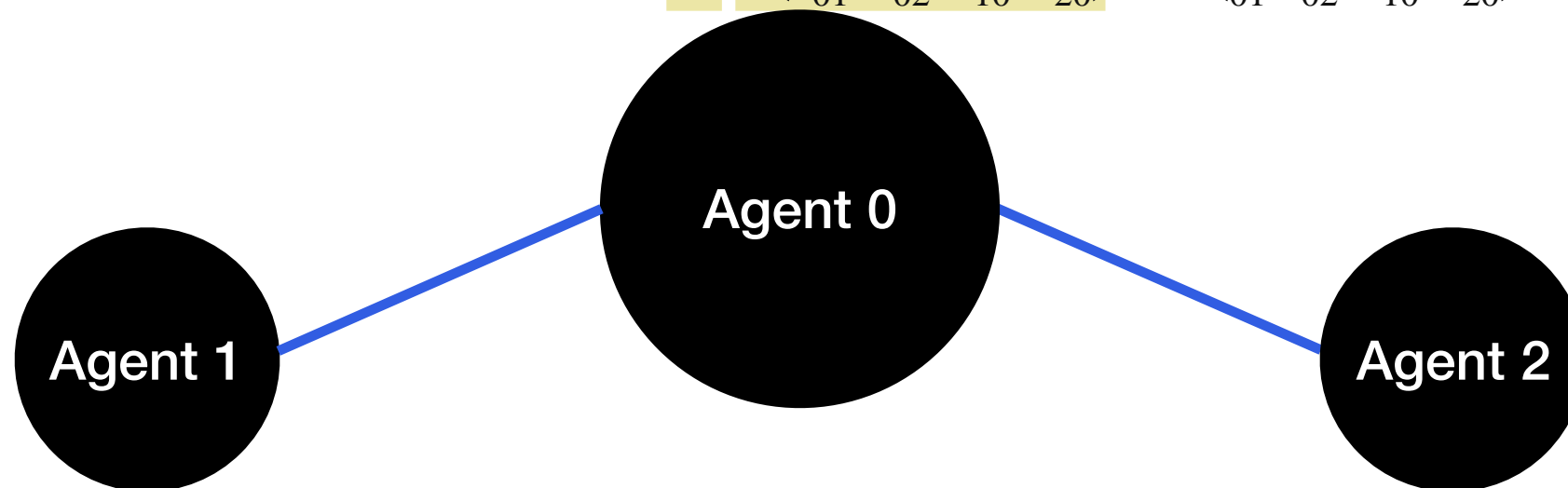
$$W(e_{01}, e_{02}, e_{10}, e_{20}) = w \cdot \{ \Pi_S^* - \Pi_S(e_{01}, e_{02}, e_{10}, e_{20}) \}$$

4.1. Node Level: Structure and Behavioral Bias

-incorporating bias in model

- Type of incentive policy depending on the degree of power (Keltner et al., 2003))
 - Greater power → more sensitive to bonus : α
 - Weaker power → more sensitive to penalty : β
- Number of transactional partner as the proximity of power

$$U_0(e_{01}, e_{02}; e_{10}, e_{20}) = \Pi_0(e_{01}, e_{02}; e_{10}, e_{20}) + \alpha \cdot V(e_{01}, e_{02}, e_{10}, e_{20}) - W(e_{01}, e_{02}, e_{10}, e_{20})$$



$$U_1(e_{01}; e_{02}, e_{10}, e_{20}) = \Pi_0(e_{01}; e_{02}, e_{10}, e_{20}) + V(e_{01}, e_{02}, e_{10}, e_{20}) - \beta \cdot W(e_{01}, e_{02}, e_{10}, e_{20})$$

4.1. Node Level: Structure and Behavioral Bias -incorporating bias in model

- Parameterizing α (sensitivity to bonus) and β (sensitivity to penalty)

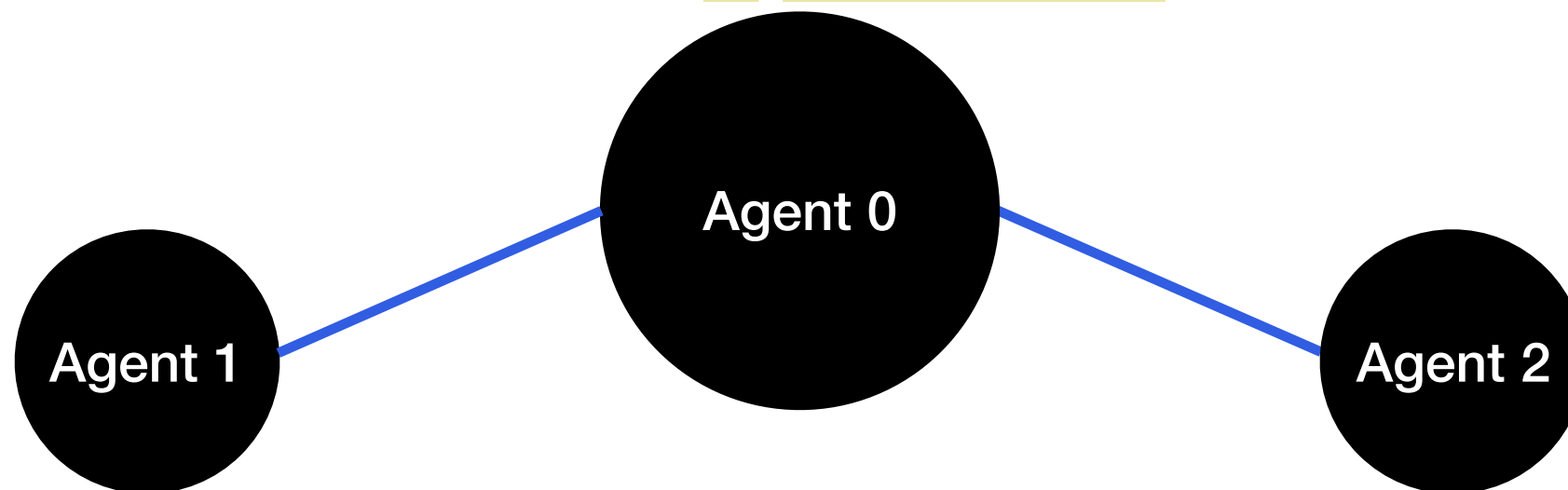
- $dr = \frac{\text{relative degree centrality}}{\text{average degree centrality}}$

- For each agent,

- If $dr > 1$, set $\alpha = dr, \beta = 1$

- If $dr \leq 1$, set $\alpha = 1, \beta = dr$

$$U_0(e_{01}, e_{02}; e_{10}, e_{20}) = \Pi_0(e_{01}, e_{02}; e_{10}, e_{20}) + \alpha \cdot V(e_{01}, e_{02}, e_{10}, e_{20}) - W_{(01, e_{02}, e_{10}, e_{20})}$$



$$U_1(e_{01}; e_{02}, e_{10}, e_{20}) = \Pi_0(e_{01}; e_{02}, e_{10}, e_{20}) + V(e_{01}, e_{02}, e_{10}, e_{20}) - \beta \cdot W_{(01, e_{02}, e_{10}, e_{20})}$$

5. Summary and Implication

- Proposed decision making model under non-cooperative simultaneous game
: each decision-maker seeks to maximize one's own profit
 - Simplification of decision variable → ease of expanding to more complex network
 - Ease of adding behavioral parameter
- Considered fairness as supply chain performance measure
: how evenly total profit is distributed
 - Gini index as measure

5. Summary and Implication

- Suggested how to measure structural feature
 - :how individual nodes are connected to form network (state of linkage)
 - :how difference in structural feature is reflected to performance in network level
- Node level measure: proportion of number of linkage (bargaining power)
- Network level: entropy (distribution throughout the network information entropy)
- → Information entropy as measure: proximity of bargaining power distribution
- Explored how decision-making model integrate behavioral bias
 - :how difference in structural feature is reflected to performance in node level
- Approach to incorporating behavioral bias into decision-making model, maintaining same model structure (additive for incentives)

5. Limitation and Future Work

- More sophisticated measure for structure
 - Information entropy is about “proportion”
 - → considering measure for “amount” of network linkage together may improve the degree of creation between structure and performance (value. e.g., degree centrality)
- Combining the concepts of structure measure with behavioral aspect (only conducted under limited setting so far)
 - Quantifying the degree of bias
- Mathematical modeling
 - So far, based on simulation and numerical method

THANK YOU



4.2. Incorporating behavioral bias: incentive policies -numerical analysis

- What is the best incentive policy?
 - effectiveness: profit maximization → 95% of optimal profit
 - efficiency: cost minimization → lowest absolute coordination cost
- If rational, behavioral parameters should be 1 → $\alpha = 1, \beta = 1$
 - → matter of finding unit bonus, v , and unit penalty, w
 - range[0, 10], by 0.1

4.2. Incorporating behavioral bias: incentive policies -numerical analysis

- When agents are fully rational, the best incentive policy is (BP,BP)
 - $v = 0.3, w = 1.0$
 - global profit: 2.3345 (95.66%)
 - absolute coordination cost: 0.0001

| | incentive policy type | | | | incentive parameters | | coordination performance indice | | |
|---|-----------------------|---------|--------------------|---------|----------------------|------|---------------------------------|-----------------------------|----------------------------------|
| | Agent 0 | | Agent 1 agent 2 | | v | w | global profit | net coordination cost | absolute coordination cost |
| | bonus | penalty | bonus | penalty | | | | | |
| 1 | O | O | O | O | 0.3 | 1 | 2.3345 | -0.0001 | 0.0001 |
| 2 | O | O | O | X | 0.7 | 0.3 | 2.3188 | 0.6711 | 0.6711 |
| 3 | O | O | X | O | 0.2 | 10.0 | 2.4324 | -0.1447 | 0.1684 |
| 4 | O | X | O | O | 0.5 | 1.6 | 2.3330 | 0.1833 | 0.1833 |
| 5 | O | X | O | X | 1.1 | - | 2.3523 | 1.2221 | 1.2221 |
| 6 | O | X | X | O | 0.6 | 1.1 | 2.3205 | -0.0604 | 0.4667 |
| 7 | X | O | O | O | 0.2 | 1.3 | 2.3779 | -0.0846 | 0.0846 |
| 8 | X | O | O | X | 0.7 | 1 | 2.3188 | 0.3502 | 0.5931 |
| 9 | X | O | X | O | - | 10.0 | 2.4324 | -0.2348 | 0.2348 |

4.2. Incorporating behavioral bias: incentive policies

-numerical analysis

- Find the better incentive parameter for given irrationality
- Reselecting incentive parameter by incorporating agents' irrationality, supply chain can be coordinated with much greater efficiency

| degree of behavioral bias | rationality assumption | incentive parameters | | coordination performance indice | | | Coordination performance | |
|---------------------------|------------------------|----------------------|-----|---------------------------------|-----------------------|----------------------------|----------------------------|---|
| | | v | w | global profit | net coordination cost | absolute coordination cost | relative profit to optimal | relative profit increase to coordination cost |
| $\alpha = \beta = 2$ | rational | 0.3 | 1 | 2.4003 | 0.2567 | 0.2567 | 98.36% | 61.36% |
| | irrational | 0.1 | 3.8 | 2.4285 | -0.0006 | 0.0006 | 99.52% | 0.13% |
| $\alpha = \beta = 3$ | rational | 0.3 | 1 | 2.4169 | 0.3212 | 0.3212 | 99.04% | 73.84% |
| | irrational | 0.1 | 0.7 | 2.3817 | -0.0031 | 0.0031 | 97.60% | 0.78% |

Notation

e_{ij} effort input of agent e in transaction (i, j)

Π_i profit of agent i

Π_S total profit of supply chain

U_i subjective utility of agent i

V bonus function

W penalty function

v bonus per unit

w penalty per unit

α subjective weight on bonus

β subjective weight on penalty