Information Sharing between Vertical Hierarchies

Marco Pagnozzi        Salvatore Piccolo

September 2012
Introduction

Why do competitors share private information?

*The essence of an organization is based on the trade-off between the costs and benefits of communication among its members (Arrow)*
Introduction

Why do competitors share private information?

*The essence of an organization is based on the trade-off between the costs and benefits of communication among its members (Arrow)*

Information sharing agreements are widespread:
Introduction

- Why do competitors share private information?

  *The essence of an organization is based on the trade-off between the costs and benefits of communication among its members (Arrow)*

- Information sharing agreements are widespread:
  - Banks exchange information about borrowers
Why do competitors share private information?

*The essence of an organization is based on the trade-off between the costs and benefits of communication among its members (Arrow)*

Information sharing agreements are widespread:

- Banks exchange information about borrowers
- Sellers share information about consumers’ demand
Introduction

Why do competitors share private information?

The essence of an organization is based on the trade-off between the costs and benefits of communication among its members (Arrow)

Information sharing agreements are widespread:

- Banks exchange information about borrowers
- Sellers share information about consumers’ demand
- Firms disclose information about management’s performance


**IO**: information sharing can increase efficiency or reduce competition — e.g., Novshek and Sonnenschein (1982), Clarke (1983), Vives (1984) …
IO: information sharing can increase efficiency or reduce competition — e.g., Novshek and Sonnenschein (1982), Clarke (1983), Vives (1984) ...

Banking: lenders exchange information to screen investment projects or discipline borrowers — e.g., Pagano and Jappelli (1993) ...
IO: information sharing can increase efficiency or reduce competition — e.g., Novshek and Sonnenschein (1982), Clarke (1983), Vives (1984) ...

Banking: lenders exchange information to screen investment projects or discipline borrowers — e.g., Pagano and Jappelli (1993) ...

The literature on information sharing covers several domains:

- **IO**: Information sharing can increase efficiency or reduce competition — e.g., Novshek and Sonnenschein (1982), Clarke (1983), Vives (1984) ...

- **Banking**: Lenders exchange information to screen investment projects or discipline borrowers — e.g., Pagano and Jappelli (1993) ...

- **Consumers’ privacy**: Sellers use information on consumers to price discriminate — Acquisti and Varian (2005), Taylor (2004)

... But these papers neglect the source of information...
Literature

- **IO**: information sharing can increase efficiency or reduce competition — e.g., Novshek and Sonnenschein (1982), Clarke (1983), Vives (1984) ...

- **Banking**: lenders exchange information to screen investment projects or discipline borrowers — e.g., Pagano and Jappelli (1993) ...

- **Consumers’ privacy**: sellers use information on consumers to price discriminate — Acquisti and Varian (2005), Taylor (2004)

... But these papers neglect the source of information

- Ganuza and Jansen (2012) show how information sharing affects firms’ incentive to acquire signals about their costs
Contribution

- Principals obtain information through contracting with exclusive and privately informed agents
Contribution

- Principals obtain information through contracting with exclusive and privately informed agents
- Principals compete and may share information
Contribution

- Principals obtain information through contracting with exclusive and privately informed agents
- Principals compete and may share information

⇒ Interaction between information exchange across organizations and agency conflicts within organizations
Contribution

- Principals obtain information through contracting with exclusive and privately informed agents
- Principals compete and may share information
  \[\Rightarrow\] Interaction between information exchange across organizations and agency conflicts within organizations

**e.g.:** Two competing manufacturers that sell through privately informed retailers and may share the information obtained from them
Contribution

- Principals obtain information through contracting with exclusive and privately informed agents
- Principals compete and may share information
  ⇒ Interaction between information exchange across organizations and agency conflicts within organizations

  e.g.: Two competing manufacturers that sell through privately informed retailers and may share the information obtained from them

- Link between information sharing and vertical contracting: Calzolari and Pavan (2006) analyze information transmission in sequential common agency
Information sharing affects principals’ incentive to distort agents’ output to extract rents
Result

- Information sharing affects principals’ incentive to distort agents’ output to extract rents
- The choice to share information only depends on:
Result

- Information sharing affects principals’ incentive to distort agents’ output to extract rents
- The choice to share information only depends on:
  - the nature of competition between principals and
Result

- Information sharing affects principals’ incentive to distort agents’ output to extract rents.
- The choice to share information only depends on:
  - the nature of competition between principals and
  - the correlation of agents’ information.
Information sharing affects principals’ incentive to distort agents’ output to extract rents.

The choice to share information only depends on:

- the nature of *competition* between principals and
- the *correlation* of agents’ information

⇒ Principals share information iff externalities and correlation have the same sign
Result

- Information sharing affects principals’ incentive to distort agents’ output to extract rents.
- The choice to share information only depends on:
  - the nature of competition between principals and
  - the correlation of agents’ information

⇒ Principals share information iff externalities and correlation have the same sign.
- This effect is of first-order relative to those with complete information.
Information sharing affects principals’ incentive to distort agents’ output to extract rents

The choice to share information only depends on:
- the nature of competition between principals and
- the correlation of agents’ information

⇒ Principals share information iff externalities and correlation have the same sign

This effect is of first-order relative to those with complete information

Principals face a prisoner’s dilemma when they do not share information
Model

- Two principals: $P_1$ and $P_2$
Two principals: $P_1$ and $P_2$

Two exclusive agents: $A_1$ and $A_2$
Model

- Two principals: $P_1$ and $P_2$
- Two exclusive agents: $A_1$ and $A_2$
- $A_i$ is privately informed about marginal cost $\theta_i \in \{\underline{\theta}, \overline{\theta}\}$, with:
Model

- Two principals: $P_1$ and $P_2$
- Two exclusive agents: $A_1$ and $A_2$
- $A_i$ is privately informed about marginal cost $\theta_i \in \{\theta, \bar{\theta}\}$, with:
  - $\Pr(\theta, \theta) = \nu^2 + \alpha$; $\Pr(\bar{\theta}, \bar{\theta}) = (1 - \nu)^2 + \alpha$
Model

- Two principals: $P_1$ and $P_2$
- Two exclusive agents: $A_1$ and $A_2$
- $A_i$ is privately informed about marginal cost $\theta_i \in \{\theta, \bar{\theta}\}$, with:
  - $\Pr(\theta, \theta) = \nu^2 + \alpha$; $\Pr(\bar{\theta}, \bar{\theta}) = (1 - \nu)^2 + \alpha$
  - $\Pr(\theta, \bar{\theta}) = \Pr(\bar{\theta}, \theta) = \nu (1 - \nu) - \alpha$
Model

- Two principals: $P_1$ and $P_2$
- Two exclusive agents: $A_1$ and $A_2$
- $A_i$ is privately informed about marginal cost $\theta_i \in \{\theta, \bar{\theta}\}$, with:
  - $\Pr(\theta, \bar{\theta}) = \nu^2 + \alpha$; $\Pr(\bar{\theta}, \theta) = (1 - \nu)^2 + \alpha$
  - $\Pr(\theta, \bar{\theta}) = \Pr(\bar{\theta}, \theta) = \nu (1 - \nu) - \alpha$

$\Rightarrow \alpha$ measures correlation between $\theta_1$ and $\theta_2$;
$\Pr(\theta) = \nu$; $\Pr(\bar{\theta}) = 1 - \nu$;
Utilities

- $P_i$ pays $t_i$ to $A_i$, and $A_i$ produces $q_i$
Utilities

- $P_i$ pays $t_i$ to $A_i$, and $A_i$ produces $q_i$
- Risk-neutral players:

\[ A_i : \quad U_i = t_i - \theta_i q_i \]
\[ P_i : \quad S_i^i(q_i, q_j) - t_i \]
\[ \equiv \kappa + \beta q_i - q_i^2 + \delta q_i q_j \]
Utilities

- $P_i$ pays $t_i$ to $A_i$, and $A_i$ produces $q_i$
- Risk-neutral players:

  $A_i : \quad U_i = t_i - \theta_i q_i$

  $P_i : \quad S^i(q_i, q_j) - t_i$

  $\equiv \kappa + \beta q_i - q_i^2 + \delta q_i q_j$

$\Rightarrow \quad \delta$ measures **production externalities:**
Utilities

- $P_i$ pays $t_i$ to $A_i$, and $A_i$ produces $q_i$
- Risk-neutral players:

$$A_i : \quad U_i = t_i - \theta_i q_i$$

$$P_i : \quad S^i(q_i, q_j) - t_i$$

$$\equiv \kappa + \beta q_i - q_i^2 + \delta q_i q_j$$

$\Rightarrow$ $\delta$ measures production externalities:

- strategic complementarity ($\delta > 0$) or substitutability ($\delta < 0$)
Utilities

- $P_i$ pays $t_i$ to $A_i$, and $A_i$ produces $q_i$
- Risk-neutral players:
  
  \[
  A_i : \quad U_i = t_i - \theta_i q_i
  \]
  
  \[
  P_i : \quad S^i(q_i, q_j) - t_i
  \]
  
  \[
  \equiv \kappa + \beta q_i - q_i^2 + \delta q_i q_j
  \]

  $\Rightarrow$ $\delta$ measures **production externalities**:

  - strategic complementarity ($\delta > 0$) or substitutability ($\delta < 0$)

  - We assume $\delta$ small and compute expected profits through Taylor expansions
Utilities

- $P_i$ pays $t_i$ to $A_i$, and $A_i$ produces $q_i$
- Risk-neutral players:

$$A_i : \quad U_i = t_i - \theta_i q_i$$

$$P_i : \quad S^i(q_i, q_j) - t_i$$

$$\equiv \kappa + \beta q_i - q_i^2 + \delta q_i q_j$$

$\Rightarrow$ $\delta$ measures **production externalities**:
- strategic complementarity ($\delta > 0$) or substitutability ($\delta < 0$)
- We assume $\delta$ small and compute expected profits through Taylor expansions
- *Limited liability* for agents
Contracts

- \( \theta_i \) can be learned by \( P_i \) through *private contracting* and by \( P_j \) through *information sharing*
Contracts

- $\theta_i$ can be learned by $P_i$ through *private contracting* and by $P_j$ through *information sharing*.
- $P_i$ offers a *direct mechanism*: $A_i$ report his cost $\theta_i$ and
Contracts

- $\theta_i$ can be learned by $P_i$ through *private contracting* and by $P_j$ through *information sharing*.

- $P_i$ offers a *direct mechanism*: $A_i$ report his cost $\theta_i$ and
  
  - without information sharing:

  \[
  \{t_i(\theta_i), q_i(\theta_i)\}
  \]
Contracts

- $\theta_i$ can be learned by $P_i$ through *private contracting* and by $P_j$ through *information sharing*.

- $P_i$ offers a *direct mechanism*: $A_i$ report his cost $\theta_i$ and
  - without information sharing:
    \[
    \{ t_i (\theta_i), q_i (\theta_i) \}
    \]
  - with information sharing:
    \[
    \{ t_i (\theta_i, \theta_j), q_i (\theta_i, \theta_j) \}
    \]
Contracts

- $\theta_i$ can be learned by $P_i$ through *private contracting* and by $P_j$ through *information sharing*.

- $P_i$ offers a *direct mechanism*: $A_i$ report his cost $\theta_i$ and
  - without information sharing:
    $$\{t_i(\theta_i), q_i(\theta_i)\}$$
  - with information sharing:
    $$\{t_i(\theta_i, \theta_j), q_i(\theta_i, \theta_j)\}$$

- $A_i$’s cost can be credibly transmitted by $P_i$ to $P_j/A_j$. 
Timing

Principals simultaneously choose whether to commit to share information
Timing

1. Principals simultaneously choose whether to commit to share information
2. $A_i$ learns $\theta_i$
## Timing

1. Principals simultaneously choose whether to commit to share information
2. $A_i$ learns $\theta_i$
3. Principals contract with agents
Timing

1. Principals simultaneously choose whether to commit to share information
2. $A_i$ learns $\theta_i$
3. Principals contract with agents
4. $P_i$ discloses her information about $A_i$’s cost if she has committed to do so
Timing

1. Principals simultaneously choose whether to commit to share information
2. $A_i$ learns $\theta_i$
3. Principals contract with agents
4. $P_i$ discloses her information about $A_i$’s cost if she has committed to do so
5. Agents produce and payments are made
Complete information within each hierarchy

- Standard duopoly where firms share cost information (Shapiro, 1986)
Complete information within each hierarchy

- Standard duopoly where firms share cost information (Shapiro, 1986)
- Let $s_i = (\theta_i, \theta_j)$ if $P_j$ shares information, $s_i = \theta_i$ if $P_j$ does not
Complete information within each hierarchy

- Standard duopoly where firms share cost information (Shapiro, 1986)
- Let $s_i = (\theta_i, \theta_j)$ if $P_j$ shares information, $s_i = \theta_i$ if $P_j$ does not
- **Lemma:** $P_i$’s expected equilibrium profit is

$$V_i^* = \kappa + \left( \mathbb{E}_{s_i} \left[ q_i^* (s_i) \mid \theta_i \right] \right)^2 + \mathbb{E}_{s_i} \left[ q_i^* (s_i) \mid \theta_i \right] - \mathbb{E}_{s_i} \left[ q_i^* (s_i) \mid \theta_i \right] \mid \theta_i \right] \right]^2.$$  
- Average of $q_i^*(s_i)$
- Variance of $q_i^*(s_i)$

*and expected output is the same regardless of principals’ communication decisions*
Complete information within each hierarchy

- Standard duopoly where firms share cost information (Shapiro, 1986)
- Let $s_i = (\theta_i, \theta_j)$ if $P_j$ shares information, $s_i = \theta_i$ if $P_j$ does not
- **Lemma**: $P_i$’s expected equilibrium profit is

$$V_i^* = \kappa + \left( \mathbb{E}_{s_i} [q_i^*(s_i) | \theta_i] \right)^2 + \mathbb{E}_{s_i} [q_i^*(s_i) - \mathbb{E}_{s_i} [q_i^*(s_i) | \theta_i] | \theta_i]$$

- average of $q_i^*(s_i)$
- variance of $q_i^*(s_i)$

*and expected output is the same regardless of principals’ communication decisions*

⇒ Principals maximize output volatility
Complete information

- **Proposition:** With complete information: both principals share information if $\alpha > -v(1 - v)$; no principal share information if $\alpha < -v(1 - v)$
Proposition: With complete information: both principals share information if \( \alpha > -\nu (1 - \nu) \); no principal share information if \( \alpha < -\nu (1 - \nu) \)

Information sharing has a direct positive effect on output volatility (since contracts are conditioned on more states) but
Complete information

- **Proposition:** *With complete information: both principals share information if $\alpha > -\nu (1 - \nu)$; no principal share information if $\alpha < -\nu (1 - \nu)$*

- Information sharing has a direct positive effect on output volatility (since contracts are conditioned on more states) but
- If $\alpha < 0$ information sharing reduces volatility because states $(\bar{\theta}, \bar{\theta})$ and $(\bar{\theta}, \bar{\theta})$ are more likely:
Proposition: With complete information: both principals share information if $\alpha > -\nu (1 - \nu)$; no principal share information if $\alpha < -\nu (1 - \nu)$

- Information sharing has a direct positive effect on output volatility (since contracts are conditioned on more states) but
- If $\alpha < 0$ information sharing reduces volatility because states $(\bar{\theta}, \bar{\theta})$ and $(\theta, \bar{\theta})$ are more likely:
  - e.g., if $\delta > 0$ outputs are more similar in those states
Complete information

- **Proposition:** *With complete information: both principals share information if* $\alpha > -\nu (1 - \nu)$; *no principal share information if* $\alpha < -\nu (1 - \nu)$

- Information sharing has a direct positive effect on output volatility (since contracts are conditioned on more states) but
- If $\alpha < 0$ information sharing reduces volatility because states $(\bar{\theta}, \theta)$ and $(\theta, \bar{\theta})$ are more likely:
  - e.g., if $\delta > 0$ outputs are more similar in those states

- **Proposition:** *Principals’ information sharing decisions always maximize their profits*
Since principals learn their agents’ costs through contracting, agents earn an information rent
Asymmetric information

- Since principals learn their agents’ costs through contracting, agents earn an information rent
- Principals want to distort outputs to minimize rent
Asymmetric information

- Since principals learn their agents’ costs through contracting, agents earn an information rent
- Principals want to distort outputs to minimize rent
- Principals want to affect rival’s output to increase profit (because of externality)
Since principals learn their agents’ costs through contracting, agents earn an information rent.

Principals want to distort outputs to minimize rent.

Principals want to affect rival’s output to increase profit (because of externality).

3 subgames:
Asymmetric information

- Since principals learn their agents’ costs through contracting, agents earn an information rent.
- Principals want to distort outputs to minimize rent.
- Principals want to affect rival’s output to increase profit (because of externality).

3 subgames:

1. No communication
Asymmetric information

- Since principals learn their agents’ costs through contracting, agents earn an information rent.
- Principals want to distort outputs to minimize rent.
- Principals want to affect rival’s output to increase profit (because of externality).

3 subgames:
1. No communication
2. Bilateral information sharing
Asymmetric information

- Since principals learn their agents’ costs through contracting, agents earn an information rent
- Principals want to distort outputs to minimize rent
- Principals want to affect rival’s output to increase profit (because of externality)

3 subgames:
1. No communication
2. Bilateral information sharing
3. Unilateral information sharing
No communication

• $P_i$ maximizes

\[
\mathbb{E}_{\theta_j} \mathbb{E}_{\theta_i} \left[ S(q_i(\theta_i), q^e(\theta_j)) - \theta_i q_i(\theta_i) \big| \theta_i \right] - \nu \Delta \theta q_i(\overline{\theta})
\]
No communication

- $P_i$ maximizes

$$E_{\theta_j}E_{\theta_i} \left[ S\left(q_i(\theta_i), q^e(\theta_j)\right) - \theta_i q_i(\theta_i) \mid \theta_i \right] - \nu \Delta \theta q_i(\bar{\theta})$$

- First-order conditions are

$$E_{\theta} \left[ S_1\left(q^e(\bar{\theta}), q^e(\theta_j)\right) \mid \bar{\theta} \right] = \bar{\theta},$$

$$E_{\theta} \left[ S_1(q^e(\bar{\theta}), q^e(\theta_j)) \mid \bar{\theta} \right] = \bar{\theta} + \frac{\nu}{1-\nu} \Delta \theta.$$
No communication

- $P_i$ maximizes

$$\mathbb{E}_{\theta_j} \mathbb{E}_{\theta_i} [S(q_i(\theta_i), q^e(\theta_j)) - \theta_i q_i(\theta_i)|\theta_i] - \nu \Delta \theta q_i(\bar{\theta})$$

- First-order conditions are

$$\mathbb{E}_{\theta} [S_1(q^e(\theta), q^e(\theta_j))|\theta] = \theta,$$

$$\mathbb{E}_{\theta} [S_1(q^e(\bar{\theta}), q^e(\theta_j))|\bar{\theta}] = \bar{\theta} + \frac{\nu}{1-\nu} \Delta \theta.$$  

$\Rightarrow$ Type $\theta$ produces the output that equalizes marginal benefit to marginal cost.

Type $\bar{\theta}$’s output is downward distorted to reduce agents’ rent.
No communication

- **Proposition.** *When principals do not share information:*

\[ q_e(\theta) < q(\theta) < q_e(\theta) \quad \text{if} \quad \delta < 0 \]

Because of production externalities, the low-cost agent's output is distorted since principals expect rivals to produce less to reduce information rents: If goods are substitutes (complements), \( A_j \)'s lower output induces \( A_i \) to produce more (less).
No communication

- **Proposition.** *When principals do not share information:*
  - \( q^e(\bar{\theta}) < q^*(\bar{\theta}) \)
No communication

- **Proposition.** *When principals do not share information:*
  - \( q^e(\bar{\theta}) < q^*(\bar{\theta}) \)
  - \( q^e(\theta) > q^*(\theta) \) iff \( \delta < 0 \)
No communication

- **Proposition.** *When principals do not share information:*
  - $q^e(\bar{\theta}) < q^*(\bar{\theta})$
  - $q^e(\theta) > q^*(\theta)$ iff $\delta < 0$

Because of production externalities, the low-cost agent’s output is distorted since principals expect rivals to produce less to reduce information rents:
Proposition. When principals do not share information:

- \( q^e(\bar{\theta}) < q^*(\bar{\theta}) \)
- \( q^e(\theta) > q^*(\theta) \) iff \( \delta < 0 \)

Because of production externalities, the low-cost agent’s output is distorted since principals expect rivals to produce less to reduce information rents:

If goods are substitutes (complements), \( A_j \)’s lower output induces \( A_i \) to produce more (less)
Bilateral information sharing

- Contracts specify $q_i$ and $t_i$ contingent on $(\theta_i, \theta_j)$
Bilateral information sharing

- Contracts specify $q_i$ and $t_i$ contingent on $(\theta_i, \theta_j)$
- Relevant constraints:

$$U_i (\bar{\theta}, \theta_j) = t_i (\bar{\theta}, \theta_j) - \bar{\theta} q_i (\bar{\theta}, \theta_j) \geq 0 \quad \forall \theta_j,$$

$$\mathbb{E}_{\theta_j} [U_i (\theta, \theta_j) | \theta] \geq \mathbb{E}_{\theta_j} [t_i (\bar{\theta}, \theta_j) - \bar{\theta} q_i (\bar{\theta}, \theta_j) | \theta]$$
Contracts specify $q_i$ and $t_i$ contingent on $(\theta_i, \theta_j)$

Relevant constraints:

$$U_i (\overline{\theta}, \theta_j) = t_i (\overline{\theta}, \theta_j) - \overline{\theta} q_i (\overline{\theta}, \theta_j) \geq 0 \quad \forall \theta_j,$$

$$E_{\theta_j} [U_i (\theta, \theta_j) | \theta] \geq E_{\theta_j} [t_i (\overline{\theta}, \theta_j) - \overline{\theta} q_i (\overline{\theta}, \theta_j) | \theta]$$

$\Rightarrow P_i$ maximizes:

$$E_{\theta_j} E_{\theta_i} [S (q_i (\theta_i, \theta_j), q^e (\theta_j, \theta_i)) - \theta_i q_i (\theta_i, \theta_j) | \theta_i]$$

$$- \nu \Delta \theta E_{\theta_j} [q_i (\overline{\theta}, \theta_j) | \theta]$$
Bilateral information sharing

- Contracts specify $q_i$ and $t_i$ contingent on $(\theta_i, \theta_j)$
- Relevant constraints:
  \[
  U_i (\bar{\theta}, \theta_j) = t_i (\bar{\theta}, \theta_j) - \bar{\theta} q_i (\bar{\theta}, \theta_j) \geq 0 \quad \forall \theta_j,
  \]
  \[
  \mathbb{E}_{\theta_j} [U_i (\theta, \theta_j) | \theta] \geq \mathbb{E}_{\theta_j} [t_i (\bar{\theta}, \theta_j) - \bar{\theta} q_i (\bar{\theta}, \theta_j) | \theta]
  \]
  \[\Rightarrow P_i \text{ maximizes:} \]
  \[
  \mathbb{E}_{\theta_j} \mathbb{E}_{\theta_i} [S (q_i (\theta_i, \theta_j), q^e (\theta_j, \theta_i)) - \theta_i q_i (\theta_i, \theta_j) | \theta_i]
  \]
  \[\quad - \nu \Delta \mathbb{E}_{\theta_j} [q_i (\bar{\theta}, \theta_j) | \theta] \]
  (No full surplus extraction due to limited liability)
Bilateral information sharing

- Necessary and sufficient first-order conditions:

\[ S_1(q^e(\bar{\theta}, \theta_j), q^e(\theta_j, \theta)) = \theta \quad \forall \theta_j, \]

\[ S_1(q^e(\theta, \theta_j), q^e(\theta_j, \theta)) = \bar{\theta} + \frac{\nu}{1-\nu} \frac{Pr(\theta_j|\theta)}{Pr(\theta_j|\bar{\theta})} \Delta \theta \quad \forall \theta_j \]
Bilateral information sharing

- Necessary and sufficient first-order conditions:
  \[ S_1 (q^e(\theta, \theta_j), q^e(\theta_j, \theta)) = \theta \quad \forall \theta_j, \]
  \[ S_1(q^e(\overline{\theta}, \theta_j), q^e(\theta_j, \overline{\theta})) = \overline{\theta} + \frac{\nu}{1-\nu} \frac{Pr(\theta_j|\theta)}{Pr(\theta_j|\overline{\theta})} \Delta \theta \quad \forall \theta_j \]

\[ \Rightarrow \] No distortion for \( \theta \) and downward distortion for \( \overline{\theta} \) to reduce information rents
Bilateral information sharing

- Necessary and sufficient first-order conditions:

\[
S_1(q^e(\theta, \theta_j), q^e(\theta_j, \theta)) = \theta \quad \forall \theta_j,
\]

\[
S_1(q^e(\overline{\theta}, \theta_j), q^e(\theta_j, \overline{\theta})) = \overline{\theta} + \frac{\nu}{1-\nu} \frac{Pr(\theta_j|\theta)}{Pr(\theta_j|\overline{\theta})} \Delta \theta \quad \forall \theta_j
\]

⇒ No distortion for \( \overline{\theta} \) and downward distortion for \( \theta \) to reduce information rents

- Distortion increases with \( \frac{Pr(\theta_j|\theta)}{Pr(\theta_j|\overline{\theta})} \) since:
Bilateral information sharing

- Necessary and sufficient first-order conditions:
  \[ S_1(q^e(\theta, \theta_j), q^e(\theta_j, \bar{\theta})) = \theta \quad \forall \theta_j, \]
  \[ S_1(q^e(\bar{\theta}, \theta_j), q^e(\theta_j, \bar{\theta})) = \bar{\theta} + \frac{v}{1-v} \frac{Pr(\theta_j|\theta)}{Pr(\theta_j|\bar{\theta})} \Delta \theta \quad \forall \theta_j \]

⇒ No distortion for \( \theta \) and downward distortion for \( \bar{\theta} \) to reduce information rents

- Distortion increases with \( \frac{Pr(\theta_j|\theta)}{Pr(\theta_j|\bar{\theta})} \) since:
  - \( Pr(\theta_j|\theta) \) measures how often \( P_i \) pays rent to type \( \theta \)
Bilateral information sharing

- Necessary and sufficient first-order conditions:

\[
S_1 (q^e(\theta, \theta_j), q^e(\theta_j, \theta)) = \theta \quad \forall \theta_j,
\]

\[
S_1(q^e(\bar{\theta}, \theta_j), q^e(\theta_j, \bar{\theta})) = \bar{\theta} + \frac{\nu}{1-\nu} \frac{Pr(\theta_j | \theta)}{Pr(\theta_j | \bar{\theta})} \Delta \theta \quad \forall \theta_j
\]

⇒ No distortion for \( \theta \) and downward distortion for \( \bar{\theta} \) to reduce information rents

- Distortion increases with \( \frac{Pr(\theta_j | \theta)}{Pr(\theta_j | \bar{\theta})} \) since:
  - \( Pr(\theta_j | \theta) \) measures how often \( P_i \) pays rent to type \( \theta \)
  - \( Pr(\theta_j | \bar{\theta}) \) measures how often output is inefficient
Bilateral information sharing

- Necessary and sufficient first-order conditions:
  \[ S_1 \left( q^e(\theta, \theta_j), q^e(\theta_j, \theta) \right) = \theta \quad \forall \theta_j, \]
  \[ S_1 \left( q^e(\overline{\theta}, \theta_j), q^e(\theta_j, \overline{\theta}) \right) = \overline{\theta} + \frac{\nu}{1-\nu} \frac{Pr(\theta_j|\theta)}{Pr(\theta_j|\overline{\theta})} \Delta \theta \quad \forall \theta_j \]

⇒ No distortion for \( \theta \) and downward distortion for \( \overline{\theta} \) to reduce information rents

- Distortion increases with \( \frac{Pr(\theta_j|\theta)}{Pr(\theta_j|\overline{\theta})} \) since:
  - \( Pr(\theta_j|\theta) \) measures how often \( P_i \) pays rent to type \( \theta \)
  - \( Pr(\theta_j|\overline{\theta}) \) measures how often output is inefficient

\[ \frac{Pr(\theta|\theta)}{Pr(\theta|\overline{\theta})} > \frac{Pr(\overline{\theta}|\theta)}{Pr(\overline{\theta}|\overline{\theta})} \iff \alpha > 0, \]

⇒ if costs are positively correlated, the distortion of type \( \overline{\theta} \)'s output is larger when his opponent has a low rather than a high cost, since this is more likely
Bilateral information sharing

• Proposition. *If both principals share information,*

\[ q_e(\theta, \theta) = q_e(\theta, \theta) < q_e(\theta, \theta) \neq 0 \]

Expected output does not depend on principals’ communication decision

Because of production externality, this induces \( P_i \) to also distort the output of type \( \theta \) when \( \theta_j = \theta \):

- If \( \delta > 0 \), \( q_e(\theta, \theta) \) is lower since \( P_i \) wants to produce less when \( P_j \) produces less
- If \( \delta < 0 \), \( q_e(\theta, \theta) \) is higher since \( P_i \) wants to produce more when \( P_j \) produces less

Strategic linkage between \( P_i \)’s output and \( A_j \)’s cost
Proposition. *If both principals share information,*

\[ q^e(\theta, \theta) = q^*(\theta, \theta) \]
Bilateral information sharing

**Proposition.** If both principals share information,

- \( q^e(\theta, \theta) = q^*(\theta, \theta) \)
- \( q^e(\overline{\theta}, \theta_j) < q^*(\overline{\theta}, \theta_j) \) \( \forall \theta_j \)

Bilateral information sharing

- **Proposition.** *If both principals share information,*
  
  \[ q^e(\theta, \theta) = q^*(\theta, \theta) \]
  
  \[ q^e(\theta, \theta_j) < q^*(\theta, \theta_j) \quad \forall \theta_j \]
  
  \[ q^e(\theta, \theta) > q^*(\theta, \theta) \text{ iff } \delta < 0 \]
Bilateral information sharing

- **Proposition.** *If both principals share information,*

  - \( q^e(\theta, \theta) = q^*(\theta, \theta) \)
  - \( q^e(\overline{\theta}, \theta_j) < q^*(\overline{\theta}, \theta_j) \quad \forall \theta_j \)
  - \( q^e(\theta, \overline{\theta}) > q^*(\theta, \overline{\theta}) \) iff \( \delta < 0 \)
  - *Expected output does not depend on principals’ communication decision*
Proposition. If both principals share information,

- $q^e(\theta, \theta) = q^*(\theta, \theta)$
- $q^e(\bar{\theta}, \theta_j) < q^*(\bar{\theta}, \theta_j) \quad \forall \theta_j$
- $q^e(\theta, \bar{\theta}) > q^*(\theta, \bar{\theta})$ iff $\delta < 0$
- Expected output does not depend on principals' communication decision

The output of type $\bar{\theta}$ is inefficiently low
Proposition. If both principals share information,

- \( q^e(\theta, \theta) = q^*(\theta, \theta) \)
- \( q^e(\bar{\theta}, \theta_j) < q^*(\bar{\theta}, \theta_j) \quad \forall \theta_j \)
- \( q^e(\theta, \bar{\theta}) > q^*(\theta, \bar{\theta}) \) iff \( \delta < 0 \)
- Expected output does not depend on principals' communication decision

The output of type \( \bar{\theta} \) is inefficiently low

Because of production externality, this induces \( P_i \) to also distort the output of type \( \theta \) when \( \theta_j = \bar{\theta} \):
Bilateral information sharing

**Proposition.** *If both principals share information,*

- \( q^e(\bar{\theta}, \theta) = q^*(\bar{\theta}, \theta) \)
- \( q^e(\bar{\theta}, \theta_j) < q^*(\bar{\theta}, \theta_j) \quad \forall \theta_j \)
- \( q^e(\bar{\theta}, \bar{\theta}) > q^*(\bar{\theta}, \bar{\theta}) \) iff \( \delta < 0 \)
- *Expected output does not depend on principals’ communication decision*

The output of type \( \bar{\theta} \) is inefficiently low

Because of production externality, this induces \( P_i \) to also distort the output of type \( \theta \) when \( \theta_j = \bar{\theta} \):

- if \( \delta > 0 \), \( q^e(\bar{\theta}, \bar{\theta}) \) is lower since \( P_i \) wants to produce less when \( P_j \) produces less
Bilateral information sharing

- **Proposition.** *If both principals share information,*
  
  - $q^e(\theta, \theta) = q^*(\theta, \theta)$
  - $q^e(\theta, \theta) < q^*(\theta, \theta)$  $\forall \theta$
  - $q^e(\theta, \theta) > q^*(\theta, \theta)$ iff $\delta < 0$
  - *Expected output does not depend on principals’ communication decision*

  - The output of type $\bar{\theta}$ is inefficiently low
  - Because of production externality, this induces $P_i$ to also distort the output of type $\theta$ when $\theta_j = \bar{\theta}$:
    - if $\delta > 0$, $q^e(\theta, \bar{\theta})$ is lower since $P_i$ wants to produce less when $P_j$ produces less
    - if $\delta < 0$, $q^e(\theta, \bar{\theta})$ is higher since $P_i$ wants to produce more when $P_j$ produces less
Bilateral information sharing

**Proposition.** If both principals share information,

- \( q^e(\theta, \theta) = q^*(\theta, \theta) \)
- \( q^e(\theta, \theta_j) < q^*(\theta, \theta_j) \quad \forall \theta_j \)
- \( q^e(\theta, \bar{\theta}) > q^*(\theta, \bar{\theta}) \text{ iff } \delta < 0 \)
- *Expected output does not depend on principals’ communication decision*

The output of type \( \bar{\theta} \) is inefficiently low

Because of production externality, this induces \( P_i \) to also distort the output of type \( \theta \) when \( \theta_j = \bar{\theta} \):

- if \( \delta > 0 \), \( q^e(\theta, \bar{\theta}) \) is lower since \( P_i \) wants to produce less when \( P_j \) produces less
- if \( \delta < 0 \), \( q^e(\theta, \bar{\theta}) \) is higher since \( P_i \) wants to produce more when \( P_j \) produces less

\( \Rightarrow \) Strategic linkage between \( P_i \)'s output and \( A_j \)'s cost
Unilateral information sharing

- \( P_i \) shares information, \( P_j \) does not
Unilateral information sharing

- $P_i$ shares information, $P_j$ does not
- FOCs are

$$
\mathbb{E}_{\theta_j} \left[ S_1(q^e_i(\theta), q^e_j(\theta_j, \theta)) | \theta \right] = \theta
$$

$$
\mathbb{E}_{\theta_j} \left[ S_1(q^e_i(\bar{\theta}), q^e_j(\theta_j, \bar{\theta}) | \bar{\theta} \right] = \bar{\theta} + \frac{\nu}{1-\nu} \Delta \theta
$$

$$
S_1(q^e_j(\theta, \theta_i), q^e_i(\theta_i)) = \theta \quad \forall \theta_i
$$

$$
S_1(q^e_j(\bar{\theta}, \theta_i), q^e_i(\theta_i)) = \bar{\theta} + \frac{\nu}{1-\nu} \frac{Pr(\theta_i|\theta)}{Pr(\theta_i|\bar{\theta})} \Delta \theta \quad \forall \theta_i
$$
Unilateral information sharing

- $P_i$ shares information, $P_j$ does not
- FOCs are
  \[
  \mathbb{E}_{\theta_j} \left[ S_1(q_i^e(\theta), q_j^e(\theta_j, \theta)) \mid \theta \right] = \theta
  \]
  \[
  \mathbb{E}_{\theta_j} \left[ S_1(q_i^e(\overline{\theta}), q_j^e(\theta_j, \overline{\theta}) \mid \overline{\theta} \right] = \overline{\theta} + \frac{\nu}{1-\nu} \Delta \theta
  \]
  \[
  S_1(q_j^e(\theta, \theta_i), q_i^e(\theta_i)) = \theta \quad \forall \theta_i
  \]
  \[
  S_1(q_j^e(\overline{\theta}, \theta_i), q_i^e(\theta_i)) = \overline{\theta} + \frac{\nu}{1-\nu} \frac{\Pr(\theta_i \mid \theta)}{\Pr(\theta_i \mid \overline{\theta})} \Delta \theta \quad \forall \theta_i
  \]
- $P_i$ conditions her contracts only on $\theta_i$, while $P_j$ conditions her contract on $\theta_j$ and $\theta_i$
Unilateral information sharing

- $P_i$ shares information, $P_j$ does not
- FOCs are
  \[
  \mathbb{E}_{\theta_j} \left[ S_1(q_i^e(\theta), q_j^e(\theta_j, \theta)) \right] = \theta \\
  \mathbb{E}_{\theta_j} \left[ S_1(q_i^e(\bar{\theta}), q_j^e(\theta_j, \bar{\theta}) \right] = \bar{\theta} + \frac{\nu}{1-\nu} \Delta \theta \\
  S_1(q_i^e(\theta, \theta_i), q_j^e(\theta_i)) = \theta \quad \forall \theta_i \\
  S_1(q_j^e(\bar{\theta}, \theta_i), q_i^e(\theta_i)) = \bar{\theta} + \frac{\nu}{1-\nu} \frac{\Pr(\theta_i|\theta)}{\Pr(\theta_i|\bar{\theta})} \Delta \theta \quad \forall \theta_i
  \]
- $P_i$ conditions her contracts only on $\theta_i$, while $P_j$ conditions her contract on $\theta_j$ and $\theta_i$
  \[\Rightarrow P_j \text{ has a competitive advantage relative to } P_i \text{ since she can impose a higher distortion in the less likely states}\]
Do principals share information?

- **Proposition**: When agents are privately informed about their marginal costs:

  - If $\delta \alpha < 0$, there is a unique equilibrium in dominant strategies in which both principals share information
  - If $\delta \alpha > 0$, there is a unique equilibrium in dominant strategies in which no principal shares information
  - If $\delta = 0$, principals are indifferent between sharing information or not
Intuition

- Principals share information iff $\delta \alpha < 0$
**Intuition**

- Principals share information iff $\delta \alpha < 0$
- If $\delta \neq 0$, a correlated distortion effect induces principals to coordinate outputs:
Intuition

- Principals share information iff $\delta \alpha < 0$
- If $\delta \neq 0$, a correlated distortion effect induces principals to coordinate outputs:
  - Suppose that $\alpha > 0$
Intuition

- Principals share information iff $\delta \alpha < 0$
- If $\delta \neq 0$, a correlated distortion effect induces principals to coordinate outputs:
  - Suppose that $\alpha > 0$
  - If $P_i$ shares information, $P_j$ distorts the output of her high-cost agent more (i.e. produces less) when $\theta_i = \theta$
    (since this is less likely than $\theta_i = \overline{\theta}$)
Principals share information iff $\delta \alpha < 0$

If $\delta \neq 0$, a correlated distortion effect induces principals to coordinate outputs:

- Suppose that $\alpha > 0$
- If $P_i$ shares information, $P_j$ distorts the output of her high-cost agent more (i.e. produces less) when $\theta_i = \theta$ (since this is less likely than $\theta_i = \bar{\theta}$)
- This increases $P_i$’s profits with strategic substitutes ($\delta < 0$) since $P_i$ wants to produce more when $P_j$ produces less
Intuition

- Principals share information iff $\delta \alpha < 0$
- If $\delta \neq 0$, a correlated distortion effect induces principals to coordinate outputs:
  - Suppose that $\alpha > 0$
  - If $P_i$ shares information, $P_j$ distorts the output of her high-cost agent more (i.e. produces less) when $\theta_i = \bar{\theta}$ (since this is less likely than $\theta_i = \tilde{\theta}$)
  - This increases $P_i$’s profits with strategic substitutes ($\delta < 0$) since $P_i$ wants to produce more when $P_j$ produces less
  - This reduces $P_i$’s profits with strategic complements ($\delta > 0$) since $P_i$ wants to produce less when $P_j$ produces less

The effect is of first-order: only the sign of $\delta$ matters and not its magnitude.
Principals share information iff $\delta \alpha < 0$

If $\delta \neq 0$, a correlated distortion effect induces principals to coordinate outputs:

- Suppose that $\alpha > 0$
- If $P_i$ shares information, $P_j$ distorts the output of her high-cost agent more (i.e. produces less) when $\theta_i = \overline{\theta}$ (since this is less likely than $\theta_i = \underline{\theta}$)
- This increases $P_i$'s profits with strategic substitutes ($\delta < 0$) since $P_i$ wants to produce more when $P_j$ produces less
- This reduces $P_i$'s profits with strategic complements ($\delta > 0$) since $P_i$ wants to produce less when $P_j$ produces less

The effect is of first-order: only the sign of $\delta$ matters and not its magnitude
The value of communication

- **Proposition.** Principals’ expected profits are higher when they both share information than with no communication.
The value of communication

- **Proposition.** Principals’ expected profits are higher when they both share information than with no communication.

- Since costs are correlated, communication creates an informational externality that reduces agents’ rent.
Proposition. Principals’ expected profits are higher when they both share information than with no communication.

Since costs are correlated, communication creates an informational externality that reduces agents’ rent.

(For small externalities, this effect is stronger than the strategic effect due to correlated distortions.)
**Proposition.** Principals’ expected profits are higher when they both share information than with no communication.

Since costs are correlated, communication creates an *informational externality* that reduces agents’ rent. (For small externalities, this effect is stronger than the strategic effect due to correlated distortions.)

**Corollary.** Principals’ decision not to share information when $\delta \alpha > 0$ does not maximize their joint profits.
Conclusions

- When do principals independently choose to share the information obtained from informed agents?
Conclusions

- When do principals independently choose to share the information obtained from informed agents?
- Principals want to:
When do principals independently choose to share the information obtained from informed agents?

Principals want to:

- affect rivals’ strategies because of externalities
Conclusions

- When do principals independently choose to share the information obtained from informed agents?
- Principals want to:
  - affect rivals’ strategies because of externalities
  - reduce agents’ information rents
Conclusions

- When do principals independently choose to share the information obtained from informed agents?
- Principals want to:
  - affect rivals’ strategies because of externalities
  - reduce agents’ information rents
- Incentive to share information only depend on the sign of $\delta \alpha$