

Free Riding in Networks

Notes on Varian (2004)
System Reliability and Free Riding
with applications to network
security and reliability
[based on Honeyman, Schwartz and Van Assche
*“Interdependence of Software
Reliability and Security”*]

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Plan

- Varian considers:
 - 1. Total effort
 - 2. Weakest link
 - 3. Best shot
- We will discuss:
 - When & where do we expect 1, 2, 3 in networks?
 - How to improve the equilibrium (i.e., how to alleviate free riding / reduce the wedge between social & individual optimum)
 - Reliability and security are interdependent. With respect to policies, these two questions **has to be** considered as ONE question: R&S.

Varian (2004): free riding & how to improve the outcome

- Free riding = social & private optimum differ
- Π_1 wrt x_1 and Π_2 wrt x_2
$$\Pi_1 = \max[v_1 P(F(x_1, x_2)) - c_1 x_1]$$
$$\Pi_2 = \max[v_2 P(F(x_1, x_2)) - c_2 x_2]$$
- Social optimum (wrt x_1 and x_2)
$$\Pi = \max[(v_1 + v_2) P(F(x_1, x_2)) - c_1 x_1 - c_2 x_2]$$
- Varian's tools: fines (strict liability) and due care may help to achieve social optimum
- These tools make incentives closer to socially optimal (i.e., lessen free riding). How? (It's just math., stupid!) But really, what do these tools change? (information, incentives, market competition)

Varian (2004)

- Varian considers:
- 1. Total effort: $F(x_1, x_2) = x_1 + x_2$
 - Perfect substitutes
 - Sum of efforts
- 2. Weakest link: $F(x_1, x_2) = \min(x_1, x_2)$
 - perfect complements
 - min effort
- 3. Best shot: $F(x_1, x_2) = \min(x_1, x_2)$
 - Max effort
 - Similar to 1
- Why 1, 2, 3 lead to free riding?
 - Socially and Privately optimal efforts DIFFER

Varian (2004): the intuition behind the equilibrium

- 1. Total effort: $F(x_1, x_2) = x_1 + x_2$
 - Only the agent with highest benefit-cost ratio invests effort
 - if sequential moves reliability is lower (reliability is higher if the agent with lower benefit-cost ratio moves first)
- 2. Weakest link: $F(x_1, x_2) = \min(x_1, x_2)$
 - All agents match the agent with the lowest benefit-cost ratio
 - same reliability in sequential and simultaneous games
- 3. Best shot: $F(x_1, x_2) = \max(x_1, x_2)$
 - 3. is similar to 1. → let's focus on 1 & 2
- Networks: Why free riding becomes important when the number of agents is large?
 - Two agents can contract & resolve free riding (as in Coase(1960)). If a large number of agents → more difficult
 - If many agents:
 - 1: large teams have an advantage (do they?)
 - 2: one bad apple among hundreds good apples → a huge inefficiency (→ small teams have an advantage)

Varian (2004): fines, strict liability & due care standard (negligence rule):

- 1. Total effort: $F(x_1, x_2) = x_1 + x_2$
 - Social optimum: Impose a fine (if system fails) on the agent with the lowest cost: a strict liability rule (payment to the other agent). BUT incentives? Tort law = the agent with the least cost of effort to avoid a failure should bear the liability. → conflicts: incentives to seek damages (+ too many plaintiffs), incentives to deny a system failure
- 2. Weakest link: $F(x_1, x_2) = \min(x_1, x_2)$
 - If identical agents → outcome is socially efficient; if not – impose a due care level (negligence rule); strict liability does not work [strict liability = infinite due care level?]
 - Due care: if care is less than due → must pay the other party's costs of failure (BUT: what happens if the weakest link was earning zero profits before the due care imposition? → he will not produce)

Varian (2004): fines, strict liability & due care standard (negligence rule): and a link to missing markets

- Networks and legal liability: problems
 - Legal liability could be socially suboptimal (indeed, due to conflicts of incentives and poor information → no legal liability for software)
- Networks and due care standard: problems
 - Optimal due care can differ with agents
 - Who chooses the standard? Why government should be involved? How to enforce the standard?
 - Due care works (creates gains) with perfect information, but if information is incomplete
 - (i) imperfect (uncertainty)
 - (ii) asymmetric (strategic manipulation)
 - Imposition of a due care will also impose losses → have to address sources of gains & losses

Extending Varian (2004): Reliability and Security [R&S]

- Varian: reliability or security but NOT on both. But R&S are interdependent:
 - Driven by errors (bugs)
 - Users cannot distinguish R & S failures →
$$f = f^r + f^s$$
- User demand $p(f)$ is decreasing & concave in f
$$p' < 0 \quad \& \quad p'' < 0$$
- x_m is the number of bugs for the m -th manufacturer $\mathbf{x} = x_1, \dots, x_M$
- $f(\mathbf{x}) = f^r(\mathbf{x}) + f^s(\mathbf{x})$ and convex in x_m
$$\partial f(\mathbf{x}) / \partial x_m > 0 \quad \& \quad \partial^2 f(\mathbf{x}) / \partial x_m^2 < 0$$

Reliability and Security [R&S] with M manufacturers

- Manufacturer m invests q_m to reduce his number of bugs $x_m \rightarrow$ this reduces the number of system failures f (if $x_m \downarrow \rightarrow f \downarrow$ and $p(f) \uparrow$)
- Manufacturer m chooses x_m & q_m
- Manufacturer's m objective:

$$\Pi_m = \max[S^m - r^m q_m]$$

$$S^m = a^m p(f) \text{ and } \sum a^m = 1 \text{ and } \sum S^m = p(f)$$

- Social planner chooses vectors \mathbf{x} & \mathbf{q}
- Social planner's objective:

$$\Pi = \max[p(f) - \sum r^m q_m]$$

Reliability and Security [R&S]

R = total effort & S = weakest link

- $p(f)$ if users cannot distinguish f^r & f^s (R&S are interdependent)
- $P(f^r, f^s)$ if users are able to distinguish f^r and f^s
- $P(f^r, f^s) \neq p(f) = p(f^r + f^s)$
- We assume:
 - $f^r(\mathbf{x}) = \sum_{m=1 \div M} (\theta^m x_m)$ [total effort]
 - $f^s(\mathbf{x}) = \max_{m=1 \div M} (\omega^m x_m)$ [weakest link]
 - The number of fixed bugs is proportional to investment q_m
 $x_m = \underline{x}^m - \gamma^m q_m$
- \rightarrow Manufacturer optimization as his choice of q_m
 - $\Pi_m = \max[q_m p(f) - r^m q_m]$
 - $f = \sum_m (\theta^m x_m) + \max_m (\omega^m x_m)$
- We prove that there exists a unique equilibrium (if the 'ties' are ignored)

The equilibrium of the game:
 $R = \text{total effort} \ \& \ S = \text{weakest link}$

- Manufacturer optimization:

$$\Pi_m = \max[a^m p(f) - r^m q_m]$$

$$f = \sum_m (\theta^m x_m) + \max_m (\omega^m x_m)$$

$$x_m = \underline{x}^m - \gamma^m q_m$$

- We define: $\underline{f} = f(\mathbf{q}=0) = f(\underline{\mathbf{x}})$,
- and let f_t and f_w be the solutions of

$$-p'(f_t) = \min_m [r^m / a^m \gamma^m \theta^m]$$

$$-p'(f_w) = \max_m [r^m / a^m \gamma^m (\theta^m + \omega^m)]$$
- In equilibrium: $f^* = \min(\underline{f}, f_t, f_w)$

making sense of R & S interdependence

- Interdependence of R & S occurs if $p(f) = p(f^r + f^s)$
- In equilibrium: $f^* = \min(f_l, f_t, f_w)$
 - $p'(f_t) = \min_m [r^m / a^m \gamma^m \theta^m]$
 - $p'(f_w) = \max_m [r^m / a^m \gamma^m (\theta^m + \omega^m)]$
- Varian (2004) recommends due care. Does due care help if R&S?
- Due care standard improves the outcome only if the standard is binding for the weakest link (but with R&S, the weakest link depends on BOTH, security and reliability parameters → No standard should be based solely on security or reliability)
- Interpretation: if due care is imposed to tackle R, it may worsen S

Regulations

when R & S are interdependent

- User cannot distinguish causes of system failures: How to formulate a due care standard for a:
 - Hacker (i.e., user)
 - Manufacturer
 - Transport provider?
 - Content provider?
- Effects of due care standard on:
 - Information [better or worse?]
 - More info: info is required;
 - Less info: more incentives to hide / alter info
 - Incentives [gains & losses]
 - Gains: improved investment incentives
 - losses: costs (possibly tremendous) of due care standard – enforcement issues, etc.
 - Competition [unclear effects]
 - More competition (ala Akerlof mechanism)
 - Less competition (if some agents stop producing)

Why & When to Regulate?

When governments are superior to markets?

- When governments should regulate? (i.e., when markets cannot resolve inefficiencies?) Answer: Only if government has tools that markets cannot replicate (but when markets cannot? If externalities are present)
- Q: Could a third party design a better (cheaper) due care standard than the government? A: Only if this third party has tools to resolve free riding
- If markets fail, but regulation improves:
 - Information (regulation to reduce uncertainty)
 - Incentives (+ a connection to asymmetric information)
 - Competition structure
- Also, regulations (laws) help to create markets [ex. create institutions, which promote / permit new goods (highways, patents, insurance)]

Summary of Today & on Future Plans

- Today:
 - Varian (2004) free riding, networks and missing markets
 - Network regulations needed only if such regulation CREATE (help to create) these missing markets
- Interdependence of security and reliability
- How to implement a due care standard?
 - Manufacturers (security and reliability)
 - Network providers
 - Transport providers – similar to problem with manufacturers (need to look at both, security and reliability)
 - Content providers ? (they are network users too)
 - Users (+ hackers)? But how?
- Problems of implementation:
 - If only some agents are subject to a due care standard → incentives to shift responsibility to other agents
- Comments are very welcome!

Mancur Olson on Free riding

- Olson (...): Question: How to resolve free riding in large groups (many agents)?
- Answer:
 - If a group is dispersed (ex. Users) it takes LONG to resolve free riding
 - To resolve free riding: need a party that will have concentrated GAINS when free riding is resolved (ex. network neutrality & google's profits)