Enforcing Truthful-Rating Equilibria in Electronic Marketplaces

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Overview

- Problem definition and related work
- The basic model (fixed punishments) and its analysis
- The extended model (reputation-based punishments) and its analysis
- Conclusions – Future Work

Reputation in Peer-to-Peer Systems

- Reputation reveals hidden information
- Only effective with reputation-based policies [1]
  - "Provider Selection" and "Contention Resolution" ones
- But, reputation is vulnerable to false or malicious ratings
- Thus, collect ratings from both transacted parties and punish both in case of disagreement [2]
  - At least one of them is lying
  - Punishment is not monetary

[1] "Reputation-based policies that provide the right incentives in peer-to-peer environments", Computer Networks, vol. 50, no. 4, March 2006.

[2] "An Incentives' Mechanism Promoting Truthful Feedback in Peer-to-Peer Systems", GP2PC'05.

The Context

- Reputation is studied in electronic marketplaces where participants act
  - both as providers and as clients
  - competitively, so as to maximize their market share
  - E.g. exchanging vinyl records among collectors, software modules among programmers, etc.

- Provider selection based on reputation

- Malicious rating may offer competitive advantage

Our Objectives

- Provide incentives for truthful rating in such a context

To this end:

- Analyze the dynamics of fixed monetary punishments
- Find necessary conditions for stable truthful rating equilibrium
- Customize punishments w.r.t. reputation to reduce social unfairness

Related Work – Monetary Penalty Approaches

- Miller, Resnick, Zeckhauser: Truthful rating is a Nash equilibrium for clients if certain penalties are induced to them for potential lying

- Jurca, Faltings: Side-payments upon evidence of lying; clients do not act as providers

- Dellarocas: Penalty to provider to compensate payoff gains from offering lower quality than promised. Nash equilibrium for truthful clients

What is innovative

- Dual role of participants
- Reputation-based competition and impact on incentives for truthful reporting
- Stability analysis of truthful-rating Nash equilibrium enforced by each mechanism
- Tailored reputation-based punishments

The Basic Model

The Basic Model

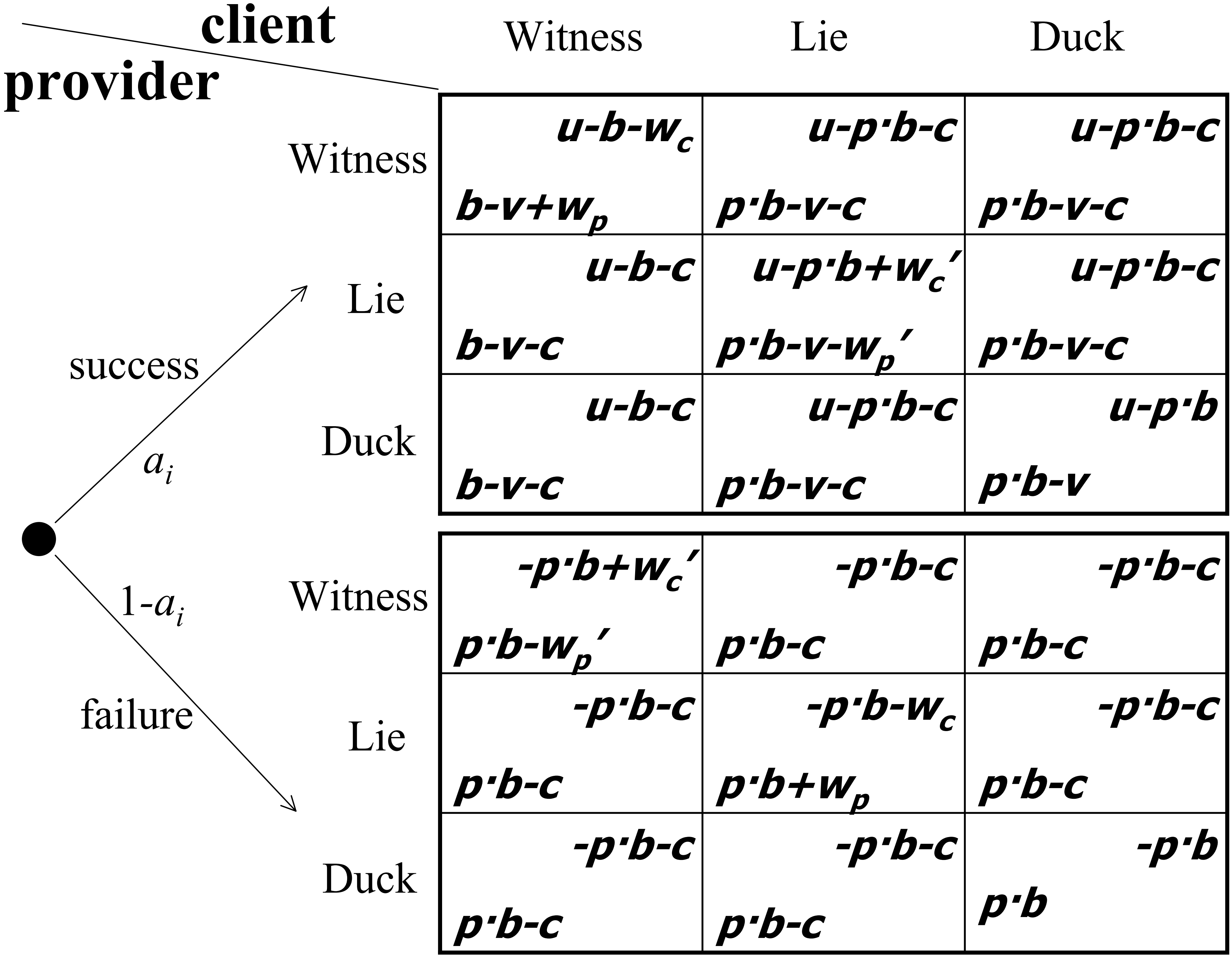
- E-marketplace with N participants
  - N either fixed or mean number of participants with geometrically distributed lifetimes
- Each participant has a probability a_i to provide service instances successfully, i.e. of satisfactory quality
  - Private information; reputation is an estimate for it
- A successfully provided service instance:
  - Offers fixed utility u to the client
  - Demands costly effort v
  - Costs b to the client, with pre-payment $p \cdot b$ to balance the risks
- Time is discretized in rounds

At each round...

- Each participant may act as a provider with probability q and as a client with probability $1\text{-}q$
- Reputation-based policy: Clients associate to providers probabilistically fair to the reputation of the latter
  - Demand attracted by provider i is proportional to his rank $R_i = \frac{r_i}{\bar{r}}$
- Both transacted parties have to rate service provision
  - Upon agreement, the client pays $(1\text{-}p)\cdot b$ and the vote is registered for the provider
  - Disagreement incurs fixed punishment c to both

Single Transaction Game

- Two sub-games depending on the service provision outcome: success or failure
- Reporting strategies in S={*Witness, Lie, Duck*}
- Impact of agreed rating to future payoffs of participants
  - A positive rating results to $w_p > 0$ and $-w_c < 0$ payoff impacts for the provider and the client respectively
  - A negative rating results to $-w_p' < 0$ and $-w_c' > 0$ payoff impacts for the provider and the client respectively
- w_p , w_p', w_c, w_c' are taken fixed



	Witness	Lie	Duck
Witness	$u-b-w_c$ $b-v+w_p$	$u-p\cdot b-c$ $p\cdot b-v-c$	$u-p\cdot b-c$ $p\cdot b-v-c$
Lie	$u-b-c$ $b-v-c$	$u-p\cdot b+w_c'$ $p\cdot b-v-w_p'$	$u-p\cdot b-c$ $p\cdot b-v-c$
Duck	$u-b-c$ $b-v-c$	$u-p\cdot b-c$ $p\cdot b-v-c$	$u-p\cdot b$ $p\cdot b-v$

	Witness	Lie	Duck
Witness	$-p\cdot b+w_c'$ $p\cdot b-w_p'$	$-p\cdot b-c$ $p\cdot b-c$	$-p\cdot b-c$ $p\cdot b-c$
Lie	$-p\cdot b-c$ $p\cdot b-c$	$-p\cdot b-w_c$ $p\cdot b+w_p$	$-p\cdot b-c$ $p\cdot b-c$
Duck	$-p\cdot b-c$ $p\cdot b-c$	$-p\cdot b-c$ $p\cdot b-c$	$-p\cdot b$ $p\cdot b$

Truthful Equilibrium Conditions and Stability

Truthful Nash Equilibrium

- Derive conditions for disagreement punishment so as truthful reporting is a Nash equilibrium in both sub-games

- Disagreement may rationally happen only in two cases
  - Upon success: providers Witness and clients Lie or Duck
  - Upon failure: clients Witness and providers Lie or Duck

- Witness is best response to itself when $c > (1\text{-}p)\cdot b+w_c$ and $c > w_p$'

- Does this equilibrium arise? Is it stable?

Evolutionary Stability

- Evolutionary Stable Strategy (ESS):
  1. Nash equilibrium
  2. Better reply to any mutant strategy than the latter to itself

- Strict Nash equilibrium of the asymmetric game ⬄ ESS of its symmetric version

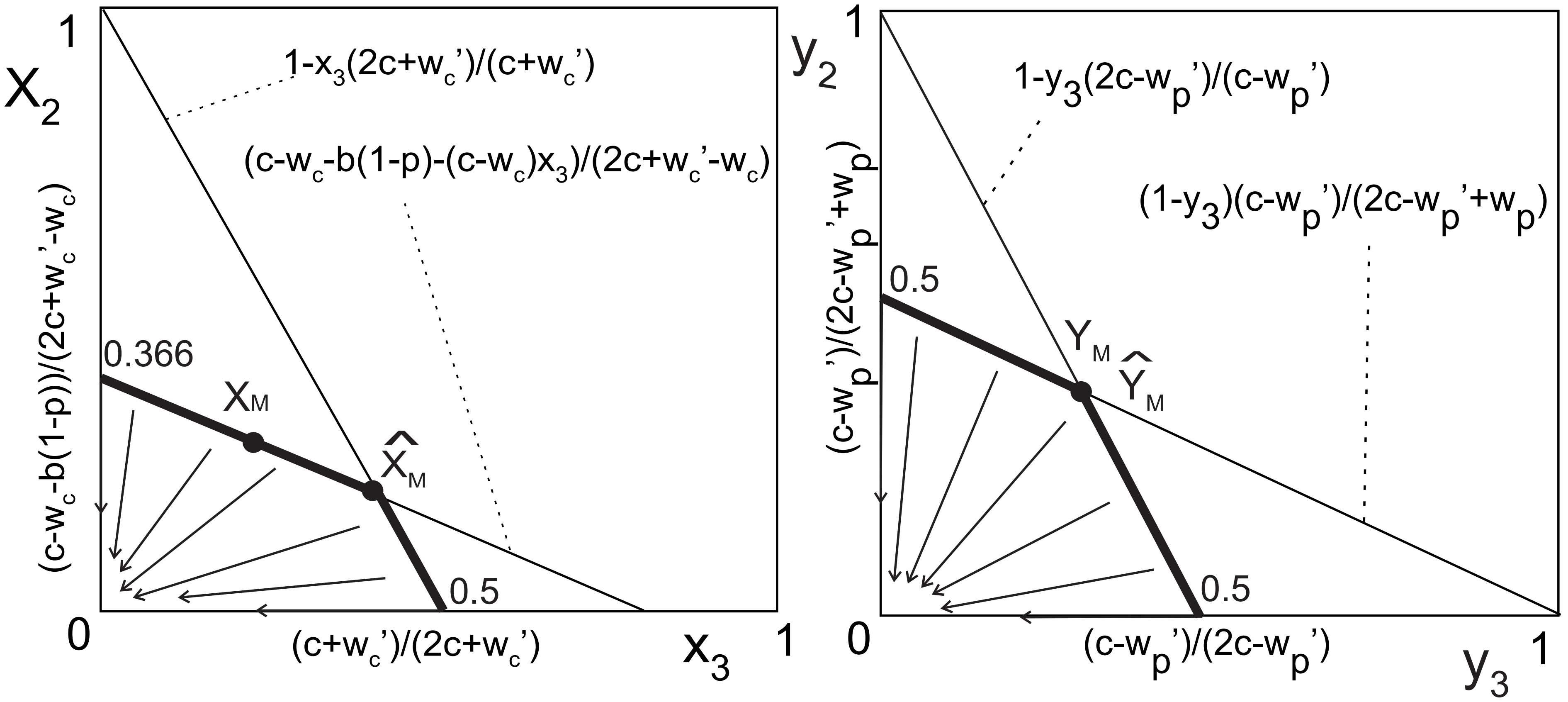
- Evolutionary dynamics for strategy s with payoff π_s played by a population fraction x_s:

$$\dot{x}_s = \frac{dx_s}{dt} = x_s(\pi_s - \overline{\pi})$$

Stable Truthful Reporting

- (x_1, x_2, x_3) (resp. (y_1, y_2, y_3)) the population fractions of providers (resp. clients) that play (*Witness*, *Lie*, *Duck*) respectively
- Basin of attraction: Region for population mix that ultimately leads to the stable equilibrium
- <u>Proposition 1:</u> The basin of attraction of ESS truthful reporting is the region $X^* \times Y^*$ given by the conditions on x_2, x_3 and y_2, y_3 …

The Basin of Attraction



The Extended Model

The Extended Model

- Two important differences from basic model
  - Monetary disagreement punishment is not fixed but depends on the transacted participant’s rank and its role
  - Payoff impacts of a vote are not taken fixed, but they are calculated algebraically
  - Expected payoff at round t for a participant i:

$$V(\overset{\text{rank}}{R_i^{(t)}},\overset{\text{success probability}}{a_i}) = q\frac{1-q}{q}R_i^{(t)}[a_i(b-v)+(1-a_i)pb]+$$

$$+(1-q)[\overline{a}(u-b)+(1-\overset{\text{mean success probability}}{\overline{a}})(-pb)]$$

Innovative Reputation Metric

- Beta reputation metric: $r' = \frac{\beta z + \mathbf{1}(success)}{\beta n + 1}$
- Results to time-dependent impact of a single vote to rank values of transacted parties
- Solution: An innovative reputation metric

$$r' = \beta r + \mathbf{1}(success)(1-\beta)$$

- Now, rank impacts are not time-dependent, e.g.

$$\Delta R_p^+ = \frac{1-q}{q} R(\frac{\beta R\bar{r} + 1 - \beta}{\bar{r} + \frac{1-\beta}{\mathrm{N}}(1-\bar{r})} - R)$$

Rank-based Punishments

- Derive conditions for disagreement punishments enforcing the truthful rating equilibrium
  - Proposition 2

- Outline of Proof. Single stage deviation from truthful reporting at stage t should not be beneficial.

  Conditions on c_i and c_j are …

Conditions on c_i, c_j

- c_i is given by:

$$c_i(R_i^{(t)}) > \sum_{\tau=t+1}^{\infty} \delta^{\tau-t} [V(\widetilde{R}_i^{(\tau)}) - V(R_i^{(\tau)})]$$

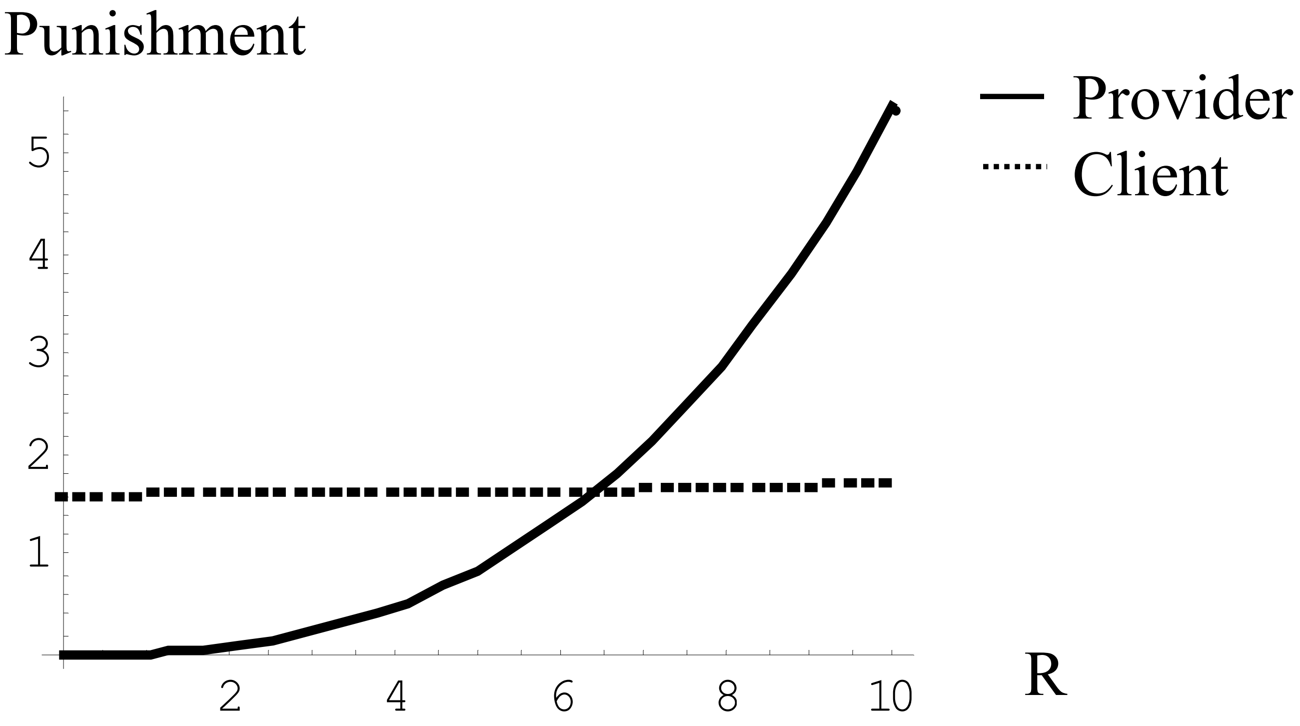
  - As N is large, c_i is approximated by a simple formula

- c_j is given by:

$$c_j(R_j^{(t)}) > (1-p)b + \sum_{\tau=t+1}^{\infty} \delta^{\tau-t} [V(\widetilde{R}_j^{(\tau)}) - V(R_j^{(\tau)})]$$

  - This can be bounded from above and below

Numerical Example



- N=1000, q=0.4, p=0.2, b=2, u=2.5, v=0.5, β=0.6

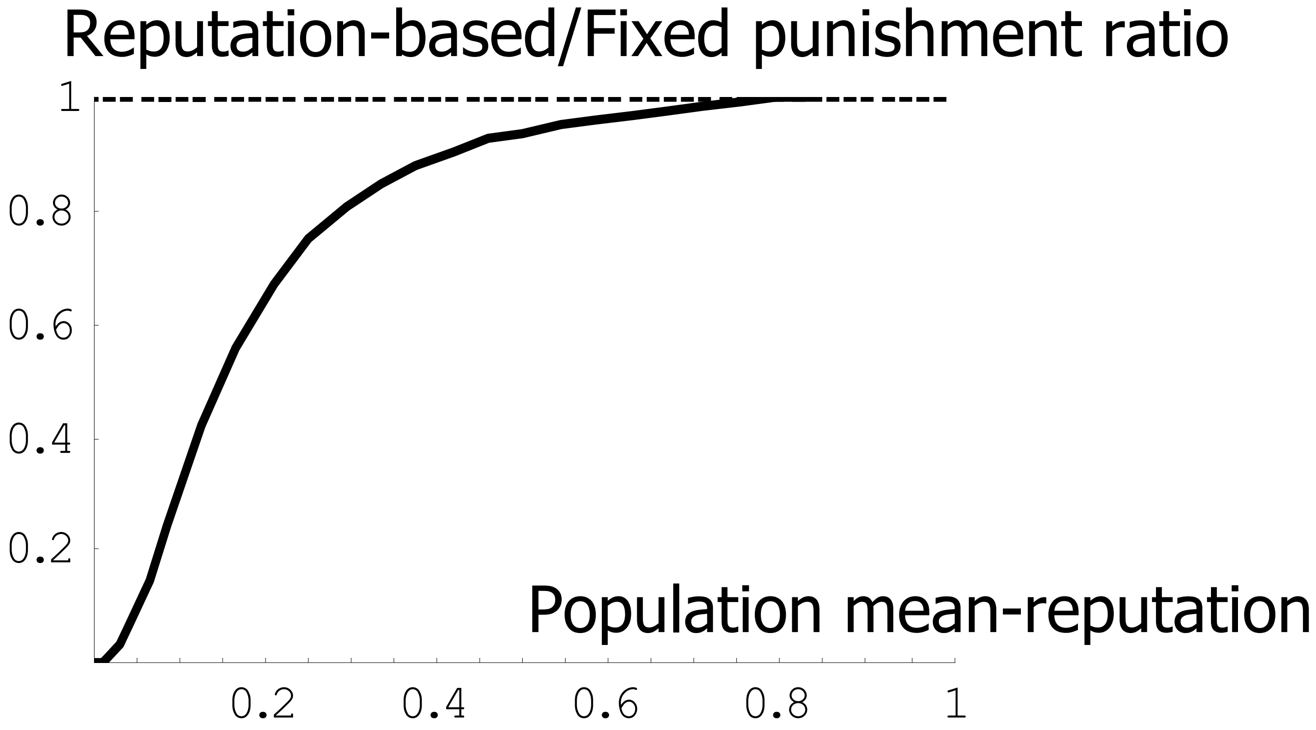
Social Loss Estimation

Social Loss

- Disagreement punishment is unfairly induced to one of the transacted peers → social loss
- When punishment is fixed, $c > q\, w_p' + (1\text{-}q)[(1\text{-}p)b+w_c]$
  - The maximum payoff impacts w_p', w_c have to be assumed
- Thus, an unfairness is created for all the non-highest ranked participants → greater social loss
- Reputation-based punishments prevent this unfairness!

Numerical Example

- Average ratio of social loss per participant per disagreement for various mean reputation values



- Normal distribution of ranks with (μ, σ)=(1, 0.5)

Concluding Remarks

Summary of our Contribution

- Proposed a simple mechanism that provides incentives for truthful rating in an interesting context of an e-marketplace
    - Reputation-based competition
    - Dual role of participants
- Derived conditions on the effectiveness of such a mechanism with fixed punishments
    - Stability analysis of truthful-rating Nash equilibrium
- Tailored reputation-based punishments
    - Calculated the payoff impacts of a rating to provider and client
- Calculated the attained social loss reduction

Recent and Future Work

- Employ different fixed punishments for provider and client
- Relax the condition on fixed success probability of participants
- Derive upper bound in the achievable social loss reduction by reputation-based disagreement punishments
- Explore stability conditions for truthful equilibrium with reputation-based disagreement punishments