

# The Perils of Exploration Under Competition:

## A Computational Modeling Approach

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### Summary & Goals

Firms face a trade-off between *exploration* and *competition*

- **Explore** to gain information to make better product tomorrow
- **Incentivize** consumers to pick me over competition today

Are “better” algorithms incentivized under competition?

- **Greedy (GR)**: pick what seems best
- **Epsilon-Greedy (EGR)**: random choice with epsilon probability, greedy otherwise
- **Adaptive (AD)**: gradually zoom in on the best arm

### Model

#### Firms:

Face identical multi-armed bandit instances

Only make progress on their learning problems if incentivize consumers to pick them over their competitors

Aim to maximize expected market share

#### Consumers:

Live a single period and aim to maximize current period utility

Choice rule: select firm with highest reputation score

Reputation score for firm  $i$  is sliding window average of reward previous  $M$  consumers experienced from  $i$ .

### Method: Numerical Simulations

Consider three representative classes of instances:

- Needle-in-Haystack: 1 “good” arm,  $K-1$  “bad” arms
- Uniform: mean rewards drawn from Uniform[0.25, 0.75]
- Heavy-Tail: mean reward drawn from Beta(0.6, 0.6)

Each experiment: competition between two bandit algorithms

- Parameters: bandit algorithms, competition model, bandit instance

### Exploration Death Spiral

“Better” algorithms in isolation  $\neq$  “Better” algorithms in competition  
Algorithms that explore may fall into “death spiral” vs Greedy

**Exploration** ➡ **Lower Reputation**

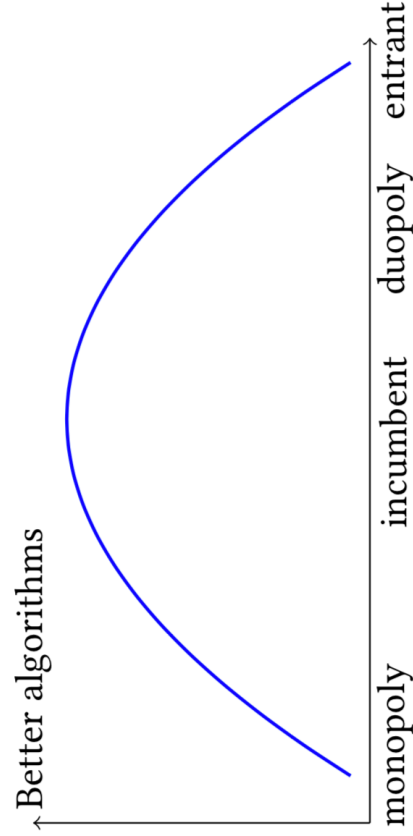


**Fewer Users**

### Equilibrium Strategies

Inverted-U relationship between competition and innovation

- Classic theme in economics
- Competition varied by timing of entry and number of firms



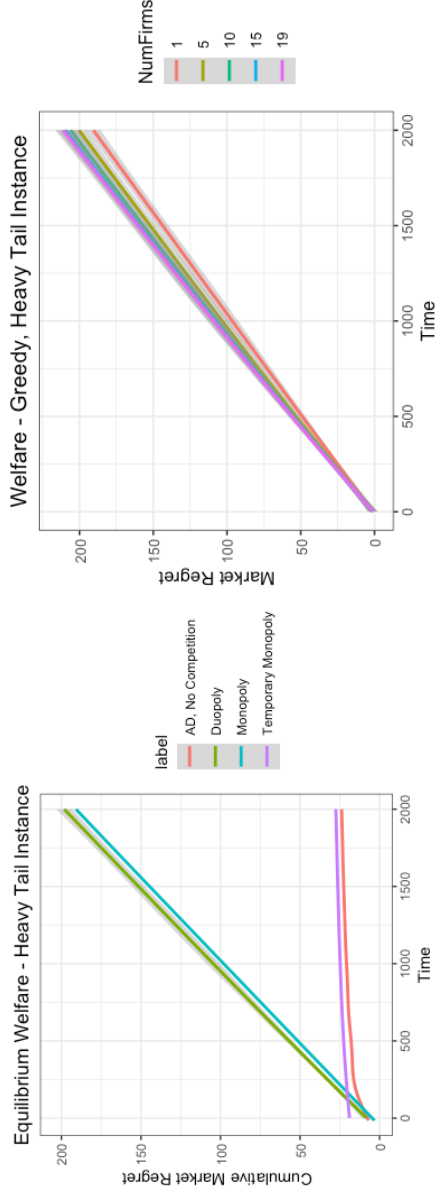
### Consumer Welfare

#### Simultaneous Entry

- Greedy wins in equilibrium => low consumer welfare

#### First Mover Advantage

- Better algorithms wins in equilibrium => higher welfare



### Data vs Reputation

First mover has a **data** and **reputation** advantage over entrant

- Both serve as strong barriers to entry alone
- Data advantage stronger when “better” algorithms deployed

	Reputation advantage (only)			Data advantage (only)		
	AD	EGR	GR	AD	EGR	GR
AD	$0.021 \pm 0.009$	$0.16 \pm 0.02$	$0.21 \pm 0.02$	$0.0096 \pm 0.006$	$0.11 \pm 0.02$	$0.18 \pm 0.02$
EGR	$0.26 \pm 0.03$	$0.3 \pm 0.02$	$0.26 \pm 0.02$	$0.073 \pm 0.01$	$0.29 \pm 0.02$	$0.25 \pm 0.02$
GR	$0.34 \pm 0.03$	$0.4 \pm 0.03$	$0.33 \pm 0.02$	$0.15 \pm 0.02$	$0.39 \pm 0.03$	$0.33 \pm 0.02$

User share of row player (entrant) after 2000 rounds

### Conclusions

- Traditionally “better” algorithms are not always incentivized under competition due to the reputational consequences of exploration
- Data can serve as a barrier to entry in online platforms, especially when exploration has reputation costs