Bandits and Collusion

Mallesh Pai
with Karsten Hansen and Kanishka Misra (UCSD Rady)

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Worries with Algorithmic Pricing

As prices are increasingly set by algorithms in competitive markets, will these algorithms find appropriate/ competitive prices?

Increasingly understood that in theory, competing algorithms could discover collusive prices

Basic idea: bake "carrot-and-stick" incentives into your algorithm, rewarding competition for high prices and punishing low prices

These concerns are attracting interest in theory and antitrust settings (see e.g. Harrington 2018)

(Note that this requires each algorithm to see others' prices)

Don't observe competitors' prices

In many settings, firms don't observe competitors' prices directly— e.g. supermarket FMCG's

Supermarket may not share competitors' prices/ only share them with preferred partner

Firms therefore only observe own price and own demand.

What if all firms experiment on price using a bandit algorithm?

Note that they're estimating a misspecified model so it's not clear what they would converge to.

A simple framework

Two firms. $D_j(p_j, p_k) = \alpha - \beta p_j + \gamma p_k$.

Full information outcomes:

- Competitive: $p_C = \frac{\alpha}{2\beta - \gamma}$
- Collusive: $p_M = \frac{\alpha}{2(\beta - \gamma)}$

Suppose both firms estimate "misspecified" demand. See demand + random ϵ, own price. 2 benchmarks:

- If DGP has independent prices, demand biased but optimal prices competitive.
- If DGP has prices matched, demand is biased an optimal prices collusive.

What if both firms use bandit algorithms?

Simulations

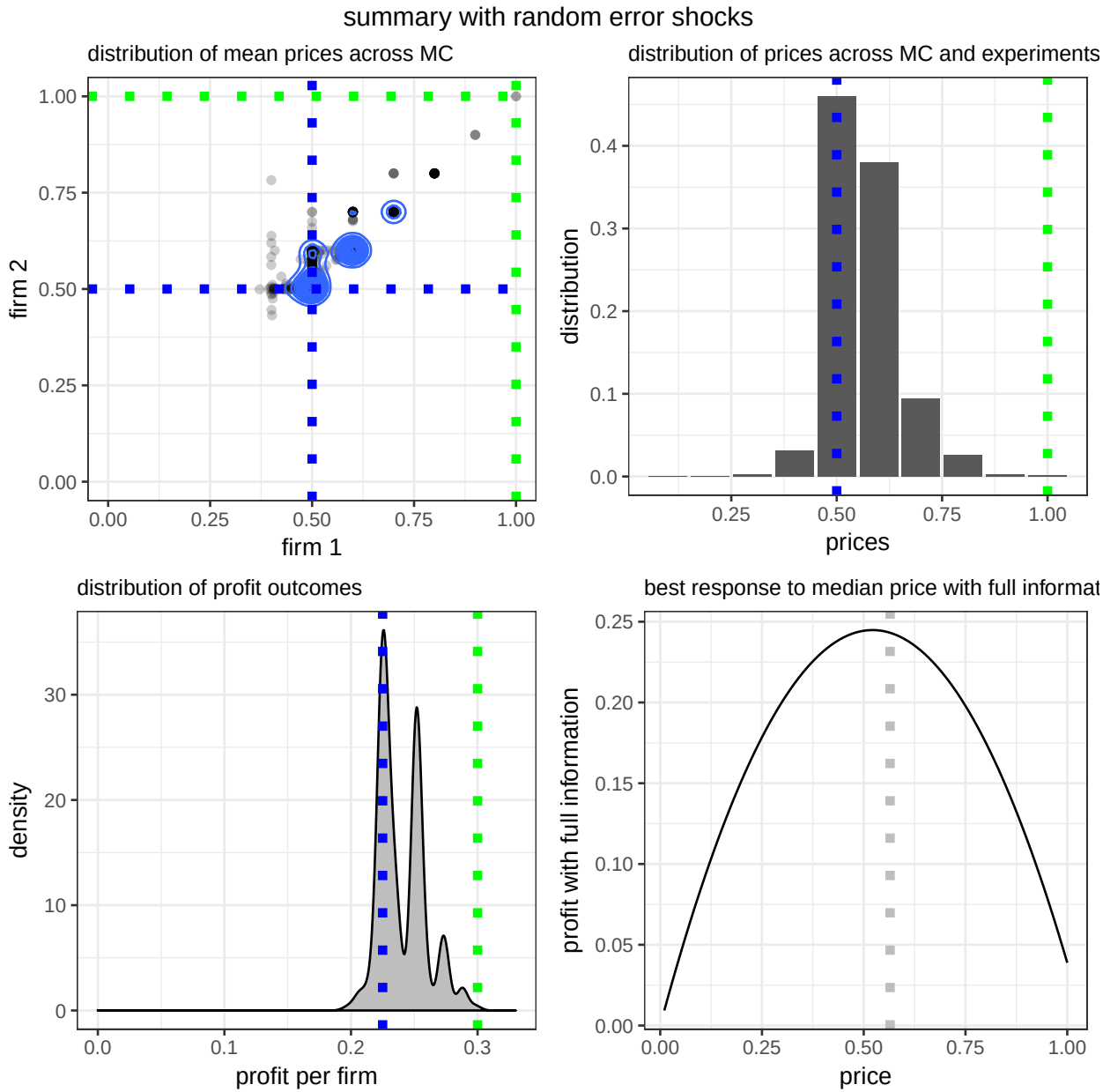
Both firms consider on a finite grid. Set prices randomly for first few periods, then do UCB.

Parameters: prices $0.1, 0.2, \ldots, 1$; $\alpha = 0.2$, $\beta = 0.9$, $\gamma = 0.8$, var(ϵ)$= 1$.

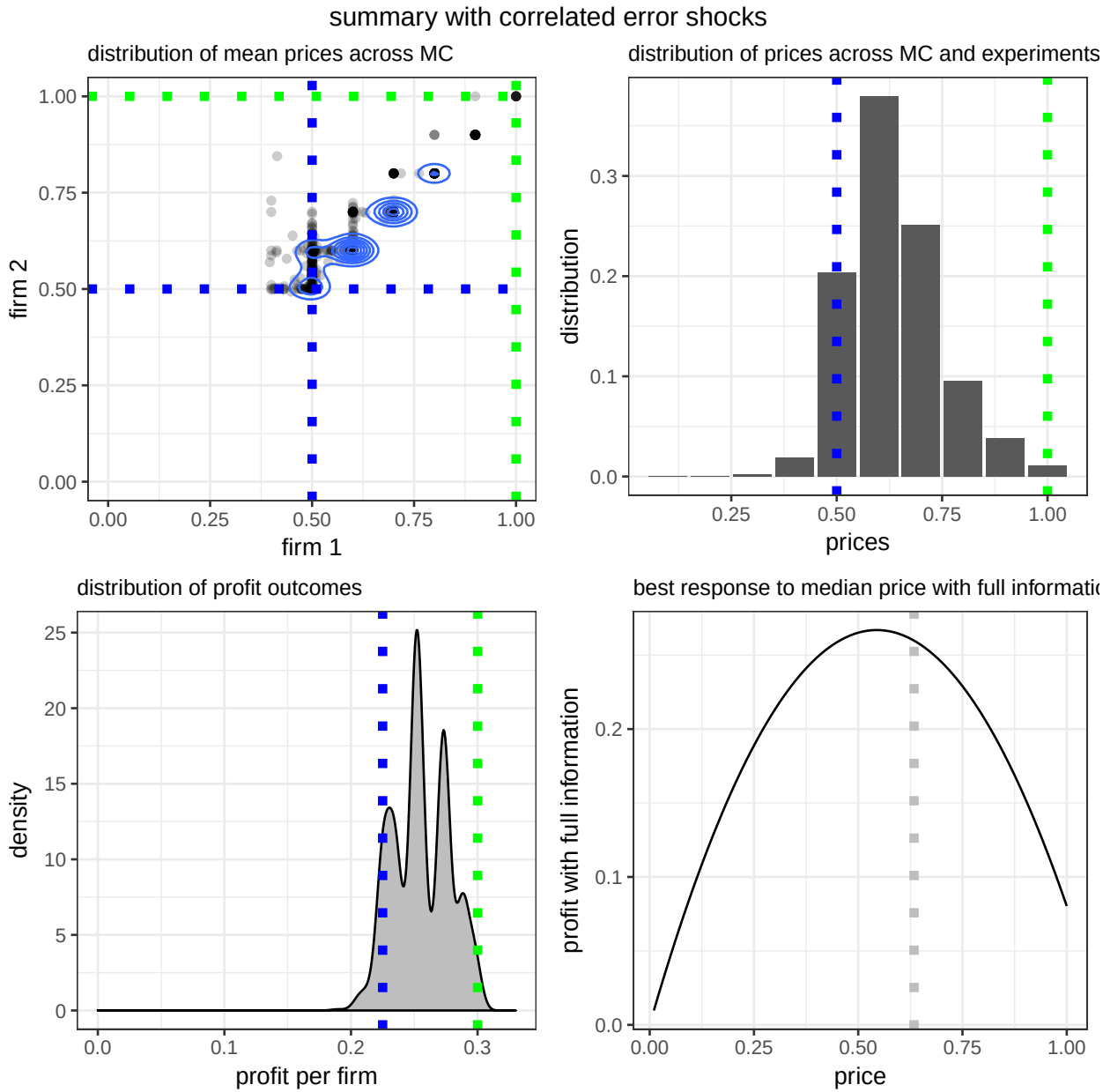
Competitive $p_C = 0.5$, Collusive $p_M = 1$.

What do steady state prices look like?

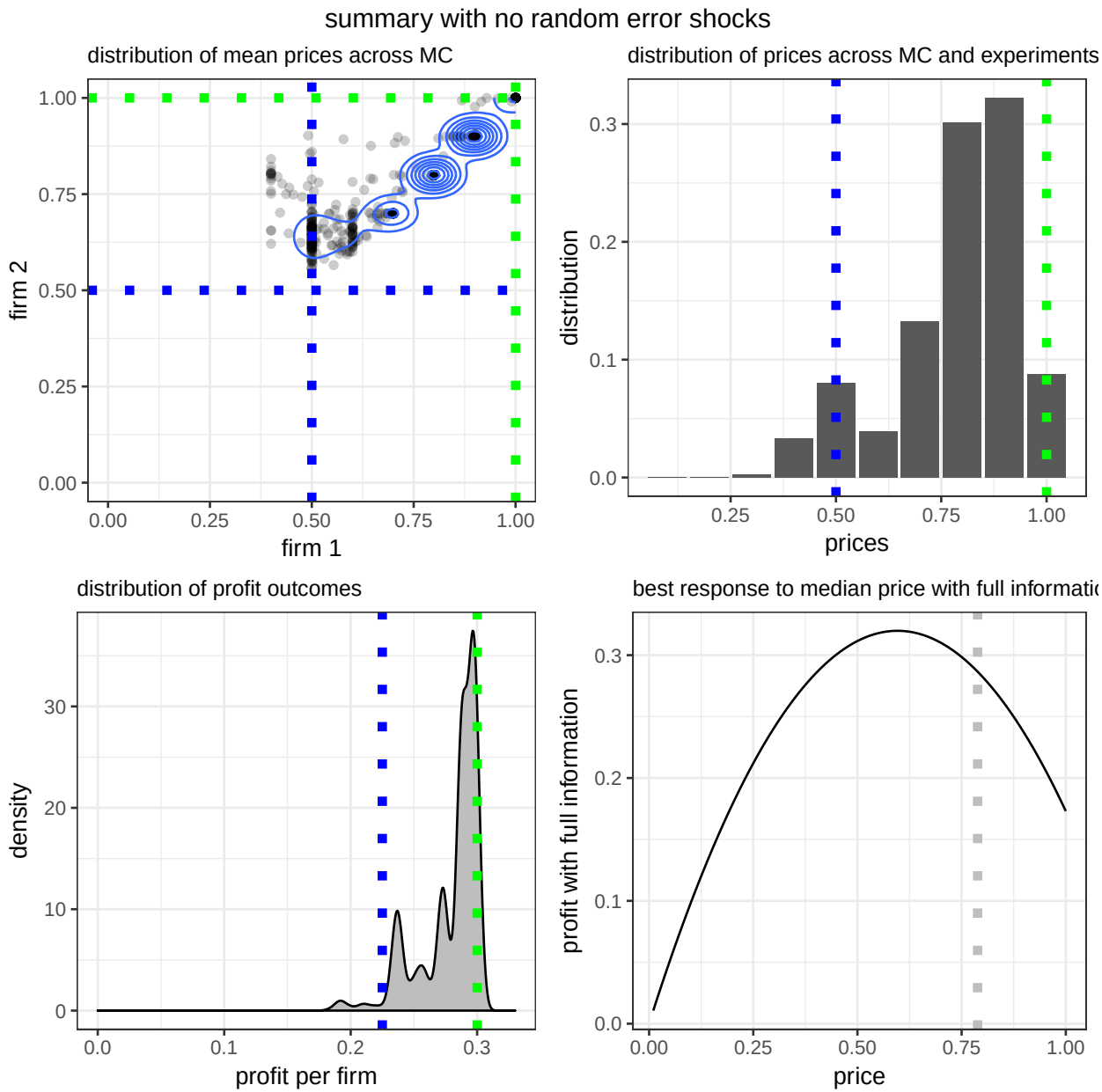
Independent Shocks



Correlated Shocks



No Shocks


summary with no random error shocks
distribution of mean prices across MC
firm 2
firm 1
0.00
0.25
0.50
0.75
1.00
distribution of prices across MC and experiments
distribution
prices
0.0
0.1
0.2
0.3
distribution of profit outcomes
density
profit per firm
0
10
20
30
best response to median price with full informatic
profit with full information
price

So, in summary

Q: Can independent profit maximizing computer algorithms lead to non-competitive prices?

A: Yes!

- Well beyond price matching!
- Even if firms do not consider strategic interaction—note that they don't in our simulations (each is running a naïve bandit)
- Should/Can policy do anything?