Possible Collusion and Equilibrium Prices

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Introduction

- Several markets in many countries have a reputation for anti-competitive behaviour, like the grocery market and the gasoline market.
- Our question: If buyers are suspicious that the sellers collude – buyers fear collusion – may that, in itself, increase prices?
- Hard to see why that should be the case if all buyers observe all prices.
- But the situation may be different if some buyers do not observe all prices, and can learn through *search*?
- May fear of collusion influence the search behaviour of buyers, and thereby also optimal price setting by sellers, even if collusion, in fact, does not take place?

Our contribution

- We show that in a standard consumer-search framework fear of collusion will reduce the buyers' incentives to search to find a lower price.
- This will, in turn, influence the price-setting behaviour of sellers, and lead to (substantially) higher prices.
- We test the main prediction in the lab, and find that prices indeed do increase substantially when there is a possibility that sellers may collude.
- The paper is part of a broader research agenda, in which we analyse anti-competitive behaviour and competition policy in models with consumer search.

Literature

1. Consumer search with learning of market state: Benabou and Gertner (1993); Dana Jr (1994); Janssen et al. (2011); Janssen and Shelegia (2020); Grubb and Westphal (2024)
   - Typically consumers make inference about firms' costs by observing prices.
2. Our fear of collusion mechanism is related to a search discouragement mechanism in concurrent work by Grubb and Westphal (2024).
   - Multi-brand firms set prices, and consumers are uncertain as to whether the firms are multi-brand or not.
3. Consumer search experiments with price dispersion: Cason and Mago (2010); Cason et al. (2021); Heggedal et al. (2024)
   - We produce (several) equilibrium predictions in the lab using human sellers and *human buyers*.
4. Experimental studies of tacit collusion in posted-offers models with price dispersion: Moellers et al. (2016) and Orzen (2008).
   - Consumers know where on the game three they are. Repeated interaction may give collusion, and thus higher prices.

Outline

- Model
- Experimental design and implementation
- Results
- Extensions

Basic model set-up (Stahl, 1989)

- Two sellers of a homogeneous good, set prices simultaneously.
- Sellers can meet any demand, and production costs are normalised to zero.
- Buyers demand one unit, willingness to pay equal to 1.
- Uninformed buyers (u per seller) choose a seller at random, inspect the price, and decide whether to search to get another price quote at cost c.
- I Informed buyers always buy from the seller with the lowest price, and randomise between them if prices are equal.
- Our mechanism is also present in the Burdett and Judd (1983) model.

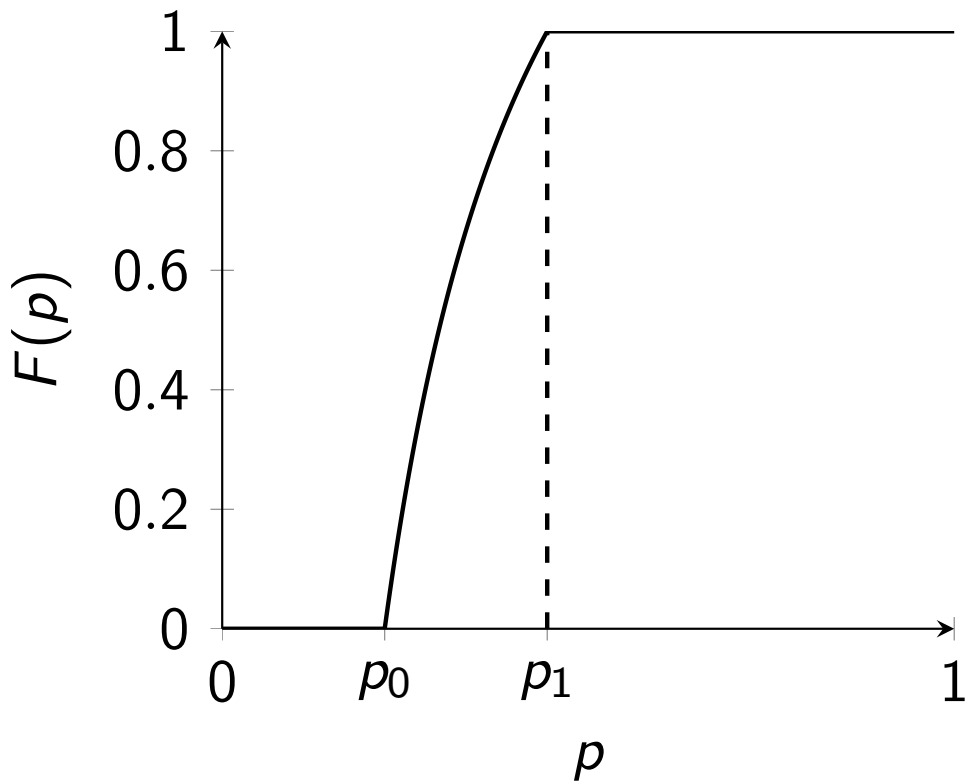
Possibility of collusion

- With exogenous probability $x > 0$, sellers collude, and set an exogenous (high) price p^M.
- With the complementary probability $1 - x$, sellers set prices independently.
- Buyers do not know if the sellers collude, but they know that collusion takes place with prior probability x.
- We derive the equilibrium when there in fact is with no collusion.

Equilibrium, no possible collusion ($x = 0$)

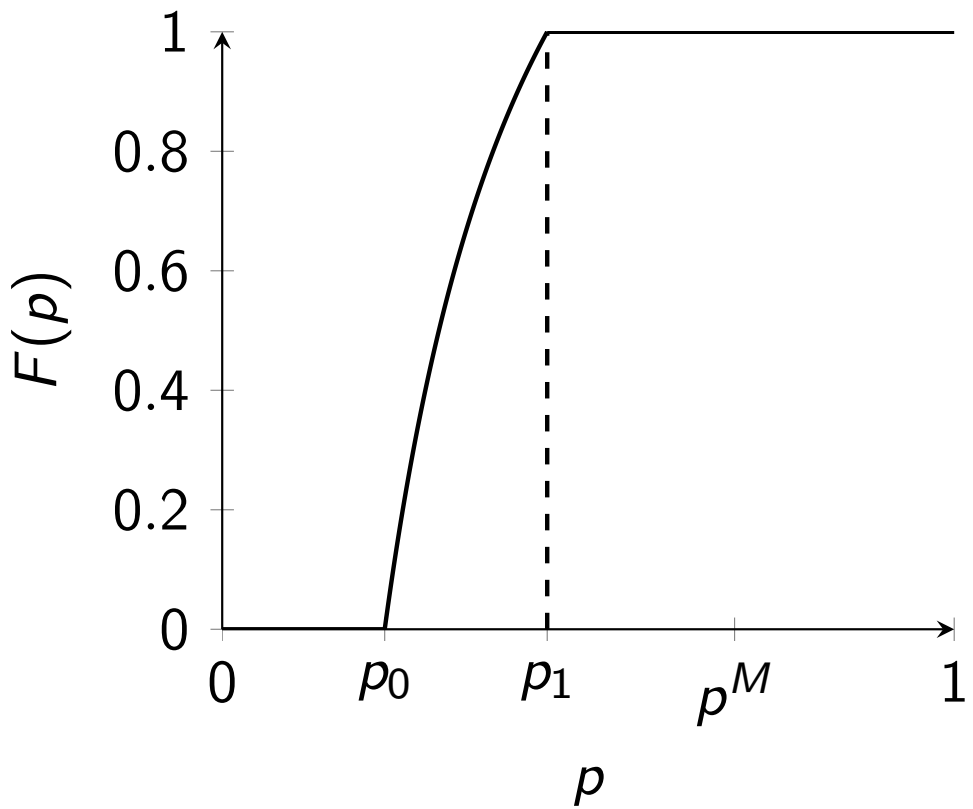
- The unique equilibrium is a *symmetric mixed-strategy equilibrium*.
- Each seller randomises according to a CDF $F(p)$ on an interval $[p_0, p_1]$, such that
  1. All sellers are indifferent between setting any price in $[p_0, p_1]$ (earn profits of up_1 for all prices in that range).
  2. Buyers at p_1 are indifferent between searching and not searching (and choose not to search).
  3. $F(p)$ has no mass points.

Equilibrium, no possible collusion ($x = 0$)



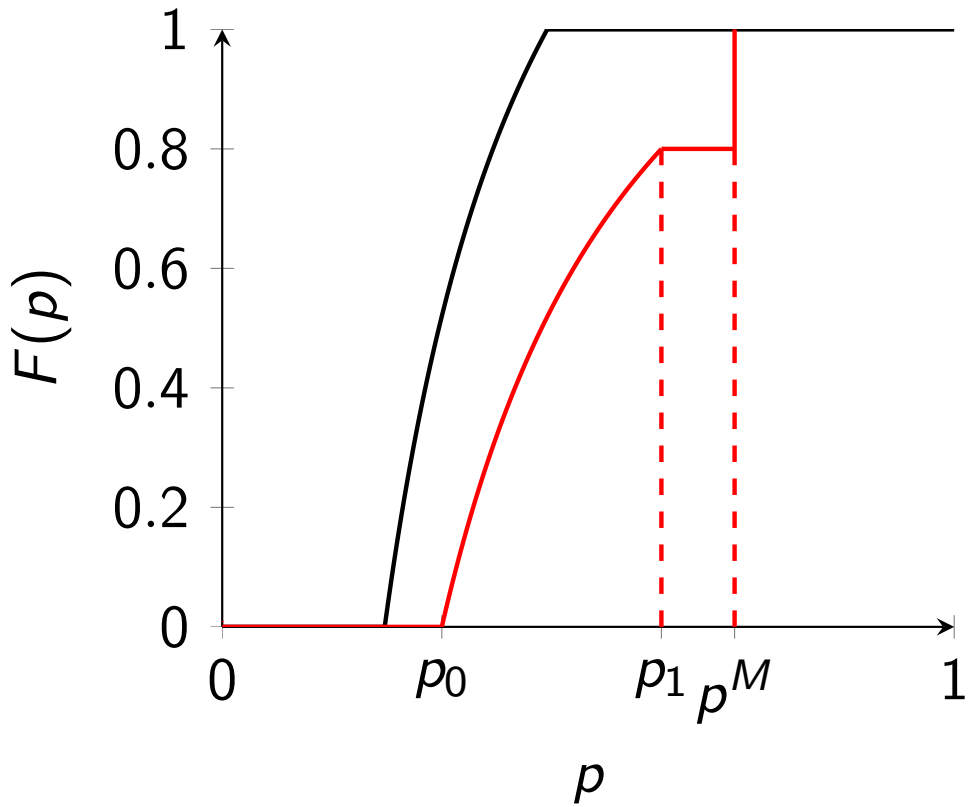
- Sellers randomise on interval $[p_0, p_1]$
- Buyers indifferent at p_1
- No search in equilibrium

Is this still an equilibrium with possible collusion ($x > 0$)?



- **NO**
- Suppose a seller deviates and sets p^M
- A buyer visiting this seller believes with probability 1 that there is collusion
- The buyers buys, and the deviation is profitable
- Cannot be an equilibrium

Equilibrium with possible collusion ($x > 0$)



- Price distribution has mass point on p^M
- Interval $[p_0, p_1]$ where sellers randomise shifts upwards
- Seller are indifferent between $[p_0, p_1]$ and p^M
- Buyers at p^M may or may not search

Search and no-search equilibrium

- We distinguish between two types of equilibria:
  1. **No-search equilibrium:** Uninformed buyers observing p^M do not search to get a second quote.
  2. **Search equilibrium:** Buyers at p^M do search with a probability $q \in (0, 1)$.
- In addition, for weird parameter values, sellers may randomise at an interval just below p^M.
- Our main focus (in theory and the experiment) is on the no-search equilibrium.
- There exists a cut-off $\bar{x}$ on the prior probability of collusion, x, so that the no-search equilibrium exists if and only if $x \geq \bar{x}$

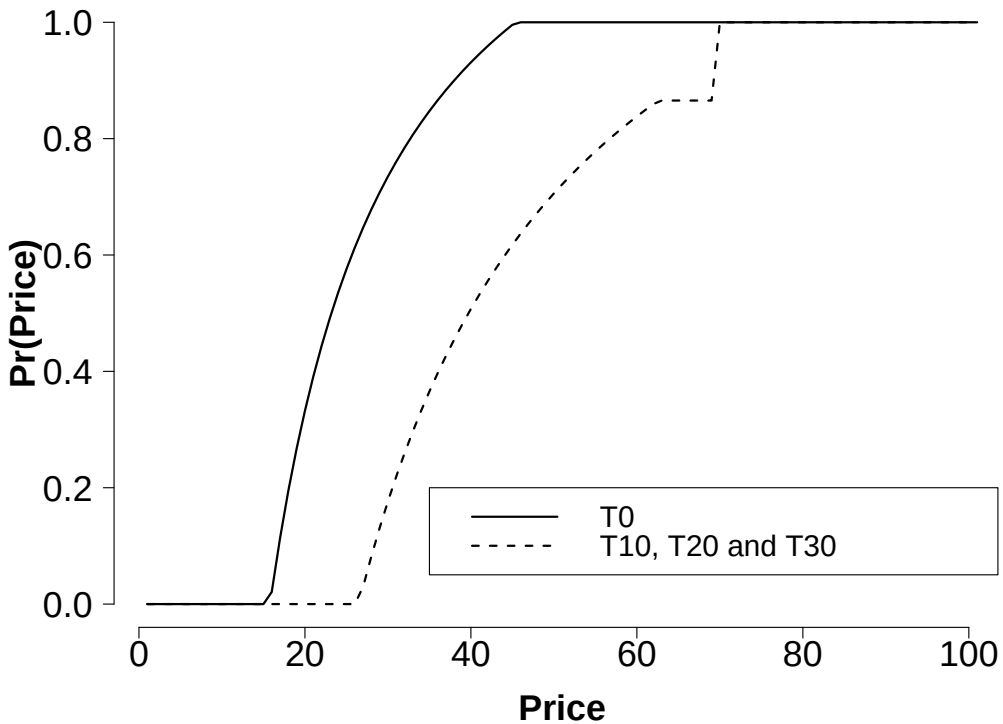
Experimental Design

- The objective of the experiment is to test if the subjects understand and react to the main economic mechanisms of the model.
- The parameters are set so that we are in the no-search equilibrium.
- In each round of play, the price is set exogeneously, i.e., there is collusion, with a certain probability.
- We have four treatments:
  - In our baseline treatment, $T0$ the price is never set exogeneously.
  - In treatments Tx: $T10$, $T20$ and $T30$, x is 0.10, 0.20 and 0.30, respectively.
  - Equilibrium is identical for all Tx.
  - x is IID across games.

Implementation

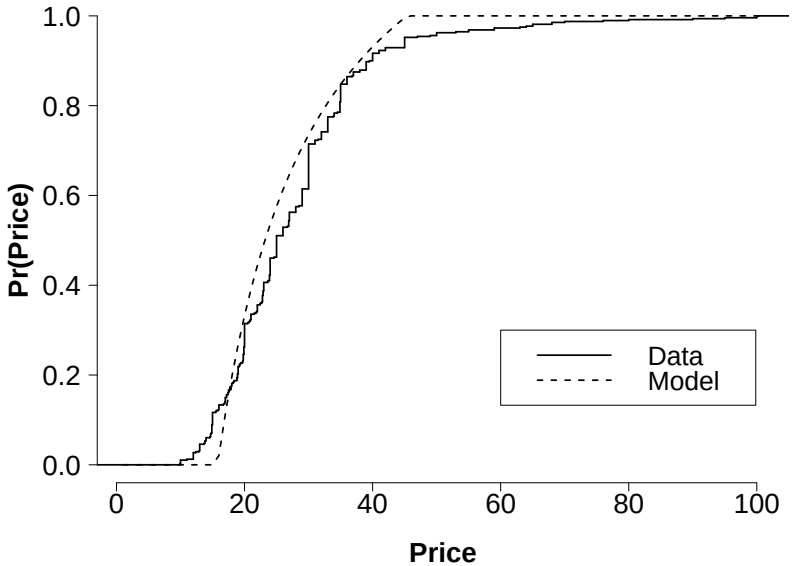
- 6 independent blocks per treatment, with 8 subjects in each block.
- Subjects play 40 independent games.
- In each game, four subjects are randomly matched into a market with two sellers and two (uninformed) buyers – one per seller ($u = 1$).
- Roles remain fixed throughout the experiment.
- Buyers value the good at 100 experimental currency units (ECU).
- Search cost c is 20.
- Exogenous collision price p^M is 70.
- Seller with the lowest price gets two additional sales ($I = 2$).

Theoretical predictions

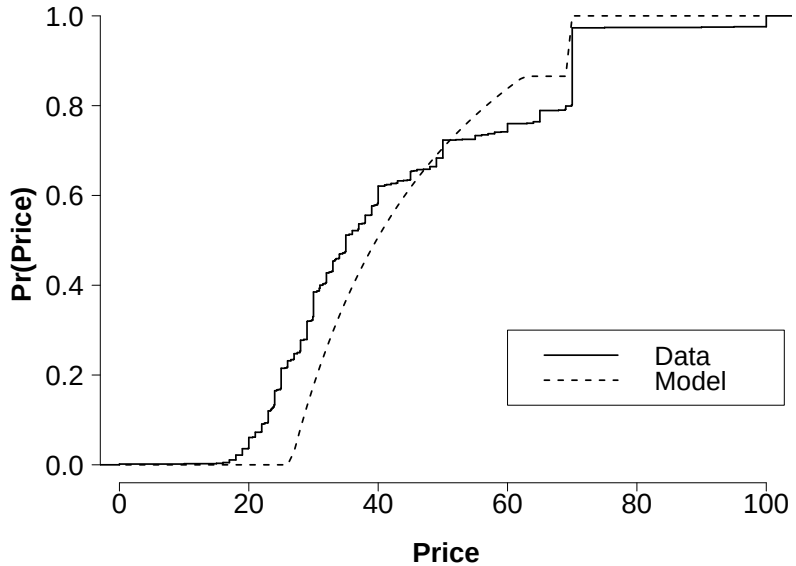


	$T0$	Tx
$E(p)$	24.4	42.6
p_0	14.8	26.5
p_1	44.4	62.6
ρ	0	0.13

Data vs model



(a) $T0$: Data vs model

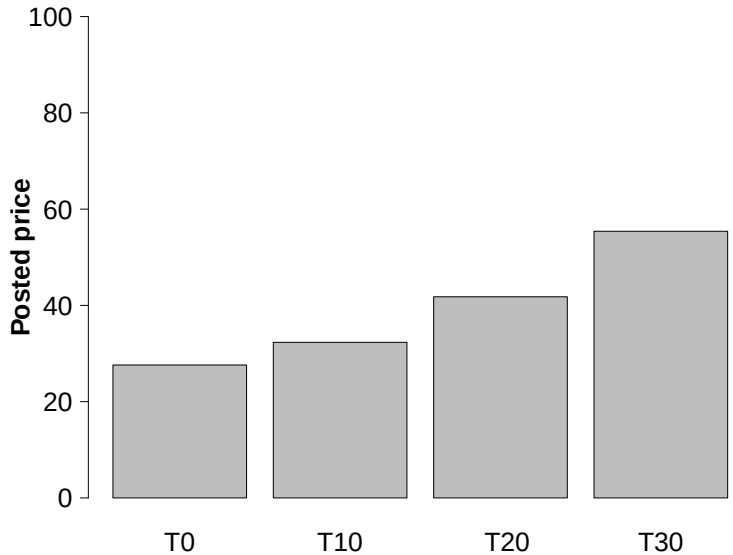


(b) Tx: Data vs model

First 20 games and games where the price was set exogenously are excluded.

Difference in average price between $T0$ and Tx is 18.1 in theory and 14.85 in data.

Results: Average prices

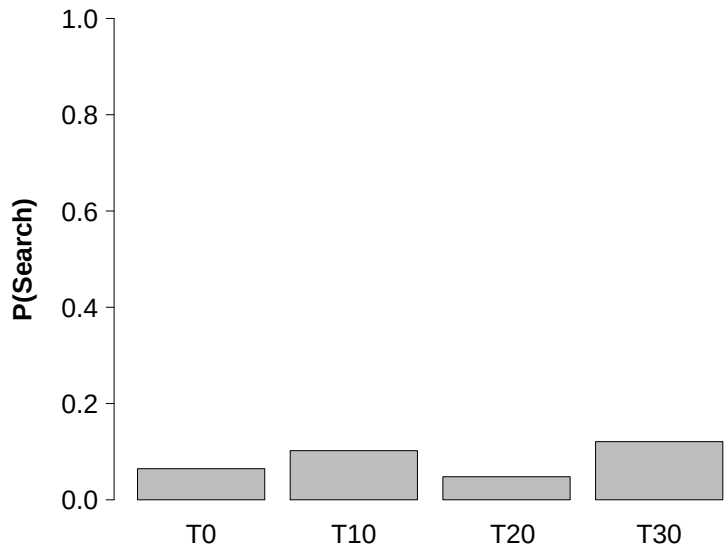


Note: First 20 games and games where the price was set exogenously are excluded. We exclude purchase price for informed buyers.

- The average price in $T0$ is 27.6 ECU.
- The average prices in $T10$, $T20$ and $T30$ are 32.3, 41.8 and 55.5 ECU respectively.
- Prices vary between treatments, which is at odds with theory.

Results: Search rates

Figure: Share of buyers who search across treatments



Note: First 20 games are excluded.

- Search rates are low in all treatments, with rates of 0.06, 0.1, 0.05 and 0.12 in $T0$, $T10$, $T20$ and $T30$, respectively.

Are search decisions optimal?

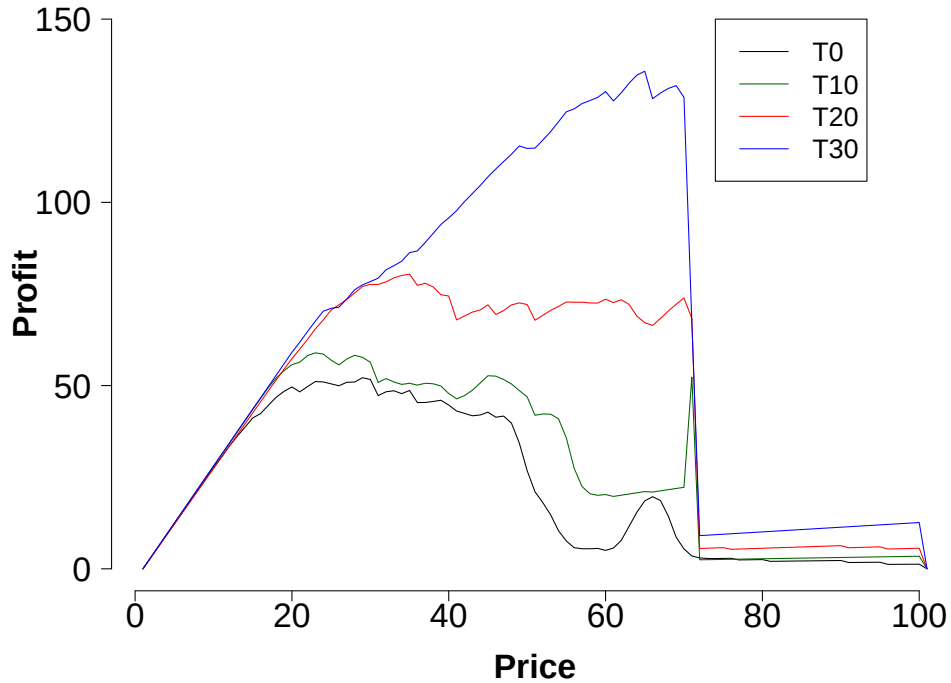
Reservation prices implied by the empirical price distributions

Treatment	Implied reservation price
$T0$	47.6
$T10$	52.3
$T20$	61.8
$T30$	75.4

How frequently do the subjects search, depending on the price?

Treatment	Observed price below reservation price	Observed price above reservation price	Overall share who best respond
$T0$	0.02	0.9	0.97
$T10$	0.08	1	0.92
$T20$	0.02	0.76	0.97
$T30$	0.09	0.94	0.91

Are sellers best responding?



Definition of *reasonable best response*	$T0$	$T10$	$T20$	$T30$
$\geq 75\%$	0.91	0.93	0.95	0.63
$\geq 80\%$	0.87	0.90	0.94	0.62
$\geq 85\%$	0.78	0.86	0.66	0.58

Explaining Deviations Across Treatments

- **Theory:** Predicted equilibrium prices are identical in T10, T20, T30.
- **Data:** Prices differ – too low in T10, too high in T30.

Reinforcement learning analysis:

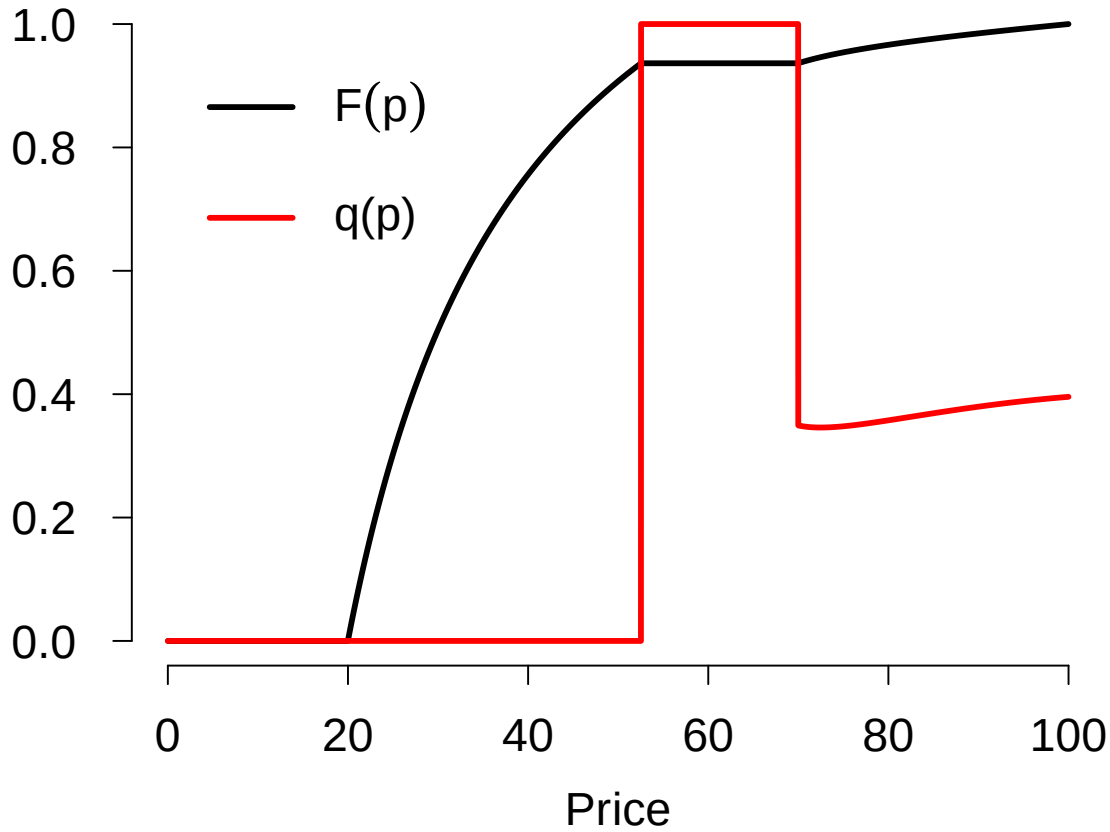
- We estimate a simple reinforcement learning model of subjects' behavior.
- **Key finding:** Variations in participants' *initial beliefs* about optimal pricing may explain deviations.
  - Sellers in T30 tend to *overshoot* equilibrium (many post 70 in the first game).
  - Sellers in T10 tend to *undershoot* equilibrium (many post too low prices in the first game).
- These initial deviations are reinforced by learning throughout play in each experiment.

Extension: Stochastic collusion price

- Sellers collude with probability x.
- Conditional on collusion, price is drawn from distribution $G(p)$, where $G(p)$ is continuous with support $[p^M, 100]$.

- Key insights from the baseline model are robust to a stochastic collusion price:
  - Prices are set outside the range of the standard Stahl equilibrium.
  - Possible collusion with a stochastic collusion price also shifts the entire price distribution upwards.

Extension: Stochastic collusion price



Note: Equilibrium for $c = 20$ and $x = 0.2$. The collusion price is uniformly distributed in the range $[70, 100]$.

Extension: $N > 2$ firms

- No qualitative difference
- In equilibrium when $N > 2$ sellers mix between setting the collusion price, and prices in some interval $[p_0, p_1]$.
- Depending on parameters, equilibrium may be with or without search as in the case with two sellers.

Extension: Possible collusion in Burdett and Judd (1983)

- Burdett and Judd (1983) introduces to model of consumer search:
  - **Noisy search**: Buyers initially observe a random number of prices
  - **Non-sequential search:** Buyers decide ex-ante how many price quotes to elicit

- Noisy search: A parametrization of the model is isomorphic to Stahl (1989).
- Non-sequential search: No gain from additional price quotes if sellers collude $\rightarrow$ fewer buyers observe more than one price $\rightarrow$ prices increase.

Conclusion

- **Main finding:** Fear of collusion can raise prices even when collusion does not occur.
- **Mechanism:** Buyers search less $\Rightarrow$ sellers set higher prices.
- **Evidence:** Lab data broadly consistent with theory; Possible collusion gives higher prices.
- **Policy implication:**
  - High value of quickly resolving suspicions of collusion.
  - Possible collusion makes actual collusion harder to detect.
- **Relevant in markers where:**
  - Sellers post observable prices.
  - Buyers search (or can search) over prices.
  - Collusion between sellers is possible.
  - Consumers are aware that collusion may occur.

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