An agent-based model of price flexing by chain-store retailers

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Price flexing

Price flexing by chain-store retailers = third-degree price discrimination in which individual stores set their prices according to their local market power.

Examples:

- UK supermarket sector – Competition Commission (2000) found this practice anti-competitive but offered no remedy
- Czech petrol stations – Shell has zero profit margin in some regions and a PM of 4 CZK in other locations (highways) – Office for the Protection of Competition did not find this practice anti-competitive

Literature review

Dobson & Waterson (2005a, 2005b, 2008)

- stylized models of a supermarket sector with two separate markets, one monopolistic and one competitive and two retailers
- choice of both local and uniform pricing might be rational for some parameters of the model
- also the welfare consequences of different combinations of pricing strategies depend on parameter values.

Problem of their approach: pricing has no effect on market structure.

I propose an agent-based model where pricing strategy affects not only prices but also number and location of stores in the market.

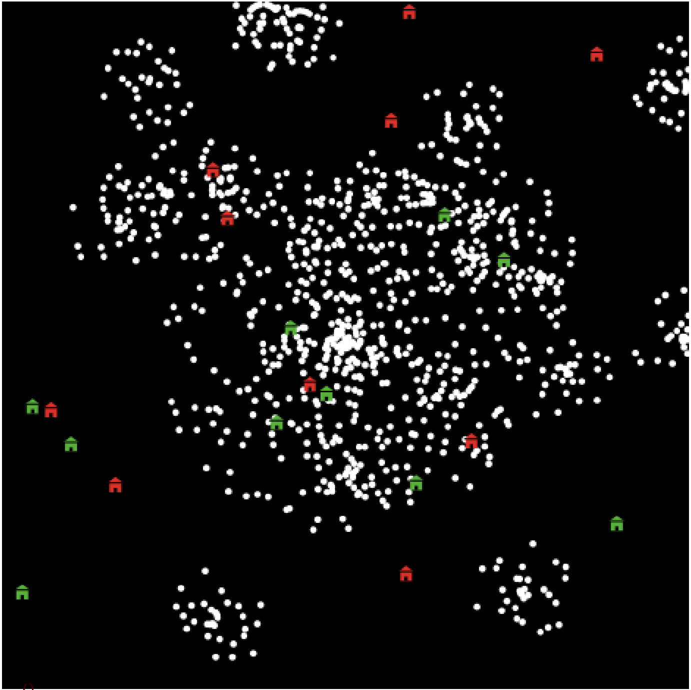
Model (1/5)

Agent-based model implemented in `Netlogo 4.1.3`.

In each run, the model is initialized + it runs for some periods.

Initialization:

- **landscape** – a square of 40×40 patches
- **1,000 consumers** who differ only in their locations. Each gets a location with random direction and distance from the center of a settlement. The distance ranges from 0 to $\sqrt{h/(\pi u)}$, where h is the number of inhabitants and u population-density parameter.
- **2 chain-stores** – chain 1 and 2 opens 10 stores of each with a random location and a price $p_R/2$, where p_R is reservation price of consumers.



Model (2/5)

Each periods has four phases: 1) opening stores, 2) adjusting prices, 3) shopping, and 4) closing stores.

1) **Opening stores** – up to v stores for each chain

A new store opens only if it increases the profit of the chain – depends on the price the new store charges:

- U – the same price as any store in its chain
- $\underline{L}$ – the lowest price charged by an incumbent store of its chain
- $\hat{L}$ – the average price charged by the stores of its chain
- L_L – the price of the store (of any chain) with the lowest distance

Model (3/5)

2) **Adjusting prices** – each store changes its price by $\epsilon > 0$ or by 0.

The adjustment decision depends on pricing strategy:

- uniform pricing (U) – each *chain* chooses the price that maximizes its profit given the price charged by the other chain.
- local pricing ($\underline{L}$, $\hat{L}$, or L_L) – each *store* chooses the price that maximizes its chain's profit given the prices charged by all the other stores.

Model (4/5)

3) **Shopping** – each consumer chooses the store with the lowest

$$p_{it} + cd_{it}^2,$$

where

- p_{it} is the price of the product,
- $c > 0$ is the per-patch transportation cost,
- d_{it} is the distance to the store i.

In this store, each consumer buys

- 1 unit of the product if her reservation price p_R is higher than price + transportation cost,
- 0 units otherwise.

Model (5/5)

4) **Closing store** – depends on profits of stores.

Assuming zero marginal cost, the profit of store i in period t is

$$\pi_{it} = q_{it} p_{it} - F,$$

where

- q_{it} are units of product sold,
- F is the quasi-fixed cost.

In period t, the chain closes store i with a probability

$$\frac{-\pi_{it}}{F}.$$

Data (1/2)

Generated in Behavior Space in `Netlogo` for all combinations of the following parameters/settings (1,024 runs):

- urban landscape (1 city of $h = 400$ and 20 villages of $h = 30$) and rural landscape (30 villages of $h = 30$)
- population-density parameters $u = 0.5$ and 1
- reservation prices $p_R = 0.5$ and 1
- numbers of new stores $v = 2$ and 4
- strategy profiles (U, U), $(\underline{L}, \underline{L})$, $(\hat{L}, \hat{L})$ and (L_L, L_L)
- transportation-cost parameters $c = 0.01$ and 0.02
- price-change parameters $\epsilon = 0.02$ and 0.03
- quasi-fixed cost $F = 5$
- random seeds 1, 2, 3, and 4

Data (2/2)

Each run of the simulation generates the following variables:

- Quantity $Q = \frac{1}{100}\sum_{t=101}^{200} \bar{n}_t$, where $\bar{n}_t$ is the number of consumers who bought 1 unit of product (customer)
- Price $P = \frac{1}{100}\sum_{t=101}^{200}\left(\frac{1}{\bar{n}_t}\sum_{j=1}^{\bar{n}_t} p_{jt}\right)$
- Number of stores of chain k $M_k = \frac{1}{100}\sum_{t=101}^{200} m_{kt}$
- Revenue of chain k $R_k = \frac{1}{100}\sum_{t=101}^{200}\sum_{l=1}^{m_{kt}} q_{lkt} p_{lkt}$
- Distance $D = \frac{1}{100}\sum_{t=101}^{200}\sum_{j=1}^{\bar{n}_t} d_{jt}^{*}$
- Consumers' surplus $CS = Qp_R - R - cD^2$ where $R = R_1 + R_2$
- Profit of chain k $\Pi_k = R_k - M_k F$
- Total profit $\Pi = \Pi_1 + \Pi_2 = R - MF$, where $M = M_1 + M_2$
- Welfare $W = CS + \Pi = Qp_R - cD^2 - MF$

Results (1/4)

Compare outcomes of 3 three pairs of strategies:

- (U, U) to $(\underline{L}, \underline{L})$
- (U, U) to $(\hat{L}, \hat{L})$
- (U, U) to (L_L, L_L).

I run a regressions for each pair of strategies and each variable of the entire dataset (24 regressions in total) - example:

$$\widehat{\text{STORES\_NO}} = \underset{(0.958)}{19.307} + \underset{(23.652)}{507.176}\,\text{TRANSP\_COST}$$

$$-\underset{(0.473)}{3.454}\,\text{POP\_DENSITY} + \underset{(0.473)}{5.935}\,\text{RES\_PRICE} + \underset{(23.652)}{19.293}\,\text{EPSILON}$$

$$+\underset{(0.118)}{0.325}\,\text{ENTRANTS} - \underset{(0.237)}{1.336}\,\text{URBAN} - \underset{(0.237)}{4.523}\,\textbf{LOCAL}$$

$$T = 512 \quad \bar{R}^2 = 0.677 \quad F(7, 504) = 153.64 \quad \hat{\sigma} = 2.676$$

(standard errors in parentheses)

Results (2/4)

I run the 24 regressions also for each of the 12 partition of the data defined by one value of the following parameters:

- TRANSP_COST $c =$ 0.01 or 0.02
- POP_DENSITY $u =$ 0.5 or 1
- RES_PRICE $p_R =$ 0.5 or 1
- EPSILON $\epsilon = 0.02$ or 0.03
- ENTRANTS $v =$ 2 or 4
- URBAN $= 0$ or 1

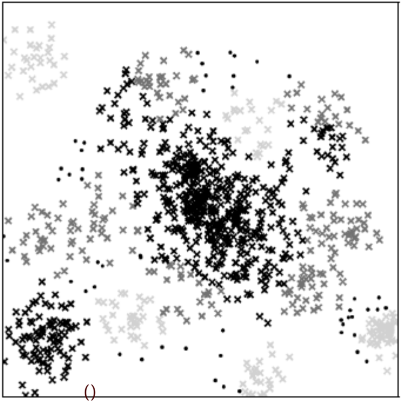
The total number of regressions is therefore 312. The following table presents the parameters and standard errors of LOCAL for the entire dataset and for the partitions restricted to $p_R =$ 0.5 and 1.

Dataset	Pricing	Q	M	cD^2	W	P	R	CS	Π
all data ($T = 512$)	(U, U)	965.4	29.6	64.7	519.9	0.285	275.2	392.5	127.4
	$(\underline{L}, \underline{L})$	−27.8	−4.52	35.3	−29.1	−0.004	−10.1	−41.6	12.5
		(2.94)	(0.24)	(1.23)	(1.38)	(0.003)	(3.10)	(3.21)	(2.47)
	$(\hat{L}, \hat{L})$	−9.23	−1.59	20.2	−17.6	−0.013	−15.1	−10.6	−7.09
		(2.63)	(0.24)	(0.84)	(1.26)	(0.003)	(2.92)	(2.78)	(2.11)
	(L_L, L_L)	−10.8	−1.39	14.09	−13.2	0.002	−0.57	−19.6	6.38
		(2.69)	(0.24)	(0.76)	(1.21)	(0.003)	(3.12)	(2.89)	(2.24)
$\mathbf{p_R = 0.5}$ ($T = 256$)	(U, U)	932.0	28.1	56.7	269.0	0.262	243.6	165.8	103.2
	$(\underline{L}, \underline{L})$	−45.6	−4.55	17.8	−17.8	−0.028	−37.0	−3.51	−14.3
		(3.27)	(0.29)	(0.71)	(1.64)	(0.003)	(2.46)	(2.32)	(1.63)
	$(\hat{L}, \hat{L})$	−15.5	−2.12	12.2	−9.33	−0.023	−25.6	5.71	−15.1
		(2.77)	(0.26)	(0.57)	(1.63)	(0.003)	(2.36)	(2.38)	(1.67)
	(L_L, L_L)	−18.6	−2.26	7.63	−5.63	−0.013	−17.3	0.34	−5.98
		(2.79)	(0.27)	(0.57)	(1.58)	(0.003)	(2.54)	(2.53)	(1.69)
$\mathbf{p_R = 1}$ ($T = 256$)	(U, U)	998.8	31.0	72.8	770.8	0.307	306.7	619.3	151.5
	$(\underline{L}, \underline{L})$	−9.99	−4.49	52.9	−40.4	0.02	16.8	−79.7	39.3
		(0.71)	(0.32)	(1.31)	(1.99)	(0.004)	(3.81)	(4.05)	(2.98)
	$(\hat{L}, \hat{L})$	−3.01	−1.07	28.3	−26.0	−0.003	−4.47	−26.8	0.86
		(0.33)	(0.33)	(0.88)	(1.79)	(0.004)	(4.06)	(4.06)	(2.91)
	(L_L, L_L)	−2.88	−0.51	20.5	−20.8	0.017	16.2	−39.6	18.7
		(0.31)	(0.34)	(0.81)	(1.72)	(0.004)	(4.28)	(4.19)	(3.07)

Results (3/4)

Prices for the strategy (L_L, L_L) for $p_R = 0.5$ (left) and $p_R = 1$:

- black crosses = customers with $p_{jt} \leq 0.2$
- dark gray crosses = customers with $0.2 < p_{jt} \leq 0.3$
- light gray crosses = customers with $p_{jt} > 0.3$
- dots = consumers with 0 units of product



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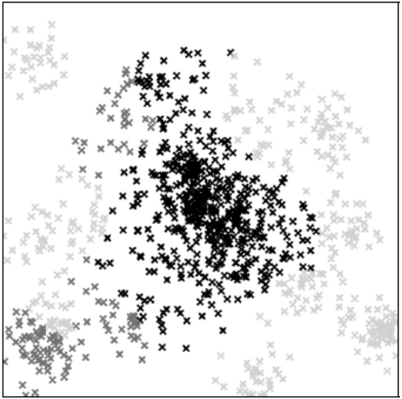


Results (4/4)

Change in welfare is

$$\Delta W = \Delta Q p_R - c\Delta D^2 - \Delta MF,$$

where

- $\Delta Q p_R$ = welfare effect of quantity traded,
- $-c\Delta D^2$ = welfare effect of distance to shops,
- $-\Delta MF$ = effect of lower number of shops.

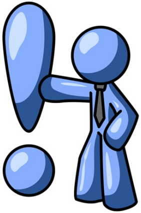
reservation price	pricing strategy	ΔW	$\Delta Q p_R$	$-c\Delta D^2$	$-\Delta MF$
$p_R = 0.5$	$(\underline{L}, \underline{L})$	−17.8	−22.8	−17.8	22.8
	$(\hat{L}, \hat{L})$	−9.3	−7.7	−12.2	10.6
	(L_L, L_L)	−5.6	−9.3	−7.6	11.3
$p_R = 1$	$(\underline{L}, \underline{L})$	−40.4	−10	−52.9	22.5
	$(\hat{L}, \hat{L})$	−26.0	−3.0	−28.3	5.3
	(L_L, L_L)	−20.8	−2.9	−20.5	2.6

Conclusion

What is the effect of local pricing on market outcomes?

The agent-based model with endogenous entry and location of stores shows that local pricing

- reduces welfare because the effect of quantity traded and distance to shops outweighs the effect of lower number of shops.
- may increase or reduce total profits and consumers' surplus, depending on the size of the reservation price relative to the equilibrium price.



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