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

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Abstract. This paper investigates the effects of local price flexing on market structure and welfare in the supermarket sector. It presents an agent-based model of a sector with two chain-store retailers in which the number and location of stores and prices charged by the stores are determined endogenously. The outcome in which all the stores within each chain charge the same price is compared to the situation in which each store sets prices according to local market conditions. The paper finds that local pricing reduces the number of stores and total welfare in the market. Furthermore, local pricing is more likely to increase the average prices and total revenue in the market, if the reservation price of consumers is high relative to the equilibrium price under uniform pricing. In this situation, local pricing is likely to reduce not only total welfare but also aggregate consumer surplus in the market.

Keywords: retail, supermarket, price flexing, agent-based, local, uniform.

JEL classification: L10, L40, L81, R30
AMS classification: 37M05, 91B26

1 Introduction

Local price flexing (or local pricing) by chain-store retailers is a form of third-degree price discrimination in which individual stores set their prices according to their local market power. Prices are typically higher in areas with higher geographical distance between competing stores. In its investigation of the UK supermarket sector in 2000, Competition Commission found evidence of local price flexing. Moreover, it concluded that this practice distorted competition and adversely affected public interest. One of the remedies considered by Competition Commission was the imposition of uniform pricing, so that all stores within one chain would have to charge the same prices for the same products (for a detailed account of the use of local price flexing in retail markets, see [2], [3], and [4]).

This paper investigates the effects of local pricing on market outcome in the retail sector. This problem is closely related to the literature on third-degree price discrimination in oligopolistic markets ([1] and [5]). A more specific theoretical approach to the problem of local price flexing was proposed by Dobson & Waterson [2] and [3]. In [3], they present a stylized model of a supermarket sector with two retailers. Each of the retailers operates in two separate local markets: they compete against each other in one of the markets (there is a differentiated Bertrand competition) and have local monopoly in the other. Using a linear demand specification, they find that the results depend on two parameters: a measure of substitutability between the products sold in the common market and the relative size of the demand in the local and common market. They show that if the demand functions are similar in both markets, local pricing increases total industry profit for highly substitutable products and reduces it if the substitutability is low. They also show that for similar demand functions and high and intermediate subsitutability, local pricing reduces aggregate consumer surplus in the market.

One of the problems of the approach by Dobson & Waterson [2] and [3] is that pricing strategy affects only prices while leaving the market structure unchanged. This paper proposes a solution to this problem. It presents a version of the agent-based model of a monopolisticaly competitive market with endogenous number and location of firms introduced by Krčál [6]. In the model presented here, local pricing affects not only prices charged by the stores but also the number and location of stores in the market. Therefore, the model provides a more realistic framework for analyzing the effects of local pricing in retail sector. The structure of the paper is straightforward. Section 2 introduces the model, Section 3 describes the data and discusses the results of the model, and Section 4 concludes.

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2 Model

In agent-based models, agents act or interact according to specific rules that are followed in a given order. In this section, I introduce the agents and explain the rules of the model in a step-by-step way similar to the order in which the simulation of the model proceeds (the model was implemented in the multiagent modeling environment `Netlogo 4.1.3`). In each run, the model is first initialized and then it runs for a certain number of periods.

In the initialization phase, the model creates a landscape, a population of consumers and an initial population of stores. *Landscape*: The retail market is set in a square landscape of 40×40 patches (a patch is a square field in Netlogo). In this model, a patch can be interpreted as any unit of distance. So, for instance, the landscape can be seen as a square island with a side of 40 kilometers. *Population of consumers*: The landscape is populated by 1,000 identical consumers who differ only in their locations. Consumers live in settlements. Each inhabitant of a settlement gets a location with a random direction from the center of the settlement and with a distance from the center of $\sqrt{h/(\pi u)}$, where h is the number of inhabitants of the settlement, $u > 0$ is the population-density parameter and $\pi \doteq 3.14$. If $u = 1$, the average population density of a round settlement with a perimeter of $\sqrt{h/(\pi u)}$ is 1 consumer per square patch. Only if a settlement is too close to the edge of the landscape, consumers who would be located outside of the landscape live on the edge of the square (or on the coastline of the square island), keeping their original direction from the center of the settlement. Then, the average population density in such a settlement is higher. *Initial population of stores*: The market is served by two chain-stores (chain 1 and chain 2) who sell identical product. Before the first period, ten stores of each chain locate randomly in the market. Each store sets its price equal to $p_R/2$, where $p_R > 0$ is the reservation price of consumers.

Once the model is initialized, the simulation proceeds in periods. In each period, the agents do their actions in four sequential steps: 1) Both chains consider opening new stores. 2) The existing stores adjust their prices. 3) Consumers shop in the stores. And 4) both chains consider closing some of their stores.

1) *Opening stores* At the beginning of period t, each chain considers building v new stores. They do it in turns. First, chain 1 and then chain 2 considers opening a store. This process is repeated v times. For each new store, each chain is assigned a random location. It would open the store in this location only if for given prices the new store increased the profit of the chain [the profit is determined in the same way as described in points 3) and 4)]. Whether a new store will enter the market therefore depends not only on its assigned location but also on the initial price it charges. The price depends on the pricing strategy of the chain. Under *uniform pricing* (strategy U), the new store charges the same price as any store in its chain. Under local pricing, the chain can assign any price to the new store. In order to test the sensitivity of the result to different pricing strategies of the new stores, I introduce three different local-pricing strategies: 1) Under *local pricing with minimal entry price* (strategy $\underline{L}$), the new store sets its price equal to the lowest price charged by an incumbent store of its chain. 2) Under *local pricing with average entry price* ($\hat{L}$), the new store sets its price equal to the average price charged by the stores of its chain. And 3) under *local pricing with local entry price* (L_L), the new store sets its price equal to the price the store (of any chain) with the lowest distance to the new store.

2) *Adjusting prices* After the new stores have been opened, each store can increase or decrease its price by a constant $\epsilon > 0$ or keep it at the same level as before. The adjustment process depends on the pricing strategy of the chain. Under uniform pricing (U), each store in a given chain charges the same price. Therefore, each *chain* chooses the price (out of the three options) that maximizes its profit given the price charged by the other chain. Under local pricing ($\underline{L}$, $\hat{L}$, or L_L), each store may charge a different price. Therefore, each *store* chooses the price that maximizes its chain's profit given the prices charged by all the other stores. Again the profit is determined in the way described in points 3) and 4).

3) *Shopping* Each consumer makes a decision whether to shop in store i based on the price of the product p_{it}, on the per-patch transportation cost $c > 0$ and on the distance to the store i d_{it}. Each consumer buys one unit of the product from the store with the lowest $p_{it} + cd_{it}^2$ if $p_R > p_{jt}^* + c{d_{jt}^*}^2$, and zero units if $p_R \leq p_{jt}^* + c{d_{jt}^*}^2$, where p_{jt}^* and d_{jt}^* are the price and the distance of the optimal store for consumer j in period t. The intuition behind the zero purchase is that each consumer can buy the product in a near-by mom-and-pop store for the price p_R. After the shopping and before the exit, all the variables used for analyzing the situation in the market are calculated and recorded.

4) *Closing stores* The closing decision is based on profit 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, and F is the quasi-fixed cost that is the same for all the stores. In period t, the chain closes store i with a probability $-\pi_{it}/F$.

3 Results

This section shows how pricing strategy affects the situation in the retail market in the model. Subsection 3.1 provides details about the data and Subsection 3.2 presents the main results of the model. The data presented in this section was generated using the function Behavior Space in `Netlogo` and analyzed using the econometric software `Gretl 1.9.5cvs`.

3.1 Data

The data analyzed in this section come from the total number of 1,024 runs corresponding to all possible combinations of the following settings and parameter values: 2 types of landscape: 1) *urban landscape* containing 1 settlement with the center in the central point of the landscape and the number of inhabitants $h = 400$, and 20 settlements with randomly located centers and $h = 30$, and 2) *rural landscape* containing 1 settlement with the center in the central point of the landscape and $h = 100$, and 30 settlements with randomly located centers and $h = 30$; 2 population-density parameters $u = 0.5$ and $u = 1$; 2 reservation prices $p_R = 0.5$ and $p_R = 1$; 2 numbers of new stores per chain and period $v = 2$ and $v = 4$; 4 strategy profiles (U, U), $(\underline{L}, \underline{L})$, $(\hat{L}, \hat{L})$ and (L_L, L_L); 2 transportation-cost parameters $c = 0.01$ and $c = 0.02$; 2 price-change parameters $\epsilon = 0.02$ and $\epsilon = 0.03$; 1 quasi-fixed cost $F = 5$; and 4 random initializations with random seed of 1, 2, 3, and 4 (using the `random-seed` function in `Netlogo`).

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 the product in one of the chains in period t (this consumers are called *customers*).
- Price $P = \frac{1}{100}\sum_{t=101}^{200}(\frac{1}{\bar{n}_t}\sum_{j=1}^{\bar{n}_t} p_{jt})$, where p_{jt} is the price paid by customer j in period t.
- Number of stores of chain k $M_k = \frac{1}{100}\sum_{t=101}^{200} m_{kt}$, where m_{kt} is the number of stores in chain k in period t.
- Revenue of chain k $R_k = \frac{1}{100}\sum_{t=101}^{200}\sum_{l=1}^{m_{kt}} q_{lkt}p_{lkt}$, where q_{lkt} and p_{lkt} are the quantity and price of store l of chain k in period t.
- Distance $D = \frac{1}{100}\sum_{t=101}^{200}\sum_{j=1}^{\bar{n}_t} d_{jt}^*$, where d_{jt}^* is the distance to the store of customer j in period t.
- Consumers' surplus $CS = \frac{1}{100}\sum_{t=101}^{200}\sum_{j=1}^{\bar{n}}(p_R - p_{jt} - c{d_{jt}^*}^2) = Qp_R - R - cD^2$ where $R = R_1 + R_2$.
- Profit of chain k $\Pi_k = \frac{1}{100}\sum_{t=101}^{200}\sum_{l=1}^{m_{kt}}(p_{lkt}q_{lkt} - F) = R_k - M_kF$
- Total profit $\Pi = \Pi_1 + \Pi_2 = R - MF$, where $M = M_1 + M_2$.
- Welfare $W = CS + \Pi = Qp_R - cD^2 - MF$.

3.2 Comparing the market outcome for uniform and local pricing

This subsection compares the outcomes of the model with both chains pricing uniformly to the outcome of the model with both chains using local pricing. First, it explains how the outcomes will be compared. Then, it shows how local pricing affects pattern of prices and what are the effects of this change on quantity Q, number of stores M, and distance D. Finally, it investigates the effect of local pricing on welfare W, consumers' surplus CS and profit Π.

The market outcomes are compared as follows: There are three pairs of strategy profiles to be compared [(U, U) to $(\underline{L}, \underline{L})$, (U, U) to $(\hat{L}, \hat{L})$, and (U, U) to (L_L, L_L)]. For each of the pairs, I investigate the effect of local pricing on a given variables using linear OLS regressions. The dependent variables are regressed against all the exogenous variables of the model changed in the simulation (except for the random-seed variable). The independent variables are denoted as follows: transportation-cost parameter c is TRANSP_COST, population-density parameter u is POP_DENSITY, reservation price p_R is RES_PRICE, price-change parameter ϵ is EPSILON, the number of entrants per chain and period v is ENTRANTS, the variable that indicates the type of landscape is URBAN – it takes the value of 1 for urban landscape and 0 for rural landscape, and the variable that indicates pricing strategy is LOCAL – it takes the value of 1 for local pricing, and 0 for uniform pricing. For instance, the parameter of LOCAL in the following regression shows the effect of local pricing [strategy profile $(\underline{L}, \underline{L})$] on number of stores M:

$$\widehat{\text{STORES\_NO}} = \underset{(0.958)}{19.307} + \underset{(23.652)}{507.176}\,\text{TRANSP\_COST} - \underset{(0.473)}{3.454}\,\text{POP\_DENSITY} + \underset{(0.473)}{5.935}\,\text{RES\_PRICE}$$

$$+\underset{(23.652)}{19.293}\,\text{EPSILON} + \underset{(0.118)}{0.325}\,\text{ENTRANTS} - \underset{(0.237)}{1.336}\,\text{URBAN} - \underset{(0.237)}{4.523}\,\text{LOCAL} \tag{1}$$

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

(standard errors in parentheses)

For all other regressions the paper will report only the mean value of the dependent variable under uniform pricing, and the parameter and standard error of LOCAL. For instance, the paper will report 29.6 and −4.52 (0.24) for the equation 1 (see Table 1, column M). The meaning of the numbers is as follows: The change from uniform pricing (U, U) to local pricing with minimal entry price $(\underline{L}, \underline{L})$ reduces the mean value of number of stores M from 29.6 by 4.52 to roughly 25.1. The standard error is 0.24, which indicates a highly significant effect of pricing strategy on number of stores. Table 1 (section **all data**) summarizes the effect of local pricing on selected variables for the entire dataset. Each field in the rows $(\underline{L}, \underline{L})$, $(\hat{L}, \hat{L})$ and (L_L, L_L) corresponds to one regression. The total number of regressions run for the entire dataset is 24. Furthermore in order to test sensitivity of the results, I run the same 24 regressions for each of the 12 different partitions of the data (with 256 observations each) restricted to TRANSP_COST = 0.01 or 0.02, POP_DENSITY = 0.5 or 1, RES_PRICE = 0.5 or 1, EPSILON = 0.02 or 0.03, ENTRANTS = 2 or 4, and URBAN = 0 or 1. The parameter that affects most the outcome of the model is reservation price. For this reason, Table 1 (sections $\mathbf{p_R = 0.5}$ and $\mathbf{p_R = 1}$) also presents the effects of local pricing for the partitions restricted to RES_PRICE = 0.5 and 1. In most of the regressions, White test or Beusch-Pagan test indicate heteroskedasticity. All the regressions in this paper therefore report heteroskedasticity-robust standard errors.

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	306.7	72.8	770.8	0.307	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)

Table 1 The effect of local pricing different dependent variables
The table shows the means of different dependent variables [see the lines denoted by (U, U)], and the parameters and standard errors (in parentheses) of the dummy variable LOCAL for three different local pricing strategies [see the lines denoted by $(\underline{L}, \underline{L})$, $(\hat{L}, \hat{L})$, and (L_L, L_L)]. This information is reported for the entire dataset (all data) and two different partitions of the dataset ($p_R = 0.5$ and $p_R = 1$).

Pricing strategy affects the prices charged by stores within each chain. While under uniform pricing all stores in a given chain charge the same price, the prices charged by stores under local pricing differ. The average difference between the highest and lowest price charged within a chain is approximately 0.24 for the reservation price $p_R = 0.5$, and 0.54 for the reservation price $p_R = 1$. Moreover, local pricing affects the geographical pattern of prices. The local level of prices depends on the density of population and other characteristics of the area. Typically, stores in larger and more densely populated areas charge lower prices. Figure 1 shows a typical spatial pattern of prices for $p_R = 0.5$ (left panel) and $p_R = 1$ (right panel) for the pricing strategy (L_L, L_L). Because of lower reservation price, lower proportion of customers in the left panel have prices higher than 0.3. And also, many of consumers living in relatively remote areas in this panel do not shop in the stores at all (see the dots in the left panel of Figure 1).

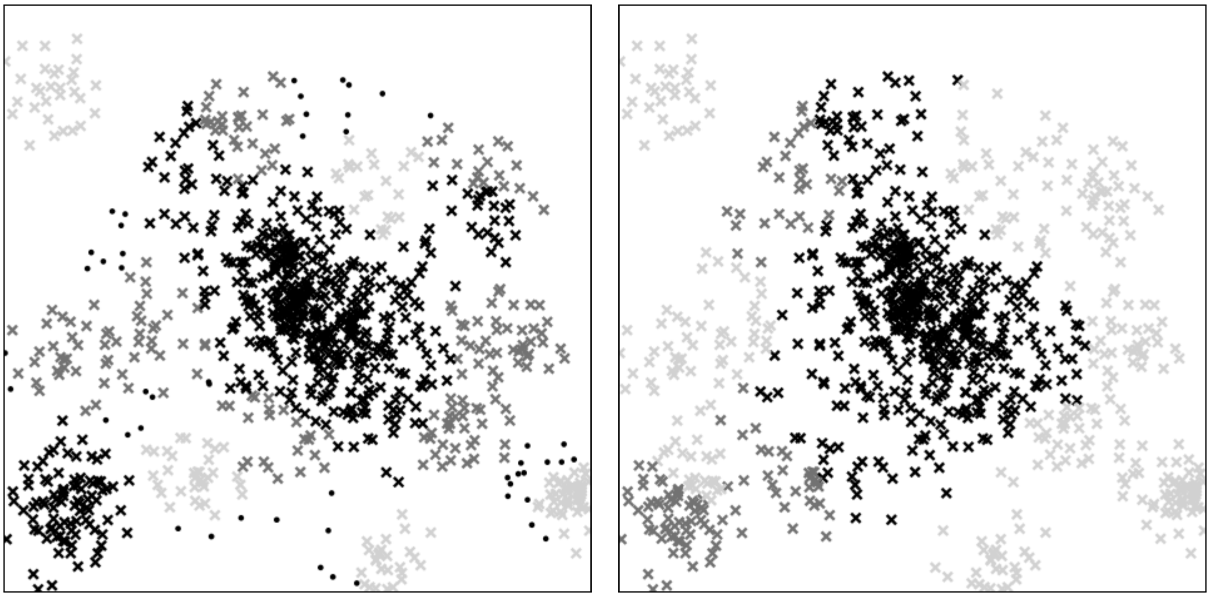

Figure 1 Examples of pattern of prices for $p_R = 0.5$ (left panel) and $p_R = 1$ and the strategy (L_L, L_L)
The panels show the market outcome in a market with the size of 40×40 patches in period $t = 200$. The crosses and dots are consumers located in the landscape. Dots show location of consumers who do not buy the product from any of the stores. Black crosses show location of customers with $p_{jt} \leq 0.2$, dark gray crosses customers with $0.2 < p_{jt} \leq 0.3$, and light gray crosses customers with $p_{jt} > 0.3$.

The pattern of prices reduces the total quantity of product bought Q (see Table 1). This effect is due to the fact that stores in less densely populated areas prefer charging higher prices even at the cost of losing some of the potential customers (see location of the dotted consumers in Figure 1). The effect is negative and significant for all partitions of the data. The pattern of prices also affects the number and location of stores in the market. Competition reduces prices and profit margins of stores in larger and more densely populated settlements. Therefore, each individual store needs to serve larger market in order to cover its quasi-fixed cost. On the other hand, the number of stores in less densely populated areas might increase because the prices charged here are higher than under uniform pricing. However, markets in smaller settlements often cannot support more stores. This seems to be the reason why local pricing reduces the number of stores M for all the local pricing strategies for the entire dataset and for $p_R = 0.5$ and $p_R = 1$ (see Table 1). Furthermore, the effect of local pricing on the number of stores is negative and highly significant for all the remaining partitions of the data. Lower number of stores implies higher distance D, which increases the total shopping cost cD^2 (see Table 1). Again, this effect of local pricing on shopping cost is positive and highly significant for all the remaining partitions of the data.

The effect of local pricing on welfare W is negative and highly significant for the entire dataset as well as for all the partitions of the data (see Table 1). The change in welfare is $\Delta W = p_R \Delta Q - c\Delta D^2 - \Delta MF$. Welfare decreases because the negative effect of lower welfare due to lower quantity traded ($p_R \Delta Q < 0$) and higher distance ($-c\Delta D^2 < 0$) outweighs the positive effect of lower number of stores and therefore lower total quasi-fixed cost paid by all the stores ($-\Delta MF > 0$). Table 2 shows the contributions of the individual effects to the change in welfare for $p_R = 0.5$ and $p_R = 1$. Interestingly, the absolute value of ΔW is lower for low reservation price. It is because the consumer surplus from buying in supermarkets is low to start with, so the increase of their distance d^*_{jt} due to local pricing forces some of the consumers out of the market (see Figure 1). Which means that they do not waste as much welfare on shopping cost as consumers with high reservation prices.

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

Table 2 The welfare effects of local pricing

And finally, Table 1 shows that the effect of local pricing on profits Π and consumers' surplus CS is ambiguous. It is due to the fact, that local pricing may lead to lower price P and revenue R, typically if the reservation price is low, or to higher price P and higher revenue R, if the reservation price is high. The intuition behind this result is as straightforward. If the reservation price is high relative to the equilibrium price in the market with uniform prices (e.g. $p_R = 1$ and $P = 0.307$), stores in areas with less competition are able to increase their prices substantially, which may increase also the average price P and revenue R. On the other hand, stores with relatively low reservation prices ($p_R = 0.5$) have less market power, therefore the average price P and the revenue R in the market are more likely to decline.

4 Conclusion

The aim of this paper was to investigate the effect of local pricing on market outcomes in the supermarket sector. For this purpose, the paper introduces an agent-based model with endogenous entry and location of stores. It finds that local pricing reduces the number of stores and the number of products sold in the market and increases the total shopping cost incurred by consumers. And since the welfare loss due to lower quantity sold and higher shopping cost outweighs the gain due to lower aggregate quasi-fixed costs, local pricing reduces total welfare. Similarly to [3], the effect on profit and consumers' surplus is ambiguous, but it is more likely that local pricing reduces the consumers' surplus. But differently to their model, the main factor that influences the direction of this effect in this model is the size of reservation price relative to the equilibrium price under uniform pricing.

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References

[1] Borenstein, S.: Price discrimination in free-entry markets. *RAND Journal of Economics*, **16** (1985), 380–397.

[2] Dobson, P. W., and Waterson, M.: Chain-Store Pricing across Local Markets. *Journal of Economics & Management Strategy*, **14** (2005), 93–119.

[3] Dobson, P. W., and Waterson, M.: Price Flexing and Chain-Store Competition. *Proceedings of the 32nd EARIE Annual Conference*, (2005) available at http://www.fep.up.pt/conferences/earie2005/cd_rom/Session%20VI/VI.J/Dobson.pdf

[4] Dobson, P. W.: Relationship between Buyer and Seller Power in Retailing: UK Supermarkets, In: *Cases in European Competition Policy* (B. Lyons, ed.). Cambridge University Press, Cambridge, (2009), 100–128.

[5] Holmes, T. J.: The effects of third degree price discrimination in oligopoly. *American Economic Review*, **79** (1989), 244–250.

[6] Krčál, O.: Agent-Based Model of an Urban Retail Market. In *Proceedings of the 29th International Conference Mathematical Methods in Economics 2011*, (M. Dlouhý, and V. Skočdopolová, eds.), University of Economics, Faculty of Informatics and Statistics, Prague, 2011, 369–374.