A duopoly model with switching and transport costs

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Introduction

We do not have a unique definition for this concept:

- *Thompson* and *Cats-Baril (2002):* associated with switching supplier.
- *Farrell* and *Klemperer (2007):* when an investment specific to his current seller must be duplicated for a new seller.

Three types of switching costs have been deeply analyzed in the literature:

1. learning costs
2. transaction costs
3. loyalty rewards or contractual switching costs

For all the previous types of switching costs, products that are ex-ante homogeneous become ex-post heterogeneous.

Effect in a two-period framework, in terms of prices:

reduce elasticity of firm's demand in the second period

$$\Downarrow$$

competition for market shares in the first period is more intense, due to the expected higher market power over their segments.

"How do experience and shopping frequency affect consumers' brand choice?" (T. Farina, 2010)

Experience good: orange juice.

Large supermarket chain in Brazil.

All else equal, the ratio the experience coefficient and the price coefficient shows consumer's willigness to pay for knowledge about a brand.

Result: consumers are willing to pay roughly R$9.50 ($\approx$ US$6) per liter more for a brand of orange juice they have already purchased.

Let us think about the switching costs as a matter of information:

It seems reasonable to assume that each signal provides me more information about the quality of the good when it is uncertain (Bayesian updating).

So, if consumers are risk-averse, increasing the number of consumptions increases the information about the brand, and therefore the switching cost is also higher.

But... is it reasonable to assume that consumers do not know with certainty the quality of the good after experiencing it?

- Environment: juice tastes better when you are thirsty.
- Memory is not perfect.

Review of the literature

- Bayesian updating:
  - *Vives: "Information and learning in markets" (2008)*
  - *Caminal & Vives: "Why market shares matter" (1996)*
- Competition in markets with switching costs:
  - *Farrell & Shapiro: "Dynamic competition with switching costs" (1988)*
  - *Klemperer: "Markets with consumer switching costs" (1987)*
- Endogenous switching costs:
  - *Villas-Boas: "Dynamic competition with experience goods" (2004)*
- Loss-aversion:
  - *Köszegi & Rabin: "A model of reference-dependent preferences" (2006)*

Model

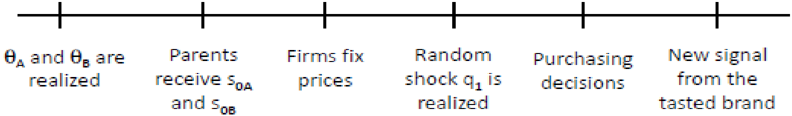
- Experience good
- Two periods: $t = 1$ and $t = 2$
- Risk-averse consumers, who are uniformly distributed into [0,1]
- Demand is a dichotomic variable
- 2 generations of consumers: parents and children
- Standard quadratic transport costs
- Consumers do not know they quality of the brands: signals $\Rightarrow$ Bayesian updating
- Firms A $[0]$ and B $[1]$ live both periods $\Rightarrow$ prices
- Firms also face uncertainty: they do not know the realization of a random shock when fixing prices

Notation

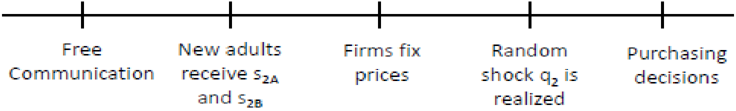
- Firms' qualities (r.v.): θ_A and θ_B
- "Public" signals (r.v.): s_{0A}, s_{0B}, s_{2A}, s_{2B}
- Signals after tasting the good (r.v.): s_{1A}, s_{2B}
- Prices: p_{1A}, p_{1B}, p_{2A}, p_{2B}
- First-period market shares: x_1 and $1 - x_1$
- Random shocks (r.v.): q_1 and q_2

Timing

t=1



t=2



$\theta_A, \theta_B \sim N(\overline{\theta}, \sigma_\theta^2)$
$s_{tf} = \theta_f + \varepsilon_{tf};\ \varepsilon_{tf} \sim N(0, \sigma_\varepsilon^2)$
$q_t \sim N(0, 1)$

Information sets

- All the information related to the distribution of random variables is common knowledge.
- Consumers:
  - $t = 1$: $C_1 = \{s_{0A}, s_{0B}, p_{1A}, p_{1B}, \overline{q}_1\}$
  - $t = 2$: $C_2 = \{s_{0A}, s_{0B}, s_{1E}, s_{2A,} s_{2B}, p_{2A}, p_{2B}, \overline{q}_2\}$
- Firms:
  - $t = 1$: $F_1 = \{\varnothing\}$
  - $t = 2$: $F_2 = \{\overline{x}_1, \overline{q}_1, p_{1A}, p_{1B}\}$

Consumers

Consumer located at x will buy one unit of brand A iff $CE_A \geq CE_B$; and will purchase one unit of brand B otherwise.

$t = 1:$

$$CE_A = E[\theta_A | s_{0A}] - \frac{1}{2}\rho Var[\theta_A | s_{0A}] - p_{1A} - \gamma x^2 + \overline{q}_1$$

$$CE_B = E[\theta_B | s_{0B}] - \frac{1}{2}\rho Var[\theta_B | s_{0B}] - p_{1B} - \gamma (1 - x)^2$$

Consumers

$t = 2:$

If consumer located at x consumed brand A in the previous period:

$$CE_A = E[\theta_A | s_{0A}, s_{1A}, s_{2A}] - \frac{1}{2}\rho Var[\theta_A | s_{0A}, s_{1A}, s_{2A}] - p_{2A} - \gamma x^2 + \overline{q}_2$$

If consumer located at x consumed brand B in the previous period:

$$CE_A = E[\theta_A | s_{0A}, s_{2A}] - \frac{1}{2}\rho Var[\theta_A | s_{0A}, s_{2A}] - p_{2A} - \gamma x^2 + \overline{q}_2$$

(Similar when finding the CE_B)

Consumers

Lemma 1: in the first period, we only have one marginal consumer located at

$$\overline{x_1} = \frac{1}{2\gamma}\left(\gamma + \frac{\tau_\varepsilon}{\tau_\theta + \tau_\varepsilon}\left(s_{0A} - s_{0B}\right) + \overline{q}_1 - p_{1A} + p_{1B}\right)$$

If $\overline{x_1} \leq 0$ (or $\overline{x_1} \geq 1$) $\rightarrow$ corner solution

If $\overline{x_1} \in (0, 1)$ $\rightarrow$ interior solution

Corollary: in the second period, for the interior solution we have two differentiated markets: fraction of customers who have three signals for brand A and two for brand B; and fraction of customers who have two signals for brand A and three for brand B.

Consumers

Due to the difference in information, the switching cost appears.
Let us describe the case of the marginal captive customer of brand A (although for the marginal captive customer of B is analogous):

$$CE_{A|A} = CE_{B|A}$$

$$\begin{aligned}
\overline{x}_{2CA} &= \frac{1}{2\gamma}(\overline{q}_2 + \gamma - p_{2A} + p_{2B} + \widetilde{\rho} - \widetilde{\theta} + \\
&\quad + \frac{3\tau_\varepsilon}{\tau_\theta + 3\tau_\varepsilon}\left[\frac{1}{3}\left(s_{0A} + s_{1A} + s_{2A}\right)\right] - \frac{2\tau_\varepsilon}{\tau_\theta + 2\tau_\varepsilon}\left[\frac{1}{2}\left(s_{0B} + s_{2B}\right)\right])
\end{aligned}$$

Consumers

$$\widetilde{\rho} = \frac{1}{2} \frac{\tau_{\varepsilon}}{(\tau_{\theta} + 2\tau_{\varepsilon})(\tau_{\theta} + 3\tau_{\varepsilon})} \rho \quad \text{is the switching cost}$$

- Only appears in the problem of the second period.
- Endogenous.
- As customer has more signals for the most repeated product, the conditional variance is always less (and this variance is not dependent on the signal values).
- When the customer chooses the brand he tasted before, the switching cost shows that the individual enjoys a positive effect due to the smaller uncertainty.
- We are NOT saying that CE should be bigger because of this fact.

Firms in t=2

In $t = 2$, firms can infer some information from the outcome of the previous period.

As in $t = 2$, $\overline{x}_1$ and $\overline{q}_1$ are known,

$$s_{0A} - s_{0B} = \frac{\tau_\theta + \tau_\varepsilon}{\tau_\varepsilon} \left(2\gamma \overline{x}_1 - \overline{q}_1 - \gamma + p_{1A} - p_{1B}\right)$$

$$s_{0A} = s_{0B} + \frac{\tau_\theta + \tau_\varepsilon}{\tau_\varepsilon} \left(2\gamma \overline{x}_1 - \overline{q}_1 - \gamma + p_{1A} - p_{1B}\right)$$

Firms in t=2

Firms plug this relationship into the expressions of the marginal consumers of each market, and then apply expectation:

$$\widetilde{x}^{E}_{2CA} = \frac{1}{2\gamma}\left(\frac{2\tau_\varepsilon}{\tau_\theta+3\tau_\varepsilon}\gamma - p_{2A} + p_{2B} + \widetilde{\rho} + \frac{\tau_\theta+\tau_\varepsilon}{\tau_\theta+3\tau_\varepsilon}\left(\underbrace{2\gamma\overline{x}_1 - \overline{q}_1 + p_{1A} - p_{1B}}_{v_1}\right)\right)$$

$$\widetilde{x}^{E}_{2CB} = \frac{1}{2\gamma}\left(\frac{\tau_\varepsilon}{\tau_\theta+2\tau_\varepsilon}\gamma - p_{2A} + p_{2B} - \widetilde{\rho} + \frac{\tau_\theta+\tau_\varepsilon}{\tau_\theta+2\tau_\varepsilon}\left(\underbrace{2\gamma\overline{x}_1 - \overline{q}_1 + p_{1A} - p_{1B}}_{v_1}\right)\right)$$

*Notice that, when the market was completely polarized in the first period, we only have one marginal consumer.

Notice that, depending on the relative position of $\widetilde{x}^E_{2CA}$ and $\widetilde{x}^E_{2CB}$, we have different possibilities.
For instance,

Equilibrium in t=2

Lemma 2: if $\overline{x}_1 \in (0,1)$, only two possibilities are sustainable in equilibrium in pure strategies; in particular, both firms cannot exploit their captive customers at the same time.

(a) $\widetilde{x}^E_{2CA} \in (0, \overline{x}_1)$, $\widetilde{x}^E_{2CB} \leq \overline{x}_1$

$$
\begin{aligned}
p_{2A} &= \frac{1}{3}\widetilde{\rho} + \frac{2}{3}\frac{\tau_\theta + 4\tau_\varepsilon}{\tau_\theta + 3\tau_\varepsilon}\gamma + \frac{1}{3}\frac{\tau_\theta + \tau_\varepsilon}{\tau_\theta + 3\tau_\varepsilon}v_1 \\
p_{2B} &= -\frac{1}{3}\widetilde{\rho} + \frac{2}{3}\frac{2\tau_\theta + 5\tau_\varepsilon}{\tau_\theta + 3\tau_\varepsilon}\gamma - \frac{1}{3}\frac{\tau_\theta + \tau_\varepsilon}{\tau_\theta + 3\tau_\varepsilon}v_1
\end{aligned}
$$

(b) $\widetilde{x}^E_{2CA} \geq \overline{x}_1$, $\widetilde{x}^E_{2CB} \in (\overline{x}_1, 1)$

* *"Exploit":* to fix higher prices taking advantage of the risk-aversion of consumers.

Lemma 3: if we are in a corner solution in the first period ($\overline{x}_1 \leq 0$, or $\overline{x}_1 \geq 1$), the firm who dominated the market fixes a price positively dependent on the switching cost.

(c1) $\overline{x}_1 \leq 0$

$$\begin{aligned} p_{2A} &= -\frac{1}{3}\widetilde{\rho} + \frac{1}{3}\frac{2\tau_\theta + 5\tau_\varepsilon}{\tau_\theta + 2\tau_\varepsilon}\gamma + \frac{1}{3}\frac{\tau_\theta + \tau_\varepsilon}{\tau_\theta + 2\tau_\varepsilon}v_1 \\ p_{2B} &= \frac{1}{3}\widetilde{\rho} + \frac{1}{3}\frac{4\tau_\theta + 7\tau_\varepsilon}{\tau_\theta + 2\tau_\varepsilon}\gamma - \frac{1}{3}\frac{\tau_\theta + \tau_\varepsilon}{\tau_\theta + 2\tau_\varepsilon}v_1 \end{aligned}$$

(c2) $\overline{x}_1 \geq 1$

Firms in t=2

$$\max_{p_{1f}} \ \pi_{1f} + \pi_{2f}^{E}$$

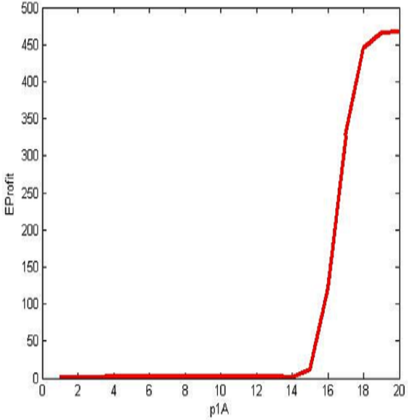
$$\begin{aligned} \pi_{2f}^{E} &= prob(c1)\pi_{2f}^{c1} + prob(c2)\pi_{2f}^{c2} + \\ &+ prob(int)\left[prob(a)\pi_{2f}^{ia} + prob(b)\pi_{2f}^{ib}\right] \end{aligned}$$

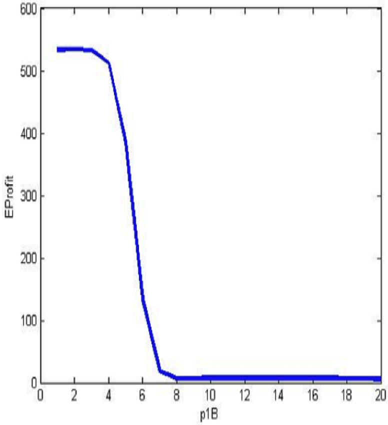
Equilibrium in t=2

Because of normality assumptions, closed-form solution for the equilibrium prices cannot be found $\Rightarrow$ simulations.

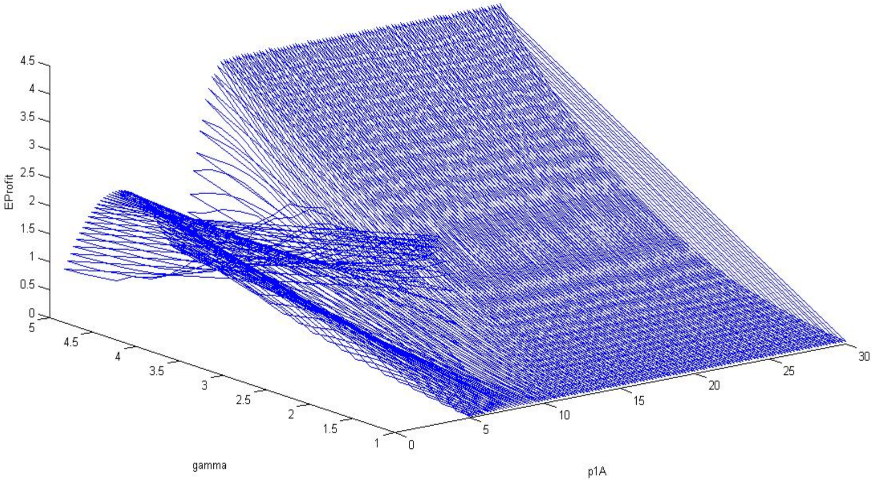
τ_ε	τ_θ	γ	$\widetilde{\rho}$	p_{1A}	p_{1B}
3	4	1	1	1.5	1.5
3	4	1	3	1	1
3	4	0.8	1	0.9	0.9
3	4	10	1	-	-

Equilibrium in t=2





Equilibrium in t=2



Equilibrium in t=2

As the profit function is not strictly concave $\rightarrow$ reaction functions will be piece-wise functions $\rightarrow$ there may be no equilibrium in pure strategies.

$\Rightarrow$ suggestions to find out the threshold?

Conclusions

- Switching costs come from risk-averse consumers and asymmetries in information (endogenous).
- If there was a corner outcome in the first period, the "dominant" firm is going to exploit the captive consumers in the second period.
- If there was an interior outcome in the first period, both firms cannot exploit their captive segments simultaneously (having one equilibrium or the other depends on some parametric conditions).
- Intuition for first-period equilibrium prices when changing the risk-aversion coefficient and the transportation costs is consistent with previous results obtained in the literature.
- Next step: finding out a closed-form solution for improving the intuition.