Can Switching Costs Reduce Prices?*

Rafael de Braga Castilho**

Abstract
The existence of switching costs for consumers may affect prices, market shares and therefore firms’ profits. While firms have an incentive to increase prices and exploit its current consumers, they also might reduce prices to increase the number of consumers next period. This paper presents a model of consumer and pricing behavior with switching costs to investigate how prices, market shares and profits vary with different switching cost levels. I also present a method to estimate the parameters of a simpler version of the model and then perform counterfactual exercises using synthetic generated data. Results show that prices increase with switching costs and that market shares and profits increase for small switching cost values and decrease for larger ones.

Keywords: Demand and supply, discrete choice, switching cost.


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1. Introduction

In many markets consumers must incur a cost to start or stop consuming a good or service. This cost is called switching cost and can be monetary or not. For example, when opening a bank account it may be necessary to pay fees or just go to the bank and wait in line and fill roles, which possibly involve some disutility for the consumer.

Along with consumers, firms are also affected by the existence of switching costs. As described in Klemperer (1995), firms have an incentive to increase prices and exploit its current consumers, but also to reduce prices and increase the number of consumers next period. The incentive to increase prices is called harvesting incentive, while the one to decrease is called investing incentive.

Therefore the net effect of switching costs on prices depends on which of these incentives prevails. In this paper I present a model of consumer and pricing behavior and use it to determine how prices, market share and profits change with different switching cost levels.

Consumers are forward-looking and choose the good that maximize its utility given their expectation on the future values of all products, which embeds that she must pay if decides to change in another period. The monopolist firm is also forward-looking and at each period chooses prices in order to maximize the present value of its profits. The firm is aware that consumer is forward-looking and also has an expectation on the future values of its products.

Due to computational limitations I estimate the model parameters for a simpler version of the model. Results suggest the dominance of the harvesting effect, since prices are increasing with the switching cost level. Market shares and profits increase for small switching costs and decrease for larger ones, which contrasts the intuition that firms always benefits from increases in switching costs.

The paper adds to the literature that analyses the effect of switching costs on prices. Klemperer (1995) presented a multi-period model with two firms and found that prices increase with switching costs, whatever their previous market share. Additionally, prices increase with the fraction of consumers that remains at each period and decrease with firms’ discount rate and new consumers entry rate.
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Ho (2015) estimates the demand for consumers deposits in Chinese banks using a dynamic model of demand with switching costs. He performs counterfactual exercises with a dynamic monopoly model and finds increasing prices on switching costs and initial market shares. Viard (2007) also found decreasing prices for lower switching costs.

Using a panel data on individual purchases of refrigerated orange juice and margarine Dube et al. (2009) estimate the switching costs. They use a model with multi-product firms and myopic consumers. Prices and profits decrease with switching costs.

With a structural model Shcherbakov (2016) estimates a model of dynamic consumer behavior with switching costs in the market for paid-television services using data on cable and satellite systems across local US television markets.

The remainder of this paper is organized as follows. Section 2 presents the model of consumer and firm behaviour. Section 3 presents a simplified version of the model. Section 4 computes the model predictions for different switching cost values. Section 5 presents the estimation method. Section 6 concludes. Appendix A shows how results change if the monopolist produces two products, how is the synthetic data generating process, a numerical example and the steps of the computational procedure.

2. Model

The model consists of an infinitely lived monopolist firm which sells its products for consumers with switching costs.

The firm set prices to maximize the expected present value of its profits. It has expectations about future values of its products and is aware of consumer’s problem.

Consumer chooses the product that maximizes the expected present value of her utility. Therefore in addition to her present utility, the consumer takes into account her expectation about products future utility (which also depends on firms pricing) and that she must pay a cost for each period she changes the purchased product.

Next I formally present the consumer’s problem and obtain the aggregate demand, then firm’s problem is presented. Section 5 and Appendix A provide details of the estimation and computational method.
2.1 Consumer Problem

Consumer is infinitely lived and discounts the future at rate $\beta$. As a discrete choice model, at each period $t$ consumer choose one and only one product to purchase. If this product is not the same purchased last period, she must pay a switching cost $\gamma$. There are $J+1$ products, wherein $J$ are produced by a monopolist firm and one is the outside good, which represents consumer possibility to not purchase any of firm’s products.

Each product has a utility $d_j$ that is constant over time, plus a shock $\eta_{jt}$ and a price $p_{jt}$ that varies over time. Consumer has a price disutility $\alpha$ and an idiosyncratic shock $\epsilon_{ijt}$ that is independently and identically distributed across models and time periods. The utility consumer $i$ receives from purchasing product $x_t \in \{0, 1, \ldots, J\}$ at period $t$ is

$$u_{ixt} = d_{xt} + \eta_{xt} - \alpha p_{xt} - \gamma 1_{[x_t \neq x_{t-1}]} + \epsilon_{ixt}$$

where $1_{[x_t \neq x_{t-1}]}$ is an indicator function which assumes value 1 if $x_t \neq x_{t-1}$ and 0 otherwise. Let $\tilde{\delta}_{jt} := d_j + \eta_{jt} - \alpha p_{jt}$ the mean utility of product $j$ at period $t$, consumer utility can be written as

$$u_{ixt} = \tilde{\delta}_{xt} - \gamma 1_{[x_t \neq x_{t-1}]} + \epsilon_{ixt}$$

the mean utility of the outside good is normalized to zero, i.e., $\tilde{\delta}_{0t} = 0$, $\forall t$.

At period $t$ consumer has $J+1$ options and chooses the product $j$ that maximizes the sum of expected discounted future utilities conditional on her information at $t$. She is aware of products utility $d_j$, shocks $\eta_t$, prices $p_t$, idiosyncratic shocks $\epsilon_{it}$ and the product purchased in the last period $x_{t-1}$. But she does not have information on future values of shocks $\eta$, prices $p$ and idiosyncratic shocks $\epsilon$.\(^1\) Additionally, define $\delta_{jt} := \tilde{\delta}_{jt} + \alpha p_{jt}$ the product mean utility before the price disutility.

I assume the mean utility $\delta$ follows a Markov process, while the shocks $\epsilon_{ijt}$ are independently and identically distributed across models and time periods and follows an extreme value type one (EVT1) distribution.

\(^1\) Notation: $\tilde{\delta}_t = (\tilde{\delta}_{0t}, \tilde{\delta}_{1t}, \ldots, \tilde{\delta}_{Jt}) \in \mathbb{R}^{J+1}$ and $\epsilon_t = (\epsilon_{0t}, \epsilon_{1t}, \ldots, \epsilon_{Jt}) \in \mathbb{R}^{J+1}$. 

The consumer state variables at period \( t \) are \((x_{t-1}, s_{t-1}, \delta_t, \epsilon_t)\), where \( s_{t-1} \) is the vector of previous period market shares. With the Markov assumption the consumer problem can be written recursively and the time subscript \( t \) omitted. Denote with a subscript \(-1\) the previous period value of a variable and with a prime the next period value, the consumer value function is

\[
V(x_{-1}, s_{-1}, \delta, \epsilon) := \max_x \left\{ \delta x - \alpha p_x - \gamma 1_{[x \neq x_{-1}]} + \epsilon x + \beta \mathbb{E}(V(x, s, \delta', \epsilon')|\delta) \right\}
\]

\[
s.t. \ s = \phi(s_{-1}, \delta, p)
\]

\[
p = g(s_{-1}, \delta)
\]

where \( \phi \) is the market share function that comes from consumer problem and \( g \) the firm policy function. These will be derived in the next subsections. The \( p_x \) and \( \epsilon_x \) are the price and idiosyncratic shock of product \( x \), respectively.

Note that consumer choice will be one of the next period state variables and she will have to pay the switching cost \( \gamma \) if she changes the product. The consumer policy function is

\[
h(x_{-1}, s_{-1}, \delta, \epsilon) = \arg\max_x \left\{ \delta x - \alpha p_x - \gamma 1_{[x \neq x_{-1}]} + \epsilon x + \beta \mathbb{E}(V(x, s, \delta', \epsilon')|\delta) \right\}
\]

\[
s.t. \ s = \phi(s_{-1}, \delta, p)
\]

\[
p = g(s_{-1}, \delta)
\]

Rust (1987) shows that when \( \epsilon \) follows a EVT1 distribution, the integral of the value function over \( \epsilon \) has closed form. The integrated value function for a consumer with product \( j \) and mean utilities \( \delta \) is defined as

\[
EV(x_{-1}, s_{-1}, \delta) := \int V(x_{-1}, s_{-1}, \delta, \epsilon) \ dG(\epsilon)
\]

and is

\[
EV(x_{-1}, s_{-1}, \delta) = \log \left( e^{\delta x_{-1} - \alpha p_{x-1} + \beta \mathbb{E}(EV(x_{-1}, s, \delta')|\delta)} + e^{-\gamma} \sum_{k \neq x_{-1}} e^{\delta k - \alpha p_k + \beta \mathbb{E}(EV(k, s, \delta')|\delta)} \right)
\]
\[ s.t.s = \phi(s_{-1}, \delta, p) \]

\[ p = g(s_{-1}, \delta) \]

where \( G(\cdot) \) is the joint CDF of shocks \( \epsilon \) and \( E \) is the conditional expectation in the information set \( \delta \).

### 2.2 Aggregate Demand

One consumer that purchases some product will not pay the switching cost in the next period unless she changes to other product. Following McFadden (1974) and Rust (1987), the proportion of consumers that purchased \( k \) in the previous period and then moves to product \( j \) is

\[
\omega_{jk} := e^{\delta_j - \alpha p_j - \gamma_1 [j \neq k]} + \beta E (EV(j, s, \delta') | \delta) \\
\sum_l e^{\delta_l - \alpha p_l - \gamma_1 [l \neq k]} + \beta E (EV(l, s, \delta') | \delta)
\]

The market shares are given by

\[
\phi(s_{-1}, \delta, p) := \Omega \cdot s_{-1}
\]

where \( \Omega \) is the matrix whose \( j, k \) element is \( \omega_{jk} \).\(^2\) This means that product’s \( j \) market share is the sum among all \( k \) existing products of the proportion of consumers that moves from product \( k \) to product \( j \) weighted by product’s \( k \) previous market share.

Therefore function \( \phi \) provides current market share given previous market share \( s_{-1} \), mean utilities \( \delta \) and price \( p \). Note this function comes from a consumer optimizing behavior which embeds that firms act according to \( g \) and consumers know the function \( \phi \).

### 2.3 Supply

There is an infinitely lived monopolist that produces \( J \) products at each period. Firm profit at period \( t \) is

\[
\pi(s_{t-1}, \delta_t, p_t) = (p_t - c_t) \cdot \phi(s_{t-1}, \delta_t, p_t) M_t
\]

\(^2\) Where \( x \cdot y \) is the inner product of vectors \( x \) and \( y \).
where $\delta_t$ is the vector of products mean utilities without the price disutility, $c_t$ is vector of products marginal costs at period $t$ and $M_t$ is the market size. To simplify the model I normalize the marginal cost do zero and the market size to one.

The firm is infinitely lived and at period $t$ chooses its products prices $p_t$ in order to maximize the sum of expected discounted future profits conditional on its information set. It is aware of previous market shares $s_{t-1}$, present mean utilities $\delta_t$ and has an expectation on its evolution.

I suppose $\delta$ follows a Markov process and therefore firm’s problem can be written recursively. Firm’s Bellman equation is

$$W(s_{-1}, \delta) = \max_p \left\{ p \cdot s + \beta \mathbb{E}\left(W(s, \delta') | \delta \right) \right\}$$

s.t. $s = \phi(s_{-1}, \delta, p)$

(10)

the state variables are the previous market shares $s_{-1}$ and the mean utilities $\delta$, while price $p$ is the control variable. The present market share $s$ is determined by equation 8, hence the expectation is taken only conditional on $\delta$.

The firm policy function is

$$g(s_{-1}, \delta) = \arg \max_p \left\{ p \cdot s + \beta \mathbb{E}\left(W(s, \delta') | \delta \right) \right\}$$

s.t. $s = \phi(s_{-1}, \delta, p)$

(11)

and returns firm price $p$ given the state variables $(s_{-1}, \delta)$.

2.4 Equilibrium

The pair of functions $(\phi, g)$ constitute an equilibrium of this game if there is no incentive to a one-period deviation. The pair $(\phi, g)$ defined above satisfy this since:

1) Given the firm policy function $g$, for any value of the state variables $(x_{-1}, s_{-1}, \delta)$ the optimizing consumer behavior in 4 results in the market share function $\phi$. Therefore it is consumers’ best response to $g$.

2) Given the market share function $\phi$, for any value of the state variables $(s_{-1}, \delta)$ the optimizing firm behavior in 11 results in the policy function $g$. Therefore it is firm’s best response to $\phi$. 

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3. Simplified Model

In this section I present a simpler version of the model described above. This simplification is mainly motivated by the computational difficulty to compute the functions $\phi$ and $g$. One of my objectives for future research is to obtain a method to estimate the original model.

The difference from the previous model is that now consumers do not observe the products mean utility before the price disutility $\delta$ and the prices $p$ at each period. Now, they only observe the mean utility $\tilde{\delta}$.

This simplifies the computation since it reduces the consumer state space. However, now consumers need to form expectations regarding the evolution of $\tilde{\delta}$, rather than $\delta$.

The consumer mean utility $\tilde{\delta}$ follows a Markov process and therefore the consumer problem can be written recursively. The consumer Bellman equation becomes

$$V(x_{-1}, \tilde{\delta}, \epsilon) = \max_x \left\{ \tilde{\delta} x - \gamma \mathbb{1}_{x \neq x-1} + \epsilon x + \beta \mathbb{E}(V(x, \tilde{\delta}', \epsilon')|\tilde{\delta}) \right\} \quad (12)$$

and integrating in $\epsilon$ as previously done gives

$$EV(x_{-1}, \tilde{\delta}) = \log \left( e^{\tilde{\delta} x_{-1} + \beta \mathbb{E}(EV(x_{-1}, \tilde{\delta}')|\tilde{\delta})} + e^{-\gamma} \sum_{k \neq x-1} e^{\tilde{\delta} k + \beta \mathbb{E}(EV(k, \tilde{\delta}')|\tilde{\delta})} \right) \quad (13)$$

The market share function is

$$\phi(s_{-1}, \tilde{\delta}) := \Omega \cdot s_{-1} \quad (14)$$

where the $j,k$ element of the matrix $\Omega$ is

$$\omega_{jk} := \frac{e^{\tilde{\delta} j - \gamma \mathbb{1}_{j \neq k} + \beta \mathbb{E}(EV(j, \tilde{\delta}')|\tilde{\delta})}}{\sum_l e^{\tilde{\delta} l - \gamma \mathbb{1}_{l \neq k} + \beta \mathbb{E}(EV(l, \tilde{\delta}')|\tilde{\delta})}} \quad (15)$$

3 Remember that for product $j$ at period $t$, the mean utility is defined as $\tilde{\delta}_{jt} := d_j + \eta_{jt} - \alpha p_{jt}$, i.e., $\delta_{jt} = \tilde{\delta}_{jt} - \alpha p_{jt}$.
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The firm still supposes that $\delta$ follows a Markov process and its problem becomes

$$W(s_{-1}, \delta) = \max_p \left\{ p \cdot s + \beta \mathbb{E}\left(W(s, \delta')|\delta\right) \right\}$$

s.t. $s = \phi(s_{-1}, \tilde{\delta})$

$$\tilde{\delta} = \delta - \alpha p$$

(16)

4. Model Predictions

Consumers must pay a switching cost $\gamma$ if they change from the previous period product. Higher switching costs decrease consumer utility from changing the consumed product and therefore increase the likelihood to continue with the same product.

To firm’s pricing, an increase in the switching cost generates an unclear effect. For consumers that are inside, the firm has an incentive to increase prices. While for consumers at the outside good, firm would like to decrease prices and thus increase the chance of having they inside next period. If prices increase or decrease as switching costs increase, depends on which of these effects dominate.

In this section I assess how prices, market shares and profits would vary with different switching cost levels. To do this I generate data on products prices and market shares for $T = 1000$ periods. The price coefficient is set $\alpha = 1.2$ and switching cost $\gamma = 4$. There is a monopolist firm that produces one product with constant over time utility $d_1 = 1.6$. Appendix A.2 give more details on the data generating process.

I use eleven switching cost levels ranging from 0% to 100% of the switching cost value used to generate the data. These are presented at Table 1.

| Table 1 |
| Switching costs |
| Percentage of original switching cost |
| 0% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
| Value | 0 | 0.4 | 0.8 | 1.2 | 1.6 | 2 | 2.4 | 2.8 | 3.2 | 3.6 | 4 |

With parameter values and the switching cost I compute the firm policy function and use it to construct a sequence of prices and market shares given one sequence of mean utilities $\delta$ draws. I generate three hundred sequences of prices and market shares. Appendix A.3 summarizes these steps.
Table 2 shows the mean value of prices, market shares and revenues (which equals profit, since costs are normalized to zero) for each $\gamma$ value. These are also shown in figure 1, figure 2 and figure 3.

<table>
<thead>
<tr>
<th>Percentage of original switching cost</th>
<th>0%</th>
<th>10%</th>
<th>20%</th>
<th>30%</th>
<th>40%</th>
<th>50%</th>
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<th>80%</th>
<th>90%</th>
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</thead>
<tbody>
<tr>
<td>Price</td>
<td>1.65</td>
<td>1.65</td>
<td>1.65</td>
<td>1.65</td>
<td>1.65</td>
<td>1.65</td>
<td>1.82</td>
<td>1.91</td>
<td>2.06</td>
<td>2.12</td>
<td></td>
</tr>
<tr>
<td>Market Share</td>
<td>0.31</td>
<td>0.45</td>
<td>0.50</td>
<td>0.51</td>
<td>0.51</td>
<td>0.52</td>
<td>0.38</td>
<td>0.33</td>
<td>0.23</td>
<td>0.21</td>
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<tr>
<td>Profit</td>
<td>0.51</td>
<td>0.74</td>
<td>0.82</td>
<td>0.84</td>
<td>0.85</td>
<td>0.85</td>
<td>0.69</td>
<td>0.63</td>
<td>0.47</td>
<td>0.45</td>
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</tr>
</tbody>
</table>

The price remains constant in 1.65 from 0 to 60% of the switching cost, then it increases monotonically until 2.12. Therefore, results indicate the dominance of the harvesting effect. Market share and profit increase for lower levels of the switching cost and decrease for higher levels.

The effect on market share suggests that larger switching costs can inhibit consumers to enter and prefer to stay with the outside good, which decrease the profits. This is an example that the firm does not always benefit from larger switching costs.

Although important in the economic literature, this article do not focus in the role of product differentiation by the firm. Only to compare with the previous results, in the Appendix A.1 I perform the same exercise but with the firm offering two products with different mean utility levels.

5. Estimation Algorithm

Now I present the estimation algorithm to recover the parameters. These are the switching cost parameter $\gamma$, products dummies ($d_1, d_2$) and price sensibility $\alpha$. The computational steps are outlined in Appendix A.4.

Given a guess $\gamma$ of the switching cost, guess a sequence $\tilde{\delta}^{JT} \in \mathbb{R}^{JT}$ of mean utilities. Suppose $\tilde{\delta}$ is a process such that

$$\tilde{\delta}_{jt} = \mu_j + \nu_{jt} \quad \nu_{jt} \sim N(0, \sigma_j^2) \quad \forall j, t$$  (17)

4 Initial market share for both products are 0. The same results were found with initial market share 0.2.
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Figure 1
Prices with different switching cost levels

Figure 2
Market shares with different switching cost levels
then estimate $\mu_j$ and $\sigma_j^2$ using maximum likelihood to construct the grid of values that $\tilde{\delta}_{jt}$ can assume, denoted $\text{grid}(\tilde{\delta})$, and then the transition matrix.\footnote{If firm produces $J$ products and each one has $D$ possible values, $\text{grid}(\tilde{\delta})$ is a set with $D^J$ elements.} The Appendix A.5 provides the details of the grid and transition matrix computation.

Following Rust (1987), integrate the consumer value function in equation 12 over $\epsilon$. This leads to a closed form solution that simplify the estimation, then compute

$$EV(x_{-1}, \tilde{\delta}) = \log \left( \exp^{\tilde{\delta}_{x_{-1}} + \beta \mathbb{E}(EV(x_{-1}, \tilde{\delta}')} + \exp^{-\gamma} \sum_{k \neq x_{-1}} \exp^{\tilde{\delta}_k + \beta \mathbb{E}(EV(k, \tilde{\delta}')} \right)$$

for all values of $x$ and $\tilde{\delta}$, where $x \in \{0, 1, \ldots, J\}$ and $\tilde{\delta} \in \text{grid}(\tilde{\delta})$.

Let $S = (S_{11}, S_{21}, \ldots, S_{J1}, \ldots, S_{JT}) \in \mathbb{R}^{JT}$ be the vector of observed market shares with $S_{jt}$ being the market share of product $j$ at period $t$. Obtain the vector.
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of mean utilities $\tilde{\delta}^{JT} = (\tilde{\delta}_{11}, \tilde{\delta}_{21}, \ldots, \tilde{\delta}_{JT}) \in \mathbb{R}^{JT}$ such that predicted market shares equals observed market shares for all products $j$ and time periods $t$, i.e.,

$$S_{jt} = \phi_{jt}(S_{t-1}, \tilde{\delta}_t) \quad \forall j, t$$

(19)

where $\phi_{jt}(S_{t-1}, \tilde{\delta}_t)$ is the predicted market share of product $j$ at period $t$. Analogously to Berry et al. (1995), given the initial $\tilde{\delta}_0$ interact the system

$$T(\tilde{\delta}^{JT}) = \tilde{\delta}^{JT} + S - \phi(S, \tilde{\delta}^{JT})$$

(20)

until obtain its fixed point, denoted $\tilde{\delta}_1$.

Once the fixed point is found, compare initial guess $\tilde{\delta}$ and $\tilde{\delta}_1$. If these vectors are different return to equation 17 and repeat all steps using $\tilde{\delta}_1$. Update the mean utility vector and repeat this process until the mean utilities are equal.

After this convergence is achieved, estimate $\hat{d}_1$, $\hat{d}_2$ and $\hat{\alpha}$ using GMM

$$\tilde{\delta}_{jt} = d_j + \eta_{jt} - \alpha p_{jt}$$

(21)

since prices at period $t$ are correlated with the shock $\eta_t$ correct for endogeneity using the instrumental variables presented in Appendix A.2.

To solve firm’s problem recover $\delta$ using $\hat{\alpha}$ and then construct $grid(\delta)$ and $grid(s)$. The details of the grid construction are provided in Appendix A.5. Since it is also supposed that $\delta$ follows a Markov process, it is possible to write the problem in the recursive form and obtain firm’s value and policy functions. For each $\delta_n \in grid(\delta)$ and $s_m \in grid(s)$ obtain

$$W(s_{-1,m}, \delta_n) = \max_p \left\{ p \cdot s + \beta \mathbb{E} \left( W(s, \delta') \mid \delta \right) \right\}$$

(22)

s.t. $s = \phi(s_{-1}, \delta, p)$

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6 I found fast convergence by iterating period by period. Which means, given $\tilde{\delta}_{old_t}$, interact until find the mean utility that equalizes the predicted and observed market share for the period $t$ and then turn to $t + 1$. 

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with the policy function \( g(s_{-1}, \delta) \) compute the vector \( \hat{p}(\gamma) \in \mathbb{R}^{JT} \) of predicted prices given \( S \) and \( \hat{\delta}^{JT} \), therefore calculate \( ||p - \hat{p}(\gamma)|| \).

Then guess another \( \gamma \) and repeat all the procedure. The estimated switching cost \( \hat{\gamma} \) is such that

\[
\hat{\gamma} = \arg \min_{\gamma} ||p - \hat{p}(\gamma)||
\]  \hspace{1cm} (23)

6. Conclusion

This paper analyzed how prices, market shares and profits behave in a market with switching costs. In the model consumers are infinitely lived and must pay a switching cost to change the purchased product, while the monopolist firm is also infinitely lived and choose price to maximize profits.

Due to computational limitations I solve for a simpler version of the model and find results that support the predictions from Klemperer (1995) that prices are increasing with switching costs. Market shares and profits of both products increase for lower switching costs and decrease for larger ones.

For future research I intend to solve the general model, preferably with more than one firm.
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References


A. Appendix

A.1 Multi-Product Monopolist

In this section I perform the same counterfactual exercise presented in Section 4 but with the monopolist producing two goods. These have constant over time utilities \( d_1 = 1.6 \) and \( d_2 = 1.4 \).

Table A.1 shows the mean value of prices, market shares and revenues for each \( \gamma \) value. These are also shown in figure A.1, figure A.2 and figure A.3.

Product 1 has a higher price than product 2 for all switching cost levels. This is expected since its constant over time utility \( d_1 \) is higher than \( d_2 \). Moreover, the price of product 1 is increasing with switching costs, while the price of product 2 decreases for some switching cost levels. Market share increases for lower switching costs and decreases for larger ones. The same occurs with profits.

Table A.1

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<th>Percentage of original switching cost</th>
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<td>Prod 1</td>
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<td>Prod 2</td>
<td>0.24</td>
<td>0.24</td>
<td>0.24</td>
<td>0.26</td>
<td>0.26</td>
<td>0.26</td>
<td>0.26</td>
<td>0.25</td>
<td>0.24</td>
<td>0.22</td>
<td>0.15</td>
</tr>
<tr>
<td>Profit</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Prod 1</td>
<td>0.51</td>
<td>0.53</td>
<td>0.54</td>
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<td>0.56</td>
<td>0.57</td>
<td>0.57</td>
<td>0.56</td>
<td>0.53</td>
<td>0.48</td>
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<tr>
<td>Prod 2</td>
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<td>0.44</td>
<td>0.46</td>
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<td>0.47</td>
<td>0.47</td>
<td>0.45</td>
<td>0.43</td>
<td>0.40</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Although prices for product 2 do not monotonically increase with switching costs, as in the case with one product, results suggest the dominance of the harvesting effect.

The market share and profits decrease for lower levels of the switching cost and increase for higher levels, likewise the result with one product.

The firm obtain higher profits offering two products, besides the product one gives higher profits when only it is offered. This raises the question of what would be the optimal choice of products by a multi-product monopolist and how prices and market shares would vary for each case. Since this is not the scope of this article, I will not discuss this issue.
Can Switching Costs Reduce Prices?

Figure A.1
Prices with different switching cost levels

Figure A.2
Market shares with different switching cost levels
A.2 Synthetic Data-Generating Process

To estimate the model I generate a synthetic data which consists of $T = 1000$ periods and $J = 2$ products. Products have a constant over time utilities $d_1 = 1.6$ and $d_2 = 1.4$, the switching cost is $\gamma = 4$ and the price coefficient $\alpha = 1.2$. The prices follow

$$p_{1t} = p_1 + \eta_{1t} + \upsilon_{1t}$$

and

$$p_{2t} = p_2 + \eta_{2t} + \upsilon_{1t}$$

where $p_1 = 1.34$ and $p_2 = 1.16$. The shocks are distributed as $\eta_{jt} \sim iid 1/4 \cdot N(0, 1)$ and $\upsilon_{jt} \sim iid 1/4 \cdot N(0, 1)$.

I simulate instrumental variables to correct for the endogeneity of prices in equation 21. Since these are correlated with the shocks $\eta_{jt}$ as shown in the equations above.

---

7 The example in Section 4 uses only the first product.
Denote $z_{jt}$ the vector of instruments for product $j$ at period $t$, these are $d_1$, $d_2$, $p_j + \kappa_{jt}$, $(p_j + \kappa_{jt})^2$, $(p_j + \kappa_{jt})^3$ and $v_{jt}$, where $\kappa_{jt} \overset{iid}{\sim} 1/4 \cdot N(0, 1)$.

Previous market share in $t = 1$ is $s_0 = (0.2, 0.2)$ and equation 8 is used to generate the data for the next periods $\{(s_1t, s_2t, p_1t, p_2t)\}_{t=1}^T$.

### A.3 Algorithm

With $d_1$, $d_2$, $\alpha$ and $\gamma$ I evaluate how prices and market shares would change with different $\gamma$. It consists of the following steps:

1. Set one switching cost $\gamma_c$.
2. Compute $EV(x_{-1}, \tilde{\delta}), \forall x_{-1} \in \{0, 1, \ldots, J\}$ and $\forall \tilde{\delta} \in grid(\tilde{\delta})$.
3. Solve firm’s problem to obtain its new policy function $g_c(s_{-1}, \delta)$.
4. Guess initial state variables $(\delta_1, s_0)$, use $g_c$ and consumer market share function to obtain the vector of prices and market share for period 1.

   (a) Draw $\delta_2$ and use $s_1$ to obtain prices and market share for the period 2.
   (b) Calculate the corresponding sequence of prices and market shares.
   (c) Return to item 4 and given the same initial state variables repeat the process with another sequence of $\delta$ draws.

### A.4 Estimation Steps

The estimation algorithm used was written in MATLAB and consists of the following steps:

1. Guess a switching cost $\gamma$.
2. Obtain $\tilde{\delta}$ that equals the predicted and observed market share.

   (a) Initial guess of $\tilde{\delta}_0$, with $grid(\tilde{\delta}_0)$.
   (b) Compute transition matrix for consumer, given $\tilde{\delta}_0$ and $grid(\tilde{\delta}_0)$.
   (c) Compute $EV(x_{-1}, \tilde{\delta}), \forall x \in \{0, 1, \ldots, J\}$ and $\forall \tilde{\delta} \in grid(\tilde{\delta}_0)$. 
(d) Obtain the vector of mean utilities \( \tilde{\delta} \) that equals the predicted and observed market shares.

(e) If \( \tilde{\delta}_0 \neq \tilde{\delta} \), \( \tilde{\delta} \) becomes \( \tilde{\delta}_0 \), update grid(\( \tilde{\delta}_0 \)) and return to (b). Else go to 3.

3. Estimate parameters \( \hat{d}_1, \hat{d}_2 \) and \( \hat{\alpha} \) using GMM.

4. Obtain \( \delta = \tilde{\delta}_0 + \hat{\alpha} p \) and construct grid(\( \delta \)).

5. Solve firm’s problem to obtain its policy function \( g(s-1, \delta) \).

6. Calculate the vector of predicted prices according to \( h \), denoted by \( \hat{p}(\gamma) \).

7. Compute the objective function \( ||p - \hat{p}(\gamma)|| \).

8. Return to item 1.

9. Repeat 8 until find a global minimum of the objective function.

A.5 Grid and Transition Matrix

The products’ mean utility \( \tilde{\delta}_{jt} \) follows

\[
\tilde{\delta}_{jt} = \mu_j + \varepsilon_{jt}
\]

where \( \varepsilon_{jt} \sim iid N(0, \sigma^2) \). Given a \( \tilde{\delta} \) sequence, use maximum likelihood to estimate

\[
\hat{\mu}_j = \frac{1}{T} \cdot \sum_t \tilde{\delta}_{jt}
\]

and

\[
\hat{\sigma}_j = \left( \frac{1}{T} \cdot \sum_t (\tilde{\delta}_{jt} - \hat{\mu}_j)^2 \right)^{1/2}
\]

the parameters of the normal distribution and then construct grid(\( \tilde{\delta} \)).

Mean utilities \( \tilde{\delta}_j \) assume the values \( \{\tilde{\delta}_{j1}, \tilde{\delta}_{j2}, \ldots, \tilde{\delta}_{jD}\} \) in the grid, with \( \tilde{\delta}_{jk} < \tilde{\delta}_{jk+1} \). Then \( \tilde{\delta}_{jk} \) is such that

\[
\tilde{\delta}_{jk} = F^{-1}\left((2 \cdot k - 1)/2D\right)
\]
where \( F(\cdot) \) is the CDF of a normal distribution with mean \( \hat{\mu}_j \) and standard deviation \( \hat{\sigma}_j \). Therefore the transition probability of product \( j \) from state \( k \) to \( l \) is

\[
\mathbb{P}(\delta_{jk} \mid \delta_{jl}) = 1/D
\]

### A.6 Numerical Example

I use the estimation procedure from Section 5 and the synthetic generated dataset to recover the switching cost \( \gamma \), products dummy \((d_1, d_2)\) and price sensibility \( \alpha \).

Table A.2 reports the results. The parameters values used to generate the data are in the second column, while the estimated values and objective function value are in the third column. Estimated coefficients have the true sign and lie around the true value.

<table>
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<tr>
<th>Variable</th>
<th>True</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switching Cost ((\gamma))</td>
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<td>4</td>
</tr>
<tr>
<td>Price ((\alpha))</td>
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<td>1.14</td>
</tr>
<tr>
<td>Dummy Product 1 ((d_1))</td>
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<td>1.75</td>
</tr>
<tr>
<td>Dummy Product 2 ((d_2))</td>
<td>1.4</td>
<td>1.21</td>
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<tr>
<td>Obj Fun Value</td>
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