PRICING OPTIMIZATION USING R

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ABSTRACT
The proposed empirical research uses a sample of 199 records from automotive industry to analyze the characteristics of pricing optimization in this industry. R software is being employed to estimate an OLS model. The coefficient estimates from our OLS estimations were used to generate a linear demand function, with errors normally distributed and standard deviation given by historic data available for the analysis. Finally, we employ GGPLOT2 package to generate the visualization of revenues and profits corresponding to different price levels. Our approach provides management with insights into the measures and steps necessary to achieve the full potential of pricing optimization across products and customers. Besides policy implications for management, our research underlines the benefits of using a quantitative approach to offer management relevant information necessary to fundament an efficient price policy.

KEYWORDS: *price policy, pricing optimization, R, GGPLOT2*

1. INTRODUCTION

Price optimization is the focus of a plethora of research both in business and economics. It supports managerial decision by offering insights for forecasting demand, help to develop pricing and promotion strategies, control inventory levels and improve customer satisfaction (Robert, 2005).
Using price optimization techniques companies determine the optimal price within the range of possible prices by customer segment and product category. Depending on the business strategy, pricing optimization supports organizational objective such as maximizing profitability, entering a market or protecting existing market share (Mon, 2018). Setting prices based on market competitiveness attract more lucrative customers' segments. Also increases revenues by cementing loyalty or boosting cross-selling (Martin and Bayley, 2010). In an increasingly competitive business environment where opportunities for profit through efficiency and cost reduction are becoming more difficult, adequate price segmentation employing different techniques of price optimization ensures growing volume while maintaining profitability (Santoni and Alvaro, 2007).
According to Mon (2018) pricing optimization techniques have evolved from markup to base cost strategies to complex techniques which control for competition, demand, operations corporate and business strategies in order to determine starting price, optimal price, discounted or promotional one. Same author differentiates between price optimization and dynamic pricing, considering that while the former is more complex, controlling for many factors, the latter one estimates the optimal price solely based on current demand.
Many more aspects adds to different nuances within the field of price optimization Thus, according to Roberts (2005) if we have constrained resources, including time for selling a product and there are different segments of customers willing to pay different prices for same resources, then the optimization problem falls within the scope of yield or revenue management. Particularly relevant

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in sectors where the proportion of variable costs is low, yield management optimizes resource utilization through inventory availability to customers with the highest propensity to pay from the entire customer base (Sanjay, 2009).

Similarly, Roberts (2005) underlines that if we have constrained capacity corroborated with a decreasing propensity to buy, we have a markdown management issue. Obsolescence, fashionability, deterioration and limited time amount to additional reasons for markdowns. When retail prices are less than those suggested by the manufacturer, price optimization uses list prices to convey manufacturer' suggested retail price. To the opposite, when the objective is tailoring prices to specific of different customers, optimization problem falls into the domain of customized pricing (Philips, 2010).

2. A LINEAR APPROACH TO DETERMINE THE OPTIMAL PRICE

Price optimization uses a quantitative approach to determine how customers will react to different prices. The optimal price will allow the company to meet its performance objective such as maximizing operating profits or the value offered to its shareholders ((Sanjay, 2009).

Fonseca (2017), Besbes and Zeevi (2015) and Cooper et al (2015) propose a simple, linear approach to determine optimal price. They argue that although simple, the linear assumption produces good results.

2.1 The model

Taking the same approach, we will consider a linear demand curve Q(p):

$$Q(p) = \alpha p + \beta \quad \text{(Eq. 1)}$$

where quantity Q is a linear function of the price P. The total revenue will be:

$$R(p) = pQ(p) = \alpha p^2 + \beta p \quad \text{(Eq. 2)}$$

where Revenue (R) is a linear function of price, as shown in Eq. 2. Total profit will then be determined by the difference between revenue and costs:

$$L(p) = (p-c)Q(p) = \alpha p^2 - \alpha pc + \beta(p-c) \quad \text{(Eq. 3)}$$

In Eq. 3 the unit cost of the product (c) is used to calculate total costs which are afterwards subtracted from the total revenues. By differentiating Eq. 2 we find the optimal price which maximizes the revenue:

$$P_{\text{max revenue}} = -\beta/2\alpha \quad \text{(Eq. 4)}$$

Similarly, we differentiate Eq. 3 to determine the price which maximizes the profits:

$$P_{\text{max profits}} = (-\beta + \alpha c)/2\alpha \quad \text{(Eq. 5)}$$

As Fonseca (2017) underlines, adding fixed costs to Eq. 3 does not change the price policy since optimization implies computing the first order conditions.

2.2 Data and methodology

For exemplification we use a dataset of 159 observations from a Hungarian dataset on Supply chains in automotive industry obtained through the courtesy of Partium Christian University, Romania. Our model requires employing information on quantities and on prices of a motor sold to two categories of customers: end customers and distributors. A list price is used by the manufacturer but prices are then differentiated by means of applying discounts for each customer, depending on its position in the supply chain (end customer or distributor) and on the quantity. For this reason, our model controls for the category of customer.

Of course, prices are expected to vary over time, with higher prices at the beginning for prototypes and lower prices after the producers obtains economies of scale. Also, in automotive industry prices also are expected to vary depending on the specifications of the product, with customization adding significantly to the price of the product sold. However, our basic approach relies on available data and we cannot control neither for time nor for customization.

Prices are in euros. Basic information on the quantities and prices is presented in table 1.

Table 1. Descriptive statistics

Variable	*Label*	*N*	*Mean*	*Std Dev*	*Minimum*	*Maximum*
Quantity	Quantity	159	3.17	1.80	1.00	9.00
Price	Price	159	111.88	43.75	78.00	293.00

For our statistical analysis we employ R statistical package. Our choice for R package in this case was determined by the large number of base functions and specialized packages for reading, visualizing and analyzing data available in R (Vinte et al., 2017). A complete display of R packages available for data processing and visualization is available at http://cran.r-project.org/web/views.
First, we estimate an OLS model using the lm package available in R. We use stargazer package for displaying the results. We have chosen Stargazer because it is well appreciated for creating LATEX code, HTML code and ASCII text for well-formatted regression tables, with multiple models side-by-side, as well as for summary statistics tables, data frames, vectors and matrices (Hlavac, 2018).
The coefficient estimates from our OLS estimations were use to generate a linear demand function, with errors normally distributed and standard deviation given by historic data available for the analysis.
Finally, we employ ggplot2 package to generate the visualization of revenues and profits corresponding to different price levels. We have chosen ggplot2 because this R package makes it simple to create complex plots from data in a data frame, providing a more programmatic interface necessary to better control the results (Hlavac, 2018).

2.3 Results

For our available dataset, the relationship between prices and quantity is visualized in figure 1.

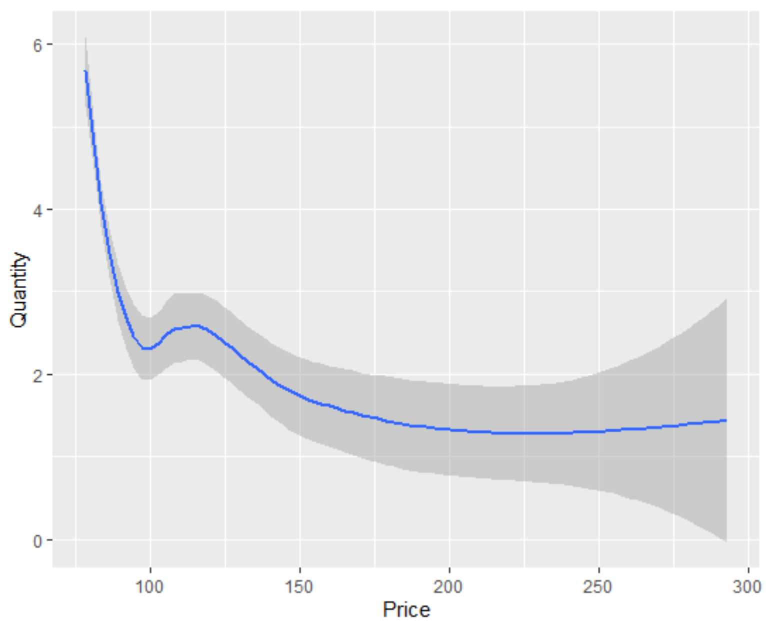

Figure 1. Demand curve

We se that the demand curve presented in figure 1 in negative slopping, as the theory suggest.

In our case the product is sold to distributors and end customers. Figure 2 present de demand curves for the two categories of customers.

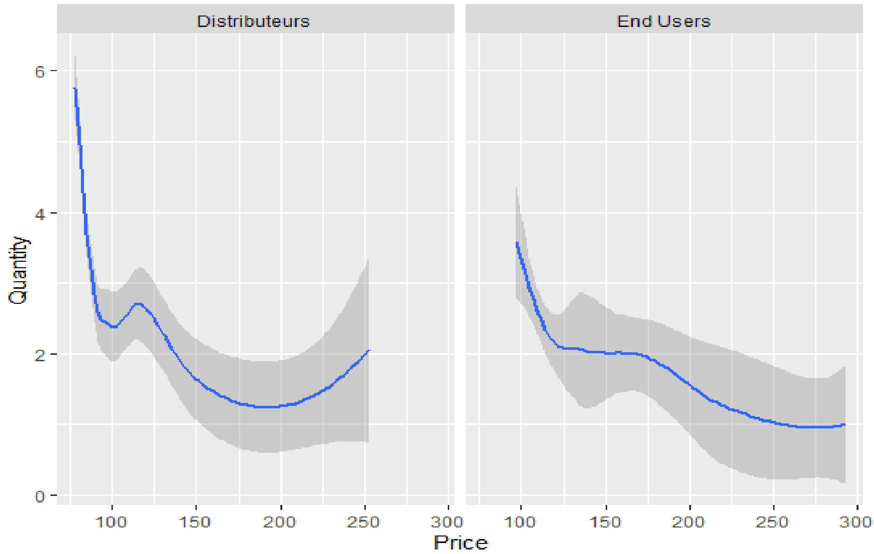

Figure 2. Demand curve for distributors and end users.

As figure 2 shows, demand is negative slopping for both of them. Nevertheless figure 2 clearly shows differences, both in slope and in intercept. It is therefore needed to estimate the parameters for both of them.
The OLS estimation results for end users are presented in table 2.

Table 2. OLS estimates of the relationship between prices and quantities for end users

	Dependent variable:
	Quantity
Price	-0.010^{***}
	(0.002)
Constant	3.654^{***}
	(0.008)
Observations	23
R^2	0.481
Adjusted R^2	0.457
Residual Std. Error	0.586 (df = 21)
F Statistic	19.483^{***} (df = 1; 21)
Note:	*p **p ***p<0.01

Table 2 show that only 23 out of the 199 observations correspond to end customers. Both price and the intercept are highly significant, with p-values of 0.002 for price and 0.008 for the intercept. Adjusted R-square shows that prices accounts for 48% of the variation in quantities for end customers. Also, F statistics shows that the model is valid.
Using the estimates in table 2 we have use ggplot2 to visualize the total revenues and the profits associated with different level of prices (figure 3).

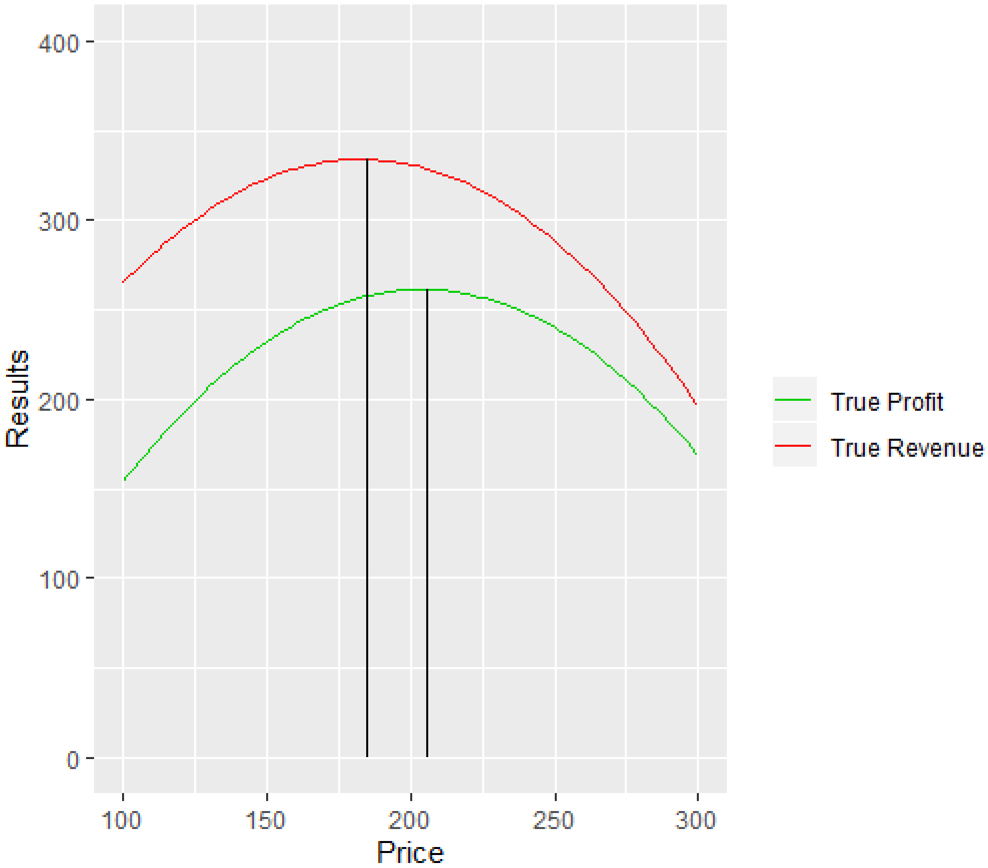

Figure 3. Revenues and profits for end customers

As figure 3 shows our models shows that for end customers the price which maximizes the revenues is 185 euro and for profits 206 euros. Maximum revenues are 334 euros and maximum profits 261euros.
OLS results for distributors are presented in table 3.
As table 3 shows, our analysis employs 136 observations corresponding to distributors. The estimated coefficients for intercept and price are statistically significant and, as expected the estimated coefficient for price is negative. Adjusted R-square shows that prices account for 25.6% of the variation in quantities. The F statistics shows that the overall model is good.

Table 3. OLS estimates of the relationship between prices and quantities for distributors

	Dependent variable:
	Quantity
Price	-0.025^{***}
	(0.004)
Constant	5.962^{***}
	(0.005)
Observations	136
R^2	0.262
Adjusted R^2	0.256
Residual Std. Error	1.620 (df = 134)
F Statistic	47.496^{***} (df = 1; 134)
Note:	*p **p ***p<0.01

Using the estimated coefficients in table 3, ggplot2 is used to visualize the profits and revenues for different levels of price.

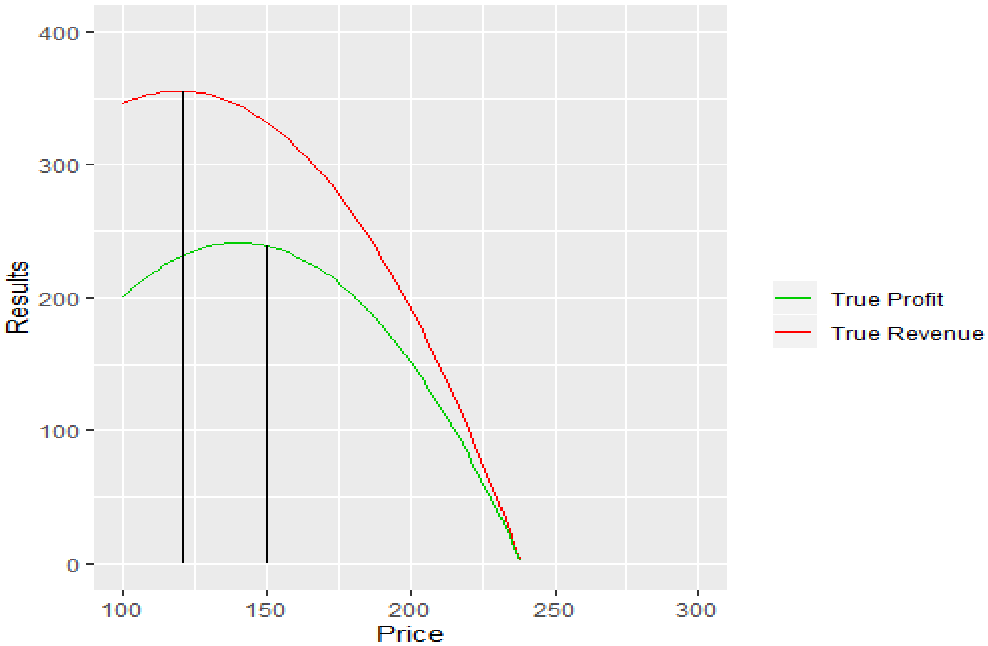

Figure 4. Revenues and profits for distributors

As figure 4 shows, the price which maximizes the profits for distributors is 142 euros and the one which maximizes the revenues is 121 euros. Maximum profit is 241 euros whereas maximum revenues is 355 euros.

2.4 Discussion

Our linear approach to estimating the optimal price provides management with the optimum level of price which maximizes either revenues or profits. Management if therefore required to consider first which policy objective is most appropriate. Although unit cost assumption is often incorporated in the accounting of enterprises (Kinni, 2003), this assumption does not hold in practice because as the sales increase, economies of scale are obtained are therefore unit const decrease. It is therefore more informative to center the price policy on the objective of revenues maximization. This is particularly true in today's business environment when has been a shift from profit maximization to maximization of value offered to shareholders (Monroe, 2004).

3. CONCLUSSION

The assumption of a linear relationship between prices and quantities sold is very restrictive and offers only a rough approximation of the reality. This is true in our case also, as shown in Figure 2 and 3. In spite of its simplistic approximation, existing literature in the field shows that a linear approximation demand used to determine the optimal price produces very good results (Fonseca, 2017; Besbes and Zeevi, 2015; Cooper et al., 2015).

Following their findings, we have chosen the same approach in our endeavor to fid the optimal price and thus to help management implement an efficient price policy.

Nevertheless, finding the optimal price is only a part of the problem. Management has to choose first which objective is most appropriate. As shown, there are reasons to prefer the revenues maximization objective versus the profit maximization one. Then the management has to consider all the factors relevant to price policy. As shown, prices vary in price as economies of scales are obtained. Then customization is especially problematic since may induce a large variation in prices. The quality of information available in the informational system of the organization is also critical for documenting the price policy. Therefore, is mandatory that management enforces adequate mechanism to maintain data quality.

Providing adequate data will be available, future research will focus in controlling for more factors.

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