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Relationship between consumer behavior and price elasticity with the participation of case analysis

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Abstract. This study systematically investigates four fundamental theoretical models: linear and non-linear demand curve models, marginal utility, price elasticity, and cross-price elasticity, discussing on consumer behavior and commodity pricing. Besides, bridging those classical economic theories and modern marketing strategies: specialty, shopping, convenience, and unsought goods, the paper analyzes the product characteristics in response to the market demand modification. For instance, the non-linear demand curve provides a better explanation of premium pricing tolerance in the specialty, while the cross-price model comes up with a greater illustration of the shopping market (taking "Starbucks" and "Tim Hortons" as examples). Moreover, the unsought market relies on the concave demand curve, connecting the perspective of psychology and situational factors. Based on the implementation of the marketing mix theory(4Ps): Product, Promotion, Place, and Price, an integrated analytical framework was shown with an emphasis on the necessity of contextualized requirements modeling. This research reveals three key limitations in the literature. Possibly, the mismatch between the theoretical assumptions and empirical consumer behavior would arise from missing or inadequate background factors in the analysis, such as geographical and cultural influences, along with the absence of a mathematical formula aligned with the raised assumptions. The outcome optimizes the theoretical system of consumer behavior and provides a theoretical basis for enterprises to develop differentiated pricing strategies.

Keywords: Demand curve; marginal utility; price elasticity; cross-price elasticity; marketing mix.

1. Introduction

Demand and supply, within the regulations of the local government, have basically determined the motivation of markets. Digging deeply into this historical mechanism, consumer behavior drives the explicit performance of demand, assisting professionals in tracking the tendency to buy and sell. To be specific, concepts such as previous experience, taste, price, and branding could be reflected in the decision-making of individuals (Kotler, 1999). Price elasticity, including related price and quantity, is challenged by public demands. Citing that, the efficiencies of the large corporation led one prominent business historian to declare that the 'invisible hand' of the market had been partially eclipsed by the 'visible hand' of the corporate manager (Johnson, 2001). The quantity offered by suppliers indeed pushed the pricing strategy. Under such a logistic process, the efficiency of the mechanism would be tested by the response of consumers to price.

In terms of corporations, competitive advantages hold the ability to renovate, leading organizations to success. The understanding of consumer behavior initiates the process of recognizing target markets, which triggers unique competitive advantages facing other competitors in the market. Marketing mix – aka.4Ps of marketing, including price, product, place, and promotion, boosts consumer awareness of provided products or services in favorably judging (Meldrum & McDonald, 2007). The assistance of capturing critical consumer behavior creates large efficiency for companies to excavate optimal pricing strategies such as price discrimination and dynamic pricing, along with the ability to forecast future trends (Dew & Fan, 2024). Among the gaps of uneven income groups, the distribution of wealth results in innovative regulations created by local government, depending on how sensitive citizens respond to price changes, especially on fuel tax and carbon tax (Andersson & Atkinson, 2020). With an effective understanding of reality, higher expectations toward environmental or social aims are attached, raising the social benefits and sustainable development gently. By getting together the rational and psychological analysis, consumer behavior would be transparent but complicated with clarified mathematical models and functions.

Models, outputted from millions of talents, are leveraged as critical roles in formally expressing abstract economic theories and concepts into concrete mathematical formulas, assisting individuals to understand and digest logistics in the systems by dismantling uncertainties and difficulties. Apart from the basic function, forecasting, on the other hand, could also be utilized as a feasible tool under the model. By implementing historical or current data, the estimated numbers would be produced by the given model. Using that data, individuals or organizations could make forward-looking decisions, enabling them to adjust on time to maximize profit. As mentioned in the discussion, optimization models, helping corporations and governments to allocate resources by generating reliable evaluations, could be taken as an example, to enhance economic efficiency.

We will largely focus on puzzles of how linear and non-linear demand curve models describe the fluctuations in market demand, within the critical thinking of the relationship between marginal utility and price elasticity, as well as their market application. Historically, what are the paper results, limitations, and improvements of previous reports?

Consumer behavior has historically been described as a series of observable behaviors instead of internal mental states, pointed out by John B. Watson in 1913, arguing that it includes all human actions, including complex behaviors, especially in the process of environmental stimulation, such as advertisements, branding, and production ordering (Watson, 1913). To state more clearly, consumer behavior should be inspired by external factors over internal cognitions. Similarly, Skinner, in 1953, presented that the concept of reward and punishment mechanisms (negative reinforcement & positive reinforcement) significantly weighed in the decision-making of consumers. Experiencing reality, promotions, consumer loyalty, and incentive purchasing influence the consumer to buy or not. Under these backgrounds, an optimized reinforcement strategy starts with the basis of consumer behaviors within marketing.

Marshall, who initially introduced the concept of price elasticity in 1890, stated the formula of demand pricing elasticity (various in percentage). With accuracy, Marshall applied the solution of ceteris paribus, which says that all the variables stay with no change except the one being experimented with. Implementing this, the characteristics of substitutes, complements, necessities, and luxuries could be discussed, especially relative to the consequence of elasticity in response to the time span. Those factors contribute reliable evidence for market segmentation and price differentiation. The company also solidified the branding and control price by leveraging the theory, thus maximizing the profit with the lowest cost. Decades, the criticizing process upgraded, while the theories were optimized. The price elasticity not only applies in the demand-price situation but also extends into other fields such as psychology, sociology, and behavioral economics.

In 2024, Lin, Chen, and Song published an article analyzing the demand curve of hotels decomposed, focused on the heterogeneity of demand elasticity across different consumer groups based on socio-demographic characteristics, preferences, and risk tolerance, as well as across various time periods (normal times vs. epidemic crisis). As found, there was a demand difference between the two time periods, that is, the demand for mid-to-high-range hotels during epidemic periods contained less elasticity, while the demand for economic hotels displayed no significant fluctuation before and after the epidemic. Based on reliable data, Lin and his colleagues discovered that heterogeneity exists between the groups of consumers who have distinct types of individuals linked to the diverse demands of a specific hotel. Nonlinear demand curve fitting and decomposition analysis were cited during the experiment, referencing the elasticity dynamics. Alternatively, the limitation of data scope lagged behind the accuracy of the results, as the specific locations or platforms were relied on in the current research. This explained that the points could be debated as they were used in other cases, gaining poor universality. Psychologically, the purchasing factor has not been considered clearly, which justifies that the consumers are rational, but naturally, the thing goes inversely. To go over the gap, worldwide data under diverse cultural backgrounds could be examined as comparison factors; besides, artificial intelligence could be drawn into the model optimization process.

Traditional marginal utility theory was criticized for its limited explanation that the assuming consumers make rational decisions by equalizing utility per unit cost was always raised but the fact

shows that consumer behavior was affected by psychological biases, social factors, and situational relying, From the contribution in 2025, Sheaff proposed, a substituted marginal utility model based on psychological and reality consumer behavior, forecasting the relationship between demand and price precisely. To be specific, the concept of utility has been completely removed by psychological motivation, illustrating the demand variance. What Sheaff emphasized is the irrational and dynamic situation with heterogeneous preferences. On the other hand, a united alternative mathematical model should be considered while the marginal utility theory is debated. Compared to the two theories, the advanced one lacks large-scale empirical testing, which leads to the uncertainty of precision. Expanded, this innovation competes for insufficient engagement in the daily purchase actions in response to low-frequency, high-involvement decision-making.

The truth is that the daily carbon footprint could also be related to the concept of price elasticity. Rafaty, in 2025, together with colleagues, priced leverage to regulate demand for CO_2 emissions—fossil energy use by businesses or consumers. The research found that the elasticity of CO_2 emissions only achieved -0.06%, which suggests that in the interval of current carbon pricing interval, the emission was highly inelastic in response to price, requiring a crucial price rocketing to stimulate the necessary reduction in emissions. As mentioned, there is a carbon price interval leveraged in the analysis, which may act as a constraint in this case since the carbon prices were always lower than what was expected.

Normally, the product categories that catch similar target consumer groups could be examined by cross-price elasticity, testing the relationship between two product categories. In 2025, Ma, Shang, and their colleagues discovered that E-cigarettes could be an economic alternative to alcohol by the data showing that the consumption of E-cigarettes rose by 0.13% and 0.05% while the price of different types of alcohol increased by 1%. Combined with the legal restriction of indoor tobacco use banning, the relationship between E-cigarettes and cigarettes displays as complementary that both categories of cigarettes increase consumption by 2.4 units and 1.9 units respectively, as both cigarettes are allowed indoors. Specifically, the outcomes were contributed from only 181 variables, which means the biases would exist since the amount of data was not sufficient, within the possibility of not reflecting precise realistic purchasing behavior.

As discussed above, the main goal of this article is to provide an overview of key mathematical models in consumer behavior and commodity pricing, especially focusing on four theoretical frameworks: linear and non-linear demand curve models, marginal utility, price elasticity, and cross-price elasticity. Logically, the content explored the results of previous research and also discussed the limitations, and suggested possible directions for improvement. The second part introduces the mentioned four mathematical models while analyzing their basic theories and calculation methods. Then, the third part reviews the outcomes of past papers on consumer behavior and commodity pricing, emphasizing the application of those models.

2. Methods

2.1 Linear and Non-Linear Demand Curve Model

Recalling the definition of a linear demand curve, the model describes the relationship between the demand and price of a given commercial item. As shown by the function:

$$Q = a - bP \tag{1}$$

Q refers to the quantity demanded, P refers to the price, and a and b are constants. Based on that, a clues the quantity demanded is stimulated by other factors as the P is equal to 0. As a result, the price elasticity could be higher than 1 or less than 1. To present in the graph, the linear demand curve is featured in a straight line with a constant slope.

Distinctly, the non-linear demand curve model could be defined with three types: concave, convex, and “S” shape. Starting from the concave demand curve, this states that the decline in quantity demanded slows down as prices rise.

$$Q = a \cdot \ln(P) + b \tag{2}$$

In general, there is a logarithmic function exists, showing an upward concave shape. The slope of the curve decreases as the independent variable increases. Similar to the linear demand curve, Q represents the quantity demanded and *P* reflects the price, while *a* is a constant. In contrast, the convex demand curve conveys a faster decrease in demand as the price increases; at the same time, the price elasticity enlarges while consumers become elastic to the specific product. In terms of the "S" shape demand curve, there are multiple price periods. Within a certain price range, demand exhibits slower rates of change, whereas in another price range, it responds more rapidly.

$$Q = a \cdot e^{bp} \tag{3}$$

In this model, typically, two or more stages are formed – "the initial stage" and "the transition stage". During the initial stage, at relatively low price levels, changes in demand are relatively slow. Meanwhile, consumers perceive goods as more reasonably priced or with a certain security of demand. Then, prices rise to a certain level, and in the transition process, the rate of change in demand suddenly accelerates, as they pass through the inflection point, consumers become more sensitive to the demand for goods, strengthening the impact of price changes. Apart from the demand curve model, the logistic function is also involved.

$$f(x) = \frac{L}{e^{-k(x-x_0)}+1} \tag{4}$$

In the function, x represents price or other factors such as quality, substitutes, complementary, personal preference, etc.; *L* displays the maximum or minimum of demand, explaining the situation that when the price level is low at a certain level, the largest quantity demanded needed by the consumers; *K* claims the parameter of the slope, affecting the steepness of the S-curve and responding to the degree of sensitivity of demand to price changes. As the amount of k increases, the sensitivity degree is enhanced. x_0 represents the inflection point of the curve as the critical point of the price. When the price is equal to x_0, the quantity demanded reaches the middle of the curve.

2.2 Marginal Utility

First of all, in the field of economics, utility refers to the satisfaction that individuals receive from the consumed commodities or services. Connected with the meaning of marginal, which displays that the additional cost or benefits brought from one more unit, marginal utility defines the utility contributed by increased products and services consumed. To be more specific, it indicates how much extra satisfaction is formed when each unit is added.

$$MU = \frac{\Delta U}{\Delta Q} \tag{5}$$

MU refers to marginal utility, ΔU displays the additional utilities based on extra products or services, and ΔQ represents the change in consumption.

$$MU = \frac{dU(Q)}{dQ} \tag{6}$$

Similarly, *Q* implicit the consumption of a certain commodity or service while *U(Q)* represents the utility when the consumption is *Q*.

$$U(Q_1, Q_2) = Q_1^{\alpha} \cdot Q_2^{\beta} \tag{7}$$

The formula shown above is called the "Coob-Douglas" utility function. Q_1 and Q_2 demonstrate two types of products or services, respectively as well as α and β conveying the degree of consumer preference toward each product or service category. According to the main model, the formulations of getting the marginal utility of both MU_1 and MU_2 are analyzed.

$$MU_1 = \frac{\partial U(Q_1,Q_2)}{\partial Q_1} = \alpha \cdot Q_1^{\alpha-1} \cdot Q_2^{\beta} \tag{8}$$

$$MU_2 = \frac{\partial U(Q_1,Q_2)}{\partial Q_2} = \beta \cdot Q_2^{\beta-1} \cdot Q_1^{\alpha} \tag{9}$$

MU_1 illustrates the contribution offered by an additional unit of Q_1; MU_2 points out the satisfaction provided by an extra unit of Q_2.

Commonly told, preference is determined by individuals, and it could be various since people have different tastes in certain products and services. On this page, the quantification methods for preference are provided.

$$\max U(Q_1, Q_2) = Q_1^{\alpha} \cdot Q_2^{\beta} \tag{10}$$

$$subject\ to\ Q_1 \cdot P_1 + Q_2 \cdot P_2 = M \tag{11}$$

Recalling the confirmation of α and β, the optimization issues matter. In this situation, utility *(U)* would be maximized by following the given specific restrictions, such as the consumer income, substitute price ($P_1\ and\ P_2$), or budgets (M), which could be the possible alternative conditions responding to the reality. This method could be considered as a solution to estimate α and β. For detailed tailoring, the least squares method and the Lagrange multiplier method are effective.

2.3 Price Elasticity

Price elasticity clarifies the fluctuation of quantity demanded in response to a shift in the item's price. With the basic theorem, the demand factor drives the ratio between the rate of demand change and the rate of price change.

$$E_p = \frac{\frac{dQ}{Q}}{\frac{dP}{P}} = \frac{dQ \cdot P}{dP \cdot Q} \tag{12}$$

$$E_p = \frac{\frac{dQ}{Q}}{\frac{dP}{P}} = \frac{dQ \cdot P}{dP \cdot Q} \tag{13}$$

Differentiate Q:

$$Q' = f'(P) = \frac{dQ}{dP} \tag{14}$$

E_p indicates the amount of price elasticity. The process shown above introduces the deducing of reasoning steps of price elasticity (first equation). $Q = f(P)$ as the initial model of demand function is derivated into $Q' = f'(P)$, then the result appears $\frac{dQ}{dP}$, which appropriately explains the right part of E_p.

2.4 Cross-Price Elasticity

As a branch of elasticity, it emphasizes the consumer effect of a certain good assessed by the price shift of other certain goods.

$$E_{xy} = \frac{\Delta Q_x \cdot P_y}{\Delta P_y \cdot Q_x} \tag{15}$$

E_{xy} highlights the elasticity of demand for good X with respect to changes in the price of good Y. ΔQ_x shows the change in quantity demanded of good X. ΔP_y implies the volume of price change for commodity Y. P_y and Q_x calls the price of item Y and quantity demanded of item X respectively. Finding that three situations would happen possibly within the model: 1. $E_{xy} > 0$, criticizing the substituted relationship between good X and Y; 2. $E_{xy} < 0$, explaining the complementary relationship between good X and good Y; 3. $E_{xy} = 0$, saying that there is no explicit relationship between two commodities.

3. Result

Expanding the concept of the linear demand curve, Maxime C. (2015), Georgia Perakis (2015), and Robert S. Pindyck (2015) concluded a pricing rule of fulfilling the linear demand curve in addition to three conditions: 1. Maximum charged price can be estimated; 2. No forecast of selling quantity; 3. Marginal cost (MC) is known and constant. The company could expect an amount of real profit that is close to the one shown in the true demand curve. To realistically apply the rule,

optimization issues such as pricing would be addressed after the limitation of the functions is determined and the expected profit implication in the random demand curves is analyzed. Apart from these numerical processes, the marketing concepts were also the inputs. With a rich-supported background that the corporations intend to chase an optimal result from the limited demand information provided, the organizations would like to cost in trials with variable pricing strategies that is, only testing the number within the limited set -- high and low price, determining the outcomes by the evaluation of related market feedback and lasting that in the long-term. To deal with the simple case, the non-differentiability curves could be a basic benchmark of non-linear demand curves (Wan et al., 2022). Nevertheless, in extreme market scenarios where the price fluctuates dramatically or where no maturity period exists for certain products, the S demand curve performs below expectations. By exemplifying the case of the electricity market, since the value of lost load (VOLL) was never cleared in the specific market, the S curve model, which has nothing to do with the unclear process, results in testing biases.

Hjertrand inserted in 2024 the unique analysis of the marginal utility of income into the paper, with specific graphs, critically resulting in the number of marginal utilities always diminishing with respect to the increasing expenditure, especially occurring in the situation of a limited level of expenditure. In other words, there is a decreasing and concave relationship between marginal utility and expenditure. Through the meta-regression model, Daniel and David pointed out in 2023 that the testing results showing differences by different inputs (lifetime consumption approach and consumer demand studies), as well as the geographical and research period factors, also contribute to the questionnaire bias. As analyzed, a single variable easily leads to inaccuracy, while a combined analysis yields a reliable mean.

Leveraging the cross-price elasticity theorem, in 2021, Lasse and Vegard discovered, with the estimation of years 2002-2016, that the probability of consumers choosing different types of vehicles has been determined by the mutual characteristics of products. By setting a premise of even price changes for all models, the corresponding elasticities would be reflected by altered market shares. Based on the combined experiment of own-price elasticity and cross-price elasticity, gasoline cars display highly elastic substitution with respect to themselves while showing a substitute relationship between diesel cars in a cross-price elasticity experiment.

Adding to that, Ryan and Yuhao touched on consumer elasticity from the perspective of macroeconomics in 2024, including recession and expansion. Taking several product categories (coffee, paper towels, soda, cereal, mustard, and ketchup), the outcomes display that the different product categories show various fluctuations, especially when they participated in the recession activity. In the observation, the elasticity curve started to drop before the economic recession, which points out that the consumer may have already experienced the external factors altering before the economic announcement. The idea has also been proved by Dube, Hitsch, and Rossi in 2018. By leveraging two models (HDF & GPDH), stable price elasticity could be discovered, as well as in the situation of the individual product.

4. Discussion + Limitation

The demand curve model has discussed real issues relating to marketing. Introducing the product in the marketing mix, at first, displays the product or services provided by the company. Then, price claims the amount of payment that consumers offer to acquire the product or services provided by the company. Next, promotion involves communication activities toward the targeted markets with the goal of enhancing brand reputation and recognition, as well as that place subject to distribution, the process of how to deliver the product/services to the consumer.

With the application of both linear and nonlinear demand curve models in pricing, the optimal pricing level could be formulated specifically. Collecting the data based on the performance of the target market, the model generates an accurate number with *"b"* (as the slope of the function), which echoes whether an additional dollar would alter the response of consumers toward the given

product/service. Associated with the pricing rule settled by Maxime C. et al. in 2015, the limitation exists. To be specific, they are insufficient engagement in future trend concerns and the narrow scope of availability in nature. However, a simple model assists in quick decision-making in routine situations. To solve the puzzles that could not be tackled by the linear demand curve, the non-linear demand curves (Concave, Convex, and S curve) have the responsibility to take charge.

In the aspect of marketing, the *product* is categorized into four groups: *specialty* (products that consumers have a strong preference for), *shopping* (products that consumers like to compare and research), *convenience* (products that consumers buy as a habit), and *unsought* (products that consumers currently not aware the need). With a distinct boundary between product aspects and a close relationship with the formed pricing strategy, this section will draw attention to shopping items that fiercely compete with substitutes. "Convex demand curve" clearly points out that increased additional dollar contributes to the acceleration of the reduction in quantity demanded. This concept can usually be combined with a promotion strategy. Take "Starbucks" and "Tim Hortons" as an example to illustrate, since they are both famous substitutes for each other in Canada if Starbucks raises a creative promotion idea of releasing a 20%-off discount on drinks, crowds will intend not to spend their budgets on Tim Hortons. In this scenario, the popularity of Starbucks is enhanced by promoting lower prices, while Tim Hortons is puzzled about the situation of decreasing quantity demanded.

To say that the S curve model matches most real-world cases, the companies that position as convenience and stick-in-budget would likely bring the new product to the segmented groups within a relatively low-price range initially, which is generally acceptable to consumers. Nevertheless, a certain number of companies will present a new corporate face to consumers through repositioning due to innovative product development (in response to market competition), a change in long-term goals and strategies, or to address new customer segments. At this time, the marketing mix will be affected, in which the pricing relating to the second period of the "S" curve mode will rise to a certain level. This move will cause the company's original customer base to become price elastic or even to disengage from the brand. Another concept in marketing complemented with

Continue the expression with the model of Concave demand, products in specialty such as luxury and technology, with the price dropping, the loss of scarcity undermines the current position of brands, while the rate of declining quantity demanded is stimulated. Even though an acceptable price will attract a rising demand from consumers, the image of the brand will be affected, and repositioning is required; otherwise, lowering-price behavior would misunderstand populations with a vogue brand position, which would negatively hurt the long-term strategy indeed. Building upon this non-linear model, the specialty market could be illustrated accurately. As explained before, specialty goods represent the product that consumers stand for, which points out that the consumers were more likely to take the premium price of the specialty goods because of their strong preference. For instance, individuals who are fans of Hermes (a luxury brand) are possibly to take an extremely high price for a Hermes item.

As discussed in the result part, the marginal utility could be exemplified in liveness, as well as in an unsought item. A classic situation is "all you can eat/drink". Initially, the first few bites will provide the highest satisfaction for the consumers, since they are satisfied with hunger. Then, it turns a twist, remaining eating starts to destroy the enjoyment while people become less hungry – flattening the marginal utility. Eventually, reaching the point of fullness, the marginal utility would turn negative as more food could cause discomfort in consumers.

5. Conclusion

The study breaks new ground by integrating demand curves with marketing-related theories, and linking with other pricing models. Novelly, explaining the demand analysis framework that addresses three key limitations that were exposed in traditional models, the contextual analysis reveals unique insights into the issues of various product categories, such as premium pricing and a close relationship

between two items. These advances empower both businesses and individuals to enhance their dynamic pricing strategies according to the specific characteristics of the commodity, as well as boost the optimization of product mix recommendations by the cross-price model. The dual perspective of the economics-marketing framework fills the theoretical gaps, pioneering new avenues of consumer behavior research.

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