МАТЕМАТИЧНІ МЕТОДИ, МОДЕЛІ ТА ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ В ЕКОНОМІЦІ

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COMPARING APPROACHES: A SCIENTIFIC OVERVIEW OF ONLINE AND OFFLINE RETAIL PRICE OPTIMIZATION

The aim of this paper is to compare online and offline retail price optimization and highlight the key differences. Online retail price optimization uses algorithms and data analysis to set the best price for an item on an e-commerce platform, considering product demand and competition. Offline retail price optimization involves manual methods, such as cost-plus pricing, market pricing, and psychological pricing, to price items in physical stores. The study involved a review of existing literature on retail price optimization and its application in online and offline retailing. The results showed that data availability is a significant difference between online and offline retail price optimization, with online retailers having access to more data. Online retailers can quickly adjust prices because of automation, while offline retailers need to manually change prices. The results of the study emphasize the importance of price optimization in both online and offline retailing and the benefits of using both methods together. The findings provide valuable insights for retail businesses and can inform future research in retail price optimization.

Keywords: *price optimization, algorithms, machine learning, market demand, market-driven pricing, psychological pricing, retail business.*

JEL classification: *M31, L81, C44*

СПІВСТАВЛЕННЯ ПІДХОДІВ: НАУКОВИЙ ОГЛЯД ОПТИМІЗАЦІЇ РОЗДРІБНИХ ЦІН В ОНЛАЙН ТА ОФЛАЙН ТОРГІВЛІ

Оптимізація роздрібних цін є ключовим аспектом успішного роздрібного бізнесу. Ця стаття має на меті порівняти відмінності між онлайн та офлайн-методами оптимізації роздрібних цін. Онлайн-оптимізація роздрібних цін використовує алгоритми та аналіз даних для визначення оптимальної ціни на товар. Вона враховує попит на товар і конкуренцію для максимізації прибутку. На противагу цьому, офлайн-оптимізація роздрібних цін покладається на ручні процеси, а також на методи такі як ринкове ціноутворення і психологічне ціноутворення. Основна відмінність між цими двома методами полягає в доступності даних і швидкості коригування цін. Онлайн-продавці мають доступ до великого обсягу даних, що дозволяє їм приймати більш точні цінові рішення і швидко адаптуватися до мінливих ринкових умов. З іншого боку, офлайн-продавці мають обмежений доступ до даних, що ускладнює прийняття точних цінових рішень та адаптацію до ринкових змін у режимі реального часу. Оптимізація цін в онлайн-торгівлі також виграє від таких інструментів, як динамічне ціноутворення, яке автоматично коригує ціни на основі ринкових умов і цін конкурентів. Офлайн-продавці покладаються на більш традиційні методи, такі як періодичні уцінки, які не завжди відображають поточні ринкові умови. Однак перевага офлайн-продавців полягає в тому, що вони можуть створювати унікальний досвід у магазині та адаптувати цінові стратегії на основі поведінки та вподобань покупців. Вони також можуть скористатися перевагами торгового персоналу для надання персоналізованого обслуговування клієнтів і рекомендацій щодо товарів. Отже, як онлайн, так і офлайн-методи оптимізації роздрібних цін мають свої переваги та недоліки. Поєднання цих методів може призвести до створення добре продуманої цінової стратегії, яка максимізує прибуток і підтримує задоволеність клієнтів. Онлайн-методи пропонують більшу точність і швидкість у ціноутворенні, тоді як офлайн-методи дозволяють персоналізувати взаємодію з клієнтами та підтримувати з ними емоційний зв'язок. Загалом, обидва методи важливі для успішного роздрібного бізнесу. Для досягнення найкращих результатів можна рекомендувати застосування цих методів разом.

Ключові слова: *оптимізація цін, алгоритми, аналіз даних, ринковий попит, ринкове ціноутворення, психологічне ціноутворення, роздрібний бізнес.*

Problem statement. Retail price optimization involves determining the best prices for goods and services to maximize profits. In today's fast-paced, technology-driven retail environment, retailers need to stay ahead of the competition by using data and information to make informed pricing decisions. However, there are different approaches to retail price optimization depending on whether the retailer operates online or offline, or has a hybrid business model that works in both formats.

Online retail price optimization uses data analytics to determine the optimal prices for products sold on e-commerce platforms, while offline retail price optimization relies on traditional methods, such as cost-plus pricing. Hybrid retailers that have both online and offline stores need to find a balance between these two approaches to maximizing sales revenue.

Analysis of recent researches and publications. The issue of sales in online and offline retail has been raised more than once in scientific circles. The problem of pricing is one of the most important issues in trade. Emek Basker [1] found that Wal-Mart's presence in a city caused a reduction in prices. Martín-Herrán [2] found that the lower the unit cost and/or the greater the price elasticity, the greater the shelf space allocated to that brand. Ellickson [3] found that firms cluster by pricing strategy, choosing actions that agree with those of their rivals. Dan [4] found that retail services strongly influence the manufacturer and the retailer's pricing strategies. Together, these papers suggest that retailers may be influenced by their rivals, the presence of other retailers, and retail services when setting prices. Bagwell [5] has found that in an equilibrium with several of the same firms, the firm with low prices and low costs dominates the market. Subsequently, Levy M., Grewal D., Kopalle P. K., Hess J. D. [6] confirmed that the then-existing methods of setting retail prices were sub-optimal because they did not take into account the effects of advertising, competition, and substitute goods. Recent research says that consumers who have more control over the prices they pay have better attitudes and loyalty to the retailer. Consequently, a retailer who can dynamically set these prices will largely win the competition (W. Reinartz [7]). Seiler [8] found that search costs play a large role in explaining purchase behavior and that a promotion for a particular product increases the consumer's incentive to search. Cachon [9] found that the retailer stocks less takes smaller price discounts, and earns lower profit if strategic consumers are present than if there are no strategic consumers. These findings suggest that price optimization does not work as intended, and may even be detrimental to the retailer, regardless of whether online or offline commerce. Gupta [10] found that to solve the resulting NP-hard discrete multi-objective optimization problem, the retailer should use a new algorithm that exploits the neighborhood search feature of the Zigzag method to extend the NSGA-II front further. This suggests that a new algorithm should be used to solve the problem.

The aim of the article is to compare the approaches to price optimization in online and offline retail and identify the key differences between them. An article will review the literature on retail price maximization and its application in both online and offline retail. The aim is to provide information for retailers and provide a basis for future research in retail price optimization.

Results. Optimal algorithms and data analysis to determine the best price aim to balance customer acquisition and profit maximization, considering factors such as market demand, supply chain costs, and competition. Algorithms used in online retail price optimization consider a variety of data points, including customer buying habits, competitor prices, and market trends, to decide informed pricing [11]. Understanding the definition and methods of online retail price optimization is essential for businesses looking to stay ahead of the ever-changing e-commerce landscape.

The process of optimizing retail prices on the Internet is a rational and expedient method of using data and algorithms to determine the current prices of goods for a given period. Machine learning techniques were used to estimate historical lost sales and predict future demand for new products. To tackle this challenge, a nonparametric structure was used for the demand prediction model, which takes into account reference price effects when determining pricing policies. An algorithm was developed that efficiently solves multi-product price optimization problems by incorporating these reference price effects [11].

Since determining the optimal prices for goods sold online involves analyzing customer behavior, competitors' pricing strategies, market trends, etc., it is possible to set competitive and profitable prices with the help of a successful financial model created by machine learning methods. Such a model will also consider the largest number of profit-and-loss statements. As practice shows, a quick financial analysis of such a large number of reports over a certain period maximizes sales revenue.

To address the differences between online and offline retail price optimization, various machine learning models can be utilized [12]. These models can analyze large amounts of data and make predictions about customer behavior, market trends, and other factors that influence pricing decisions. Machine learning models offer a powerful tool for retailers looking to optimize their pricing strategies and make data-driven decisions. Whether it is online or offline retail, machine learning models can be customized to fit the specific needs and challenges of each business, and can help retailers to stay ahead of the curve and remain competitive in an ever-changing retail landscape.

Some of the most common machine learning models used in retail price optimization include:

1. Regression models: Regression models can predict the relationship between different variables, such as the relationship between price and demand. This type of model can be useful in online retailing, where data on customer behavior and preferences can inform pricing decisions.

2. Decision Trees: Decision trees are a type of model that can decide based on a set of rules. They are well suited for retail price optimization because they can model the complex relationships that affect pricing decisions.

3. Neural Networks: Neural networks are a type of machine learning model that can make predictions based on large amounts of data. In retail price optimization, neural networks can analyze customer behavior, market trends, and other factors.

4. Random forests: Random forests is a type of machine learning model that can make predictions based on data from multiple sources. In retail price optimization, random forests can be used for analytical calculations based on the results of recent customer loyalty programs in interaction with market conditions and product lifecycle.

5. Genetic algorithms: effective for optimization, including price optimization. [13] Therefore, any of these types of algorithms can be used for price optimization. However, more recent studies consider price optimization with uncertainty, so robust quadratic programming algorithms may be a better choice when there is uncertainty in the data. When there is no uncertainty, any type of algorithm can be used.

Algorithms used in this type of analysis include predictive modeling techniques, such as machine learning algorithms, which can apply to large datasets collected from various sources (e-commerce platforms or other third-party services). Data analysis typically includes forecasting demand based on historical patterns; understanding consumer preferences through surveys/ interviews; evaluating competitors' pricing models and promotional activities; assessing product availability across different channels or optimizing inventory levels according to expected future orders, etc.

Online retailers have access to a vast amount of data that can be used for price optimization. This includes customer behavior, competitor pricing strategies, market trends, and other insights collected from e-commerce platforms or third-party services. On the other hand, offline retailers typically only have limited internal information about production costs and desired profit margins when determining prices for products sold in physical stores. Online retailers can quickly and easily adjust prices due to the vast amount of data available. This includes customer behavior, competitor pricing strategies, market trends etc., which allows them to make informed decisions about how best to optimize their product pricing strategy across different channels (online/offline).

Online retail price optimization has the benefit of allowing retailers to quickly adjust prices in response to changes in demand and competition [14]. This can help them maximize profits by setting optimal prices for their products or services.

Offline commerce is conceptually different from online on many counts. This also applies to processes. The advantage of offline retail price optimization is that businesses can adjust prices in real-time based on changes in supply and demand; this can help them always offer competitive prices while maximizing sales profits. Physical stores also provide customers with a face-to-face experience, which can lead to more informed purchasing decisions than those made online without human contact. This involves considering production costs, desired profit margins, and other factors such as market trends or competitor pricing strategies when determining a selling price. The most common methods used are cost-plus pricing (setting prices based on adding up all associated costs plus an additional margin), market-oriented pricing (pricing according to what customers perceive value), and psychological pricing [15]. Other techniques include promotional activities like discounts or loyalty programs, which can increase sales volume while still maintaining profitability. Offline retail price optimization also allows retailers to set competitive pricing, but it is more difficult because they must manually update store shelves with new product information and pricing data [16]. Efficient time series forecasting techniques, auction-based market mechanisms, and Spot pricing, including the use of machine learning models, will help to reduce uncertainty and improve results by offering insight into future outcome-based decisions. One of the algorithms of machine learning used linear regression. It is easy to implement and is used for purposes such as predicting real estate prices, financial performances, and traffic. Cluster analysis is also used for understanding the relationship between consumers and the products they mostly search for. This work proposes a hybrid model, exploring linear and nonlinear modeling [17].

Online retail price optimization is a more efficient method of setting prices. Process automation can free up retailers to focus on other aspects of their business by reducing the time and resources required. This also eliminates the possibility of human error, which can be costly in billing. [11]

Despite the obvious benefits of using price optimization algorithms in retailing, there are also some difficulties and challenges. One of the most significant constraints a researcher may face is the analysis of customer behavior and preferences. The difficulty is that these very factors can be difficult to predict. There are always factors (such as personal tastes or values) that algorithms do not consider. This is a weighty challenge because these factors influence the consumer's decision-making process.

Relying too heavily on data analysis can lead retailers to decide based solely on past performance rather than considering future trends or changes in market conditions. Another disadvantage of using algorithms for pricing is that it often developed based on certain assumptions about customers' buying habits. If those assumptions prove too incorrect, they may set prices at levels that do not reflect actual demand from consumers.

This can lead to missed sales opportunities by overpricing or underpricing products relative to what customers would pay for them, given their circumstances and needs. One of the major limitations of price optimization in offline retail is that the amount of data needed for analysis can exceed all reasonable limits. In addition, there's a lot of data needed – customer preferences, market trends, and competitors' pricing strategies. Without the data, it can be difficult to set prices.

Likewise, businesses cannot always react quickly enough to sudden changes in demand or competition that result in immediate price changes. Finally, relying too heavily on intuition rather than facts increases the risk of making mistakes because of incorrect assumptions about consumer behavior.

The best way to use both online and offline retail price optimization in a complementary manner is by leveraging the strengths of each method. For example, you could use data analysis from online sources such as customer reviews or competitor pricing strategies to inform your decisions when setting prices manually at physical stores. This would allow you to take advantage of the insights provided by algorithms while still being able to adjust rates quickly if needed based on changes in demand or competition. It may be beneficial for retailers who operate both an online store and brick-and-mortar locations to consider offering discounts or other incentives that are only available through one channel; this can help encourage customers who prefer shopping exclusively via either digital platforms or traditional outlets depending on their individual needs and preferences.

Conclusions. Online retail price optimization has transformed the way prices are set for products, bringing increased efficiency, speed, and transparency to the process. However, there are also some challenges, like accurately predicting customer behavior and ensuring pricing reflects actual demand.

In short, online retail price optimization is a powerful tool for retailers looking to optimize their pricing and boost revenue. While there are some obstacles to overcome, the benefits are substantial and make it an essential part of any successful retail strategy. Future research should continue exploring the potential of online retail price optimization and finding ways to address its limitations.

As technology advances, machine learning and artificial intelligence are ready to revolutionize the retail industry. With their ability to process huge amounts of data quickly and accurately, retailers can make complex pricing decisions based on a range of variables. Soon, we can expect to see a shift to personalized pricing, where retailers will tailor their pricing strategies to specific segments of their customer base. Using the latest algorithms, retailers can analyze customer data and make real-time price adjustments based on individual preferences and buying habits, leading to a more personalized shopping experience. There may be more emphasis on integrating retail price optimization with other aspects of retail operations, such as inventory management and marketing. This will help retailers create a more integrated retail strategy and maximize the use of their data and resources.

In conclusion, the future of retail price optimization is bright and full of opportunities for innovation and growth. It will well position retailers who stay ahead of the curve and adopt the latest technology to succeed in the coming years.

References:

1. Basker, E. (2005). Selling a Cheaper Mousetrap: Wal-Mart's Effect on Retail Prices. IO: Empirical Studies of Firms & Markets.
2. Martín-Herrán, G., Taboubi, S., & Zaccour, G. (2006). The Impact of Manufacturers' Wholesale Prices on a Retailer's Shelf-Space and Pricing Decisions. *Decis. Sci*., 37, 71–90.
3. Ellickson, P. B., & Misra, S. (2008). Supermarket Pricing Strategies. *Mark. Sci*., 27, 811–828.
4. Dan, B., Xu, G., & Liu, C. (2012). Pricing policies in a dual-channel supply chain with retail services. *International Journal of Production Economics,* 139, 312–320.
5. Bagwell, K. et al. Dynamic Retail Price and Investment Competition *The RAND Journal of Economic*s, 28 (1997): 207–227.
6. Levy, M., Grewal, D., Kopalle, P.K., & Hess, J.D. (2007). Emerging trends in retail pricing practice: implications for research. *Journal of Retailing*, 80, 165–180.
7. Reinartz, W., & Wiegand, N. (2019). The Perils of Retail Price Differentiation: Why Nobody Wins When Customers Lose. *NIM Marketing Intelligence Review*, 11, 30–5.
8. Seiler, S. (2013). The impact of search costs on consumer behavior: *A dynamic approach. Quantitative Marketing and Economics*, 11, 155–203.
9. Cachon, G. P., & Swinney, R. (2009). Purchasing, Pricing, and Quick Response in the Presence of Strategic Consumers. *Manag. Sci.*, 55, 497–511.
10. Vishal Kumar Gupta, Q.U. Ting, Manoj Kumar Tiwari, Multi-period price optimization problem for omnichannel retailers accounting for customer heterogeneity, *International Journal of Production Economics*, Volume 212, 2019, Pages 155–167, ISSN 0925-5273, https://doi.org/10.1016/j.ijpe.2019.02.016.
11. Ferreira, K. J., Lee, B., & Simchi-Levi, D. (2016). Analytics for an Online Retailer: Demand Forecasting and Price Optimization. Manuf. Serv. *Oper. Manag*., 18, 69–88.
12. Mathur, P. (2018). Overview of Machine Learning in Retail. Machine Learning Applications Using Python.
13. Dirk Czarnitzki, Thorsten Doherr (2002). Genetic Algorithms: A Tool for Optimization in Econometrics – Basic Concept and an Example for Empirical Applications. *ZEW Discussion Paper*. No. 02–41.
14. Zhang, J., Zhao, S., Cheng, T.C., & Hua, G. (2018). Optimisation of online retailer pricing and carrier capacity expansion during low-price promotions with coordination of a decentralised supply chain. *International Journal of Production Research*, 57, 2809–2827.
15. Kumar, S., & Pandey, M. (2017). The impact of psychological pricing strategy on consumers' buying behaviour: a qualitative study. *International Journal of Business and Systems Research*, 11, 101–117.
16. Wang, K., & Goldfarb, A. (2017). Can Offline Stores Drive Online Sales? *Journal of Marketing Research*, 54, 706–719.
17. Krishna, V. V., & Mahesh, K. (2022). A Review On: Retailer Pricing Analysis using Machine Learning. *International Journal of Advanced Research in Science, Communication and Technology.*