Scientific Research Publishing

Open Journal of Applied Sciences, 2024, 14, 1963-1978
https://www.scirp.org/journal/ojapps
ISSN Online: 2165-3925
ISSN Print: 2165-3917

Dynamic Pricing Strategies Using Artificial Intelligence Algorithm

Murat Basal[1], Emel Saraç[2], Kadir Özer[3]

[1]Logistics, Vocational School, Istanbul Gelisim University, Istanbul, Turkey
[2]Department of Business Administration, Institute of Social Sciences, Ostim Technical University, Ostim, Turkey
[3]Department of Insurance, Faculty of Financial Sciences, Ankara Hacı Bayram Veli University, Ankara, Turkey
Email: mbasal@gelisim.edu.tr, emel.saraç@ostimteknik.edu.tr, kadir.ozer@hbv.edu.tr

How to cite this paper: Basal, M., Saraç, E. and Özer, K. (2024) Dynamic Pricing Strategies Using Artificial Intelligence Algorithm. *Open Journal of Applied Sciences*, **14**, 1963-1978.
https://doi.org/10.4236/ojapps.2024.148128

Received: July 9, 2024
Accepted: July 29, 2024
Published: August 1, 2024

Abstract

Pricing strategies can have a huge impact on a company's success. This paper focuses on the advantages and disadvantages of using artificial intelligence in dynamic pricing strategies. A good understanding of the possible benefits and challenges will help companies to understand the impact of their chosen pricing strategies. AI-driven Dynamic pricing has great opportunities to increase a firm's profits. Firms can benefit from personalized pricing based on personal behavior and characteristics, as well as cost reduction by increasing efficiency and reducing the need to use manual work and automation. However, AI-driven dynamic rewarding can have a negative impact on customers' perception of trust, fairness and transparency. Since price discrimination is used, ethical issues such as privacy and equity may arise. Understanding the businesses and customers that determine pricing strategy is so important that one cannot exist without the other. It will provide a comprehensive overview of the main advantages and disadvantages of AI-assisted dynamic pricing strategy. The main objective of this research is to uncover the most notable advantages and disadvantages of implementing AI-enabled dynamic pricing strategies. Future research can extend the understanding of algorithmic pricing through case studies. In this way, new, practical implications can be developed in the future. It is important to investigate how issues related to customers' trust and feelings of unfairness can be mitigated, for example by price framing.

Keywords

Artificial Intelligence, Algorithm, Dynamic, Pricing, Strategy

1. Introduction

In today's hyper-competitive market, businesses are constantly looking for new

ways to increase revenues and maintain a competitive edge. One approach that has emerged as a promising solution is Price Optimization using artificial intelligence algorithms. With the ability to analyze large amounts of data in real time, AI algorithms offer the potential to determine optimal pricing for products or services at any given time. The use of AI in pricing has revolutionized the way businesses approach pricing strategy. Dynamic Pricing, using AI-powered predictive analytics, involves adjusting prices in real time based on market demand, inventory levels and other factors. AI algorithms analyze real-time data to forecast demand, identify pricing trends and adjust prices in real time. This approach ensures that brands are always aware of changes in the market and can quickly adjust prices to optimize revenue. Price Optimization involves using algorithms that analyze real-time market data, competitor prices and customer behavior to determine the best pricing strategy. With the help of AI algorithms, businesses can process large amounts of data to determine the optimal price point for their products or services at any given moment.

Price management is one of the most central parts of sales strategies. Fluctuating demand has been a challenge for decades. Already in 1999, Douglas Ivester, CEO of Coca-Cola, came up with the idea of changing the prices of soft drinks in vending machines according to the outside temperature [1]. In a dynamic pricing (DP) strategy, prices are changed dynamically to generate larger profits when there is uncertain demand in the market [2]. Dynamic pricing can help you make bigger profits, but problems with customers can arise with irrelevant use of the strategy.

Artificial intelligence (AI) has quickly become one of the most discussed topics and is inevitably becoming part of our daily lives as it becomes more accessible to the public. According to a study by Swiss bank UBS [3], ChatGPT reached a significant milestone, reaching 100 million users just two months after its launch. For context, the same benchmark took Instagram two and a half years and TikTok 9 months to reach OpenAI's ChatGPT is not the only AI company on the market. Grand View Research [4] valued the global AI market size at USD 136.55 billion in its 2022 market analysis report. The research also forecasts that the global AI market will grow at an annual rate of 37.3% to reach US$1811.75 billion by 2030. This growth is likely to increase AI awareness and susceptibility to being manipulated or treated by AI. Artificial intelligence is changing all aspects of business. AI undoubtedly has incredible potential in dynamic pricing applications. Algorithmic pricing means combining AI and dynamic pricing by using complex algorithms to determine how much to charge for each product. As companies implement different applications of algorithmic pricing, it is important for companies to be aware of the potential advantages and disadvantages of their chosen pricing strategies. Implementing algorithmic pricing can increase a firm's revenue and consumers' personalized experience. On the other hand, algorithmic pricing can lead to feelings of unfairness and loss of trust. The aim of this research is to provide a comprehensive overview of the potential consequences of using AI-powered algorithmic pricing. What are the

main advantages and disadvantages of using AI in dynamic pricing strategies? To investigate the question.

2. Dynamic Pricing and Artificial Intelligence

Initially, the concept of dynamic pricing and the literature on artificial intelligence in general are reviewed and other commonly used pricing models are presented. The use of algorithms in pricing is called algorithmic pricing.

2.1. Different Pricing Models

Pricing models are a fundamental part of businesses' sales strategies. Nagle and Müller [5] define a pricing strategy as well-planned decisions to increase demand and consumers' desire to buy in order to increase a firm's relevance. Some pricing models change over time, some remain constant, and some vary by customer. Here is a brief overview of some of the most common pricing strategies.

In fixed pricing, prices are initially fixed, but sometimes the pricing strategy is combined with flexible pricing and therefore prices are negotiable [6]. According to the research, fixed pricing with flexible prices is often used in housing, used car, boat or jewelry markets. Fixed prices are usually fair but lack flexibility

In cost-plus pricing, the price is determined by the sum of costs and the resulting profit margin [7]. Cost-plus pricing is easy to implement, but it can overlook many factors such as customer demand and competitor prices. Cost-plus pricing can be effective if the margin is well chosen and a thorough market analysis is done before choosing the price.

The focus of competitive pricing is outside the company. It focuses on the prices and reactions of competitors and adjusts prices accordingly [8]. In cooperative competitive pricing, the company matches what other companies are doing. Conversely, a company chooses a price and expects others to follow or compete with aggressive pricing. These pricing models offer different approaches to setting prices. Understanding what pricing models are helps us understand a more advanced pricing model known as dynamic pricing.

2.2. Fundamentals of Dynamic Pricing

In a dynamic pricing strategy, prices change depending on demand and some other variables that influence consumer behavior and therefore affect demand. These other factors can be, for example, the weather or the day of the week. Price changes can be distributed weekly, daily or very quickly, even in real time. The price can also change depending on the customer, which means personalized pricing. The main objective of dynamic pricing is to maximize profits and minimize price inefficiencies.

As Neubert [9] notes, dynamic pricing strategies are growing in popularity due to their positive impact on revenues and company valuations. This trend is supported by Bouchet *et al.* [10], who conducted a study on the sporting event industry. According to their research, 70 percent of respondents reported ad-

justing ticket prices on a weekly or monthly basis. Notably, only 5 percent updated their ticket prices several times a day.

While Bouchet *et al.*'s [10] study provides valuable insights into the sport event industry, it is likely that the use of dynamic pricing has grown since their research. This growth is not limited to sporting events; dynamic pricing is used for all kinds of events. A good example is Live Nation's use of dynamic pricing when it announced that the band Coldplay will perform in Finland in 2023. The impact was huge, with some ticket prices going over one hundred euros and basic tickets for a concert reaching 394 euros [11]. This example demonstrates the adjustability and applicability of dynamic pricing across various events and sectors.

2.3. Artificial Intelligence (AI)

AI has improved human life, for example by improving healthcare diagnostics. AI has also significantly improved manufacturing efficiency and service systems [12]. Artificial intelligence is the study and development of intelligent machines and software that can act in ways we associate with human behavior [8] [12].

Knowledge representation means storing information in a form that computers can use to solve complex problems. Robotics and artificial intelligence can be used in decision-making processes [13] Automated reasoning refers to the ability of AI systems to draw logical conclusions, make decisions and solve problems. It is used in robotics, motion tracking and problem solving [14]. Machine learning is a feature of AI that focuses on learning and improving independently of experience. It is widely used in object and speech recognition, autonomous vehicles, robotics and predictive analytics [15]. There are countless ways to use artificial intelligence. As an example, AI can be used in voice recognition, translation, autonomous vehicles, and robotics [16]. This research will focus on the application of AI in dynamic pricing. Aparicio and Misra [17] describe the use of AI in dynamic pricing quite accurately:

"*AI models frame this as a dynamic optimization problem, with the goal of maximizing gain while learning.*"

Artificial intelligence can be divided into two main categories: weak AI and strong AI. Weak AI is designed for specific tasks and is made to replicate something it does as closely as possible. Strong AI is made to process human-like abilities in a variety of tasks. Strong AI is truly intelligent, unlike weak AI [18].

3. Algorithmic Pricing Models and Price Optimization Algorithms

3.1. Algorithmic Pricing

Algorithmic pricing was used by travel websites and large retailers, but the tools can now also be used by small-scale sellers. It is difficult to implement in traditional retail due to lack of data and physical constraints (price tags need to be changed manually), but in e-commerce it is not affected by physical constraints

and data collection is easier [19]. Algorithmic pricing is a pricing strategy based on automated computer algorithms that adjust product and service prices in real time. Algorithms can price discriminate at the group or individual level. Price discrimination means charging consumers different prices for the same product or service. Algorithms can help mitigate the effects of demand shocks as well as supply shocks and realize demand learning based on machine learning. Adjustments are based, for example, on competitors' prices, demand, customer behavior and characteristics [2] [17]. Cormen *et al.* [20] describe algorithms as follows:

"*A series of computational steps that convert input into output.*"

Adaptive algorithms and learning algorithms are two types of price optimization algorithms neural network studies. Reinforcement learning algorithms are more autonomous as they can adapt to changing market conditions without the help of a programmer [21]. For example, stochastic approximation methods [22] and Fibonacci algorithms [23] are two of the most common algorithms. For businesses, AI-powered dynamic pricing is crucial due to its ability to reliably process large volumes of data. AI-powered DP can therefore offer better personalized pricing for consumers and reduce the need for manual work once the system is implemented. However, data analysis processes are easier to implement in traditional dynamic pricing [24]. For consumers, the use of AI in dynamic pricing may raise concerns about fairness as prices may be different for different customers. In traditional dynamic pricing, price changes affect everyone equally. The use of AI can also lead to continuous price adjustments. Frequent adjustments create uncertainty for customers who prefer stable and predictable prices. On the other hand, personalization by AI can lead to personalized discounts and offers, whereas in traditional dynamic pricing everyone benefits from the same discounts [24]. Going beyond traditional fixed pricing models, dynamic price optimization is a more advanced approach. Basically, it entails continuously changing the costs of goods or services in response to data from the live market, changes in demand and other external variables. Since dynamic pricing is flexible and can be adapted to constantly changing market conditions, it is preferable to static pricing, which remains fixed for a longer period of time. Dynamic Price Optimization is based on the use of cutting-edge technologies, mainly artificial intelligence and machine learning algorithms, to quickly analyze large volumes of data. Businesses can maximize their profitability by optimizing their pricing strategies in real time by studying competitor pricing, consumer behavior and overall market trends.

In today's fast-paced market environment, this dynamic strategy helps businesses seize opportunities, stay competitive and adapt quickly to changes in demand, ultimately creating a more robust and resilient business model. In today's fast-paced and competitive business market, dynamic pricing optimization using AI is necessary for many compelling reasons.

3.2. Advantages of AI in Dynamic Pricing

The third part of the thesis will examine the positive impact of AI-enabled dy-

namic pricing strategies. The advantages for both; consumers and companies will be examined and visualized. AI-powered DP algorithms running in real time on computers with machine learning capabilities are powerful tools for companies to use in their pricing strategies. This section will also compare some of the advantages of AI-powered DP with traditional DP.

3.3. Final Decision Making

The implementation of AI-driven dynamic pricing strategies can change the pricing decision-making process for businesses. AI-powered DP can improve the accuracy of pricing decisions as it can categorize customers into groups or offer specific prices even on a personal level [25]. Advanced algorithms and machine learning techniques using AI can perform comprehensive analysis of large datasets containing information about customer preferences, purchase history, and market trends in real time. [26] suggest that AI-enabled dynamic pricing will enable retail gas stations to update their prices more frequently. Demand fluctuations or changes in competitors' behavior will be updated faster and more accurately. Assad *et al.* [26] argue that advanced algorithms can also make small adjustments to the size of price changes if consumers react negatively to price changes. AI-assisted DP of course has room for error, as poorly implemented pricing algorithms can react in unexpected ways, especially if the environment is complex and other algorithms are also used [19]. Using computers to make pricing decisions eliminates the possibility of human error in decisions. Algorithms using reinforcement learning may be too complex for humans to understand their decisions [24].

3.4. Efficiency and Automation

Efficiency and automation are two of the key parts of AI in dynamic pricing strategies. Dynamic pricing strategies powered by AI involve frequent price adjustments. These accurate price adjustments can be made in real time based on the vast amount of data available today. In traditional dynamic implementation, physical constraints slow down the price adjustment process [19] and adjustments are often made on a daily or weekly basis rather than in real time [10]. Therefore, using AI reduces the amount of manual work required by humans. As an example, the pricing of electricity is fully dynamic and autonomous. However, the use of digital shelf labels in retail stores has increased and the gap between e-commerce and traditional retail is narrowing [27]. Martinez [18] emphasizes that the main purpose of AI is to function as a tool that increases operational efficiency. Therefore, AI can work as a tool that speeds up the price adjustment process. By making fast pricing decisions in real time, a firm's profit can be maximized [17].

3.5. Adaptability and Competitive Advantage

Finally, it moves from efficiency and automation to the competitive advantages

that AI-powered dynamic pricing can offer. Analyzing customer preferences, purchase history and market trends can be a huge competitive advantage. Companies that successfully implement AI-powered DP can have a huge advantage over firms without any dynamic pricing or dynamic pricing not supported by AI [24].

3.6. Disadvantages of AI in Dynamic Pricing

While companies can benefit from using AI in dynamic pricing, there are many limitations to the strategy and many potential risks. Most of the risks concern the customer side. The ethical challenges of dynamic and personalized pricing are among the biggest concerns. With AI, it is possible to adjust customers' prices on an individual level according to their personal behavior and characteristics. As a prime example, the company Uber received a lot of backlash for being too slow to turn off surge pricing after the terrorist attacks in London in 2017, when demand for Uber taxis skyrocketed and prices were several times higher than usual [28]. This can lead to a sense of unfairness and loss of trust in the company. As different customers pay different prices for the same service or product, issues of discrimination and fairness arise [24]. Another challenge with AI in dynamic pricing is the complexity of the AI algorithms used. Algorithms are often complex and utilize machine learning. These make the pricing mechanics used really difficult for consumers to decipher, so there is less transparency in pricing. Consumers may find it difficult to understand the reasons for price adjustments. This can lead to concerns about transparency and loss of trust in a company [17]. As companies seek to maximize profits through frequent price changes, changes can cause uncertainty for customers. Frequent price changes can create confusion and frustration among consumers. This may also affect their trust and loyalty to the company [29].

3.7. Ethical Concerns and Justice

Dynamic pricing powered by AI can have huge benefits. However, it is also important to understand what kind of disadvantages the pricing strategy can have on businesses and consumers. Price discrimination is one of the elements that can cause ethical issues. The ability to adjust prices for individual customers has brought ethical issues to light. There have been debates about the hidden values in the algorithm, such as in the aforementioned case involving Uber, which was seen as unfair and even inhumane [24]. While personalized pricing can increase a firm's profits and enhance the personal customer experience, it can raise fairness concerns. When it is revealed that a firm uses personalized pricing and customers realize that they are paying a much higher price than other customers, the system is perceived as unfair or manipulative. This can lead to reduced demand and trust [30]. As an example of unethical personalization, Edelman *et al.* [30] uncovered systemic racial discrimination on Airbnb.com as they learned that black hosts receive lower rent than non-black hosts. AI-powered algorith-

mic pricing is also prone to algorithmic biases related to personalized pricing. Because AI-powered algorithms with machine learning capabilities use biased data to train or fine-tune, they become more vulnerable to exploiting algorithmic biases. Continuing in the context of Airbnb.com, Zhang *et al.* [31] suspect that since the platform's "smart pricing" tool fails to overcome the racial income gap between hosts, the marketplace may have a racial bias in terms of guests' willingness to pay more for a property owned by a white host than a corresponding property owned by a black host. Another ethical consideration of AI-powered DP concerns consumer privacy. Seele *et al.* [24] describe algorithmic pricing as a very invasive technology because companies are constantly sending personalized nudges asking users to reduce the collection of different data as a way of personalized pricing. The personal data collected can be a real issue regarding a consumer's privacy. As an example, attackers can access highly sensitive personal user purchase information from eBay's public profiles and link users to social network profiles [32]. The ethical concerns of AI-enabled dynamic pricing extend beyond the individual level. The societal implications of personalized pricing are examined and, according to Borgesius and Poort [33], personalized pricing is regulated in Europe, as European data protection laws apply to the collection of personalized information. The user can choose to allow or not allow the collection of personalized data, commonly referred to as "cookies".

3.8. Complexity and Transparency

The complexity of AI-powered dynamic pricing algorithms has a negative impact on the transparency of businesses' pricing. Diakopoulos [34] explains that algorithms are often referred to as black boxes because they are so complex and difficult to understand. Nobody really understands what is really going on inside the algorithms. Because algorithms are really complex and hard to understand, the transparency of pricing decisions is weakened. Transparency issues are closely related to consumers' perceptions of fairness [35]. Research by K. Chen *et al.* [36] examines the effects of consumers being able to see price history as a reference. The study showed that when a consumer behaves more strategically, the seller's profit decreases. Profit increases when consumers behave less strategically. Thus, the ability to see price history has an impact on consumer behavior, but the magnitude of the impact depends on the consumer's propensity to act strategically.

3.9. Consumer Uncertainty and Frequent Price Changes

As the use of AI-enabled dynamic pricing has increased, consumers have faced a new aspect of uncertainty in the form of rapid price changes. Consumer behavior research shows that consumers can react negatively to frequent price changes. Rotemberg's [37] research also shows that consumers want to harm companies they perceive to be giving a bad deal. Therefore, making unfair price

changes hurts the customer who got a bad deal and the company with a bad reputation. Research has shown that frequent price changes often cause uncertainty among consumers. In a study by Danziger *et al.* [38], respondents acting as consumers were more likely to choose a daily low pricing strategy over occasional large discounts. The study shows that most consumers prefer stable prices that are more predictable. A study represented by Martin *et al.* [39] examines the link between perceptions of price fairness and customer loyalty. According to Martinez [18] *et al.*'s study, price changes have negative effects on how consumers perceive the fairness of prices. The study also showed that higher changes in prices have a greater impact on consumers' perceptions of fairness.

3.10. Overconfidence in Artificial Intelligence and Possible Mistakes

The increasing use of artificial intelligence raises several concerns. AI has a lot of power in dynamic pricing as it can make pricing decisions autonomously. Over-reliance on AI can lead to errors and disruptions as there is no human supervision and competing algorithms can act in unexpected ways. Relying on automated pricing decisions made by algorithms using AI exposes businesses to the problems of these systems. In the first example, two rival dynamic pricing algorithms in the Amazon marketplace competed against each other indefinitely. If the data tracked by the algorithm is flawed, unexpected actions can occur if potential problems in the code are not taken into account. Research also shows that continuous learning can lead to long-term price declines if multiple algorithms continue to learn from each other. In this way, companies can collude unwittingly and have a negative impact on consumer trust [17]. Human supervision is needed as over-reliance on AI in dynamic pricing makes companies vulnerable to possible errors and glitches. Autonomous pricing decisions expose businesses to errors, as seen in cases such as Amazon, where competing algorithms raised the price of a book to over $23 million. If AI is trained on faulty data, flaws and biases can be reflected in the prices of products or services. As the world moves to automate repetitive tasks, business leaders and experts are turning to making other complex decisions. This leads to more revenue and profit margin growth. Similarly in pricing, AI today has taken automation to the next level by providing high precision in results and overall efficiency. Its complex algorithm performs all the complex analysis and repeated price changes based on market changes. Algorithms are computational models that utilize artificial intelligence techniques to determine optimal prices for products or services. By processing and interpreting this data, AI pricing algorithms can accurately predict consumer demand and set prices accordingly. One of the key advantages of AI pricing algorithms is their ability to process large amounts of data. Traditional pricing methods such as Excel and ERP systems often rely on manual analysis, which can be time-consuming and prone to human error. In contrast, AI algorithms can process and analyze very large data sets in much less time, allowing businesses to make more informed pricing decisions. AI pricing

algorithms analyze historical sales data to identify patterns and correlations between pricing and customer behavior. By understanding these relationships, businesses can optimize pricing strategies to increase sales and profitability. In addition to historical data, AI pricing algorithms incorporate real-time data to make pricing decisions. This includes factors such as competitor prices, inventory levels and more. By considering these dynamic factors, businesses can respond quickly to market changes and adjust their prices accordingly. AI pricing algorithms also take into account various pricing strategies for price recommendations, such as dynamic pricing, personalized pricing, and even bundled pricing. These strategies allow businesses to tailor their pricing to specific customer segments or market conditions, maximizing their competitiveness and profitability.

4. Dynamic Pricing Strategies Using Artificial Intelligence Algorithms

Pricing optimization has always been an important aspect of businesses and has become even more important with the advent of technology. Artificial intelligence (AI) is gaining more and more attention, especially when it comes to pricing strategy. Through the use of AI-powered algorithms and machine learning, businesses can analyze data, predict trends, make data-driven decisions and optimize pricing models to maximize profits. The benefits of AI-powered pricing optimization are limitless, especially in e-commerce and subscription-based businesses. While we can see that there are many benefits to using AI for price optimization, there are also some important considerations to keep in mind when implementing it for your business.

1) Data quality: The price prediction will be as good as the data you feed ml. If you are in an industry that does not have enough data or poor data to start with, AI may not give an accurate estimate of the price. The data may be biased or contain discriminatory patterns that will lead to unfair pricing practices. Here are some suggested solutions:

a) Data preprocessing and cleaning: Techniques such as data imposition (using alternative values to replace missing data), outlier detection (detecting data points that are far from the mean) and normalization ensure that the data used to train AI is accurate, complete and consistent.

b) Data verification and validation: Cross-referencing data from multiple sources, conducting data audits and regular checks ensure that there are no anomalies in the data.

c) Data enrichment and augmentation: Combining third-party data, market data or customer feedback complements the existing dataset and provides a more comprehensive view of pricing factors.

2) Complex implementation with high maintenance costs: AI for pricing optimization requires significant upfront investment in terms of technology infrastructure, data management and skilled personnel. The costs associated with developing and implementing AI models as well as maintaining them over time

can be significant and pose challenges for organizations with limited resources. Here are some suggested solutions that can help with the above problem and reduce the cost of implementation:

a) Define clear project objectives and scope: Identify specific situations or areas where AI can provide the most value and focus on these initially. This helps manage complexity by breaking the application into smaller manageable chunks.

b) Agile method approach: To manage complexity effectively, an agile method such as Scrum should be adopted. This approach allows for continuous learning, improvement and iterations as needed.

c) Change management and training: Recognize the complexity of an AI pricing model that requires changes in the organization's processes, roles and responsibilities.

3) Customer non-acceptance: AI pricing models may face resistance from customers who prefer human-driven pricing or find it difficult to trust pricing decisions made solely by AI algorithms. They may have concerns about fairness, transparency or the inability to negotiate prices, leading to negative perceptions of AI-based pricing strategies.

a) Explain to customers the rationale behind price changes: Make sure your customers understand the rationale behind pricing changes and make it transparent to them using marketing tools.

b) Human involvement: AI models are excellent at suggesting the right price for certain products at a certain time, but this does not mean that the company should always follow this suggestion without at least having a marketing plan and sales directors overseeing the change.

4) Limited context awareness: AI pricing models typically operate based on historical data patterns and may not fully capture the contextual factors that influence pricing decisions.

5) Vulnerability to adversarial attacks: Some AI models are susceptible to malicious manipulation or exploitation by adversarial actors. Adversarial attacks aim to deceive or manipulate the decision-making process of AI models by presenting carefully constructed input data.

Some of the enemy attacks include:

Price manipulation: Some adversarial actors may attempt to manipulate the pricing recommendations generated by AI models in order to gain a competitive advantage or take advantage of marketing conditions.

Reverse engineering: Some adversarial actors may attempt to reverse engineer AI models or gain access to sensitive pricing-related information. Addressing the vulnerability of adversary attacks requires the implementation of various strategies to increase the robustness and security of AI models. Here are some potential solutions:

a) Hostile training: Incorporate adversarial training techniques during the model development phase. Hostile training involves the creation and inclusion of hostile instances in the training dataset to make the model more resilient to

potential attacks.

b) Robust feature engineering: Pay attention to the features and variables used in AI pricing models. Feature engineering should focus on creating inputs that are more resilient to enemy attacks.

6) While AI will take most variables into account when making its calculations, it may miss some critical variables that only a human can analyze, such as cultural influencers, market dynamics, customer behavior, etc.

Some potential solutions to address limited context awareness in pricing optimization using AI:

a) Involve domain expertise: Involve domain experts such as pricing analysts or experienced professionals in the development of AI models.

b) Qualitative analysis and customer feedback: Combine quantitative analysis from AI models with qualitative analysis techniques. Include customer feedback, surveys, focus groups or interviews to understand their preferences, willingness to pay and perception of value.

What are the requirements for dynamic pricing?

Dynamic pricing is data-driven. Dynamic pricing refers to a pricing strategy in which the prices of goods and services are adjusted regularly. Changes can be made, for example, on an hourly or monthly basis. A number of variables can be included in the price setting process. Some of the possible variables include time, weather, supply and demand, as well as website traffic.

How to use AI in dynamic pricing?

Dynamic pricing can be further enhanced with the application of artificial intelligence. Pricing decisions can be made more accurately and in real time. Decisions can also be made independently by the machine. Autonomous operation reduces the need for human interaction.

What are the main advantages of using AI in dynamic pricing strategies?

With AI-driven dynamic pricing, pricing adjustments can be made by algorithms on their own. Real-time adjustments are also possible. Moreover, AI is autonomous, which minimizes the need for human intervention in the pricing process, reducing costs. For example, AI-powered DP can react to spikes or drops in demand, as well as changes in competitors' strategies. AI-powered DP is superior to traditional DP in this sense because adjustments can be made on a personal level, not just for groups of people. This is called personalization.

What are the disadvantages and ethical considerations arising from AI-driven dynamic pricing?

The growing popularity of AI-driven dynamic pricing has led to a discussion of the ethical concerns raised by the pricing strategy. Algorithms can make unpredictable decisions if the data they use is faulty or if there are problems with the algorithms' code. One of the biggest advantages of AI-powered DP is personalized pricing, but it can be perceived as unfair.

5. Conclusion and Recommendations

There are numerous research results as well as real-world applications of this re-

search. As AI becomes more mainstream, many businesses are using or considering implementing AI-enabled dynamic pricing for their goods and services. This study provides a comprehensive review of the expected outcomes for any company considering or currently using AI dynamic pricing strategies. Companies can benefit from the ideas presented in this study as they become more aware of ethical and sustainability concerns. This research aims to help companies better understand the implications that AI-powered DP strategies can have by examining the key advantages and disadvantages of the strategy. The existing research on this topic is quite extensive. This is due to decades of interest in pricing methods and their effects. Existing research focuses on dynamic pricing, algorithmic pricing or artificial intelligence, but rarely all three components are included. Extensive research can be found for each of the subtopics in its own right. While this study provides a good overview of the different advantages and disadvantages of AI-assisted DP, not all concepts in this area have been thoroughly explored. All the concepts discussed have been around for a longer time, but strategies have only now gained popularity as AI has become more easily accessible to everyone. As the popularity of the strategy has become more popular and accessible to smaller companies in recent years, the study of the long-term effects of these strategies has not yet been researched much. Long-term effects include consumer psychological effects, ethical considerations and company profits. Future research could examine the long-term effects of AI-assisted DP, for example, by conducting case studies of companies using such pricing strategies. It is also unclear how AI-assisted dynamic pricing algorithms affect demand. The literature provides good data for dynamic pricing and some data for algorithmic pricing, but there is no comprehensive research for companies using AI-driven DP. Psychological studies mention consumer perceptions of fairness, but not demand. This study does not include instructions for mitigating the negative effects of the strategy. Subsequent studies may look at methods that effectively mitigate the disadvantages of using AI-driven DP strategies. While Price Optimization using AI algorithms can be highly effective, there are some potential disadvantages that businesses should be aware of. These include data bias, lack of context, reduced human involvement, resistance to change, and privacy concerns.

In conclusion, the aim of this study was to provide companies with a comprehensive overview of the main advantages and disadvantages of using AI-powered DP. Further research on the long-term effects, such as changes in demand and shifts in consumer behavior, could be further explored. This study works as a good knowledge base for companies interested in or implementing strategies for AI-driven dynamic pricing.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Phillips, R. (2005) Pricing and Revenue Optimization. Stanford University Press. https://doi.org/10.1515/9780804781640

[2] Ayadi, N., Paraschiv, C. and Rousset, X. (2017) Online Dynamic Pricing and Consumer-Perceived Ethicality: Synthesis and Future Research. *Recherche et Applications en Marketing* (*English Edition*), **32**, 49-70. https://doi.org/10.1177/2051570717702592

[3] Hu, K. (2023) ChatGPT Sets Record for Fastest-Growing User Base. Analyst Note, Reuters.

[4] Grand View Research (2023) Artificial Intelligence Market Size, Share & Trends Analysis Report by Solution, by Technology (Deep Learning, Machine Learning), by End-Use, by Region, and Segment Forecasts, 2023-2030. https://www.grandviewresearch.com/industry-analysis/artificial-in-telligence-ai-market

[5] Nagle, T.T. and Müller, G. (2017) The Strategy and Tactics of Pricing: A Guide to Growing More Profitably. Routledge.

[6] Selcuk, C. and Gokpinar, B. (2018) Fixed vs. Flexible Pricing in a Competitive Market. *Management Science*, **64**, 5584-5598. https://doi.org/10.1287/mnsc.2017.2922

[7] Corman, F., Vofi, S. and Negenborn, R.R. (2015) Computational Logistics. Springer.

[8] Sudhir, K. (2001) Competitive Pricing Behavior in the Auto Market: A Structural Analysis. *Marketing Science*, **20**, 42-60. https://doi.org/10.1287/mksc.20.1.42.10196

[9] Neubert, M. (2022) A Systematic Literature Review of Dynamic Pricing Strategies. *International Business Research*, **15**, 1-17. https://doi.org/10.5539/ibr.v15n4p1

[10] Bouchet, A., Troilo, M. and Walkup, B.R. (2016) Dynamic Pricing Usage in Sports for Revenue Management. *Managerial Finance*, **42**, 913-921. https://doi.org/10.1108/mf-01-2016-0017

[11] Sanchez-Cartas, J.M. and Katsamakas, E. (2022) Artificial Intelligence, Algorithmic Competition and Market Structures. *IEEE Access*, **10**, 10575-10584. https://doi.org/10.1109/access.2022.3144390

[12] Pannu, A. (2015) Artificial Intelligence and Its Application in Different Areas. *Artificial Intelligence*, **4**, 79-84.

[13] Levesque, H.J. (1986) Knowledge Representation and Reasoning. *Annual Review of Computer Science*, **1**, 255-287. https://doi.org/10.1146/annurev.cs.01.060186.001351

[14] Davis, E. and Marcus, G. (2016) The Scope and Limits of Simulation in Automated Reasoning. *Artificial Intelligence*, **233**, 60-72. https://doi.org/10.1016/j.artint.2015.12.003

[15] Blasch, E., Pham, T., Chong, C., Koch, W., Leung, H., Braines, D., *et al.* (2021) Machine Learning/Artificial Intelligence for Sensor Data Fusion-Opportunities and Challenges. *IEEE Aerospace and Electronic Systems Magazine*, **36**, 80-93. https://doi.org/10.1109/maes.2020.3049030

[16] Russell, S.J., Norvig, P. and Davis, E. (2010) Artificial Intelligence: A Modern Approach. Prentice Hall.

[17] Aparicio, D. and Misra, K. (2023) Artificial Intelligence and Pricing. In: Malhotra, N.K., Ed., *Review of Marketing Research*, Emerald Publishing Limited, 103-124. https://doi.org/10.1108/s1548-643520230000020005

[18] Martinez, R. (2019) Artificial Intelligence: Distinguishing between Types & Definitions. *Nevada Law Journal*, **19**, 1015-1042.

[19] Chen, L., Mislove, A. and Wilson, C. (2016) An Empirical Analysis of Algorithmic Pricing on Amazon Marketplace. *Proceedings of the* 25*th International Conference on World Wide Web*, Montréal, 11-15 April 2016, 1339-1349. https://doi.org/10.1145/2872427.2883089

[20] Cormen, T.H., Leiserson, C.E., Rivest, R.L. and Stein, C. (2009) Introduction to Algorithms. 3rd Edition, MIT Press.

[21] Calvano, E., Calzolari, G., Denicolo, V. and Pastorello, S. (2019) Algorithmic Pricing: What Implications for Competition Policy? *Review of Industrial Organization*, **55**, 155-171. https://doi.org/10.1007/s11151-019-09689-3

[22] Robbins, H. and Monro, S. (1951) A Stochastic Approximation Method. *The Annals of Mathematical Statistics*, **22**, 400-407. https://doi.org/10.1214/aoms/1177729586

[23] Bitran, G.R. and Mondschein, S.V. (1997) Periodic Pricing of Seasonal Products in Retailing. *Management Science*, **43**, 64-79. https://doi.org/10.1287/mnsc.43.1.64

[24] Seele, P., Dierksmeier, C., Hofstetter, R. and Schultz, M.D. (2019) Mapping the Ethicality of Algorithmic Pricing: A Review of Dynamic and Personalized Pricing. *Journal of Business Ethics*, **170**, 697-719. https://doi.org/10.1007/s10551-019-04371-w

[25] Chen, M. and Chen, Z. (2015) Recent Developments in Dynamic Pricing Research: Multiple Products, Competition, and Limited Demand Information. *Production and Operations Management*, **24**, 704-731. https://doi.org/10.1111/poms.12295

[26] Assad, S., Clark, R., Ershov, D. and Xu, L. (2020) Algorithmic Pricing and Competition: Empirical Evidence from the German Retail Gasoline Market. CESifo Working Paper No. 8521. https://ssrn.com/abstract=3682021

[27] Stamatopoulos, I., Bassamboo, A. and Moreno, A. (2021) The Effects of Menu Costs on Retail Performance: Evidence from Adoption of the Electronic Shelf Label Technology. *Management Science*, **67**, 242-256. https://doi.org/10.1287/mnsc.2019.3551

[28] Cox, J. (2017) London Terror Attack: Uber Slammed for Being Slow to turn off 'Surge Pricing' after Rampage. https://www.independent.co.uk/news/uk/home-news/london-terror-attack-uber-criticised-surge-pricing-after-london-bridge-black-cab-a7772246.html

[29] Haws, K.L. and Bearden, W.O. (2006) Dynamic Pricing and Consumer Fairness Perceptions. *Journal of Consumer Research*, **33**, 304-311. https://doi.org/10.1086/508435

[30] Edelman, B. and Luca, M. (2014) Digital Discrimination: The Case of Airbnb.com. Harvard Business School Working Papers 14-054, Harvard Business School. https://ssrn.com/abstract=2377353

[31] Zhang, S., Mehta, N., Singh, P.V. and Srinivasan, K. (2021) Frontiers: Can an AI Algorithm Mitigate Racial Economic Inequality? An Analysis in the Context of Airbnb. *Marketing Science*, **40**, 813-820. https://doi.org/10.1287/mksc.2021.1295

[32] Minkus, T. and Ross, K.W. (2014) I Know What You're Buying: Privacy Breaches on Ebay. *Privacy Enhancing Technologies*, Amsterdam, 16-18 July 2014, 164-183. https://doi.org/10.1007/978-3-319-08506-7_9

[33] Zuiderveen Borgesius, F. and Poort, J. (2017) Online Price Discrimination and EU Data Privacy Law. *Journal of Consumer Policy*, **40**, 347-366. https://doi.org/10.1007/s10603-017-9354-z

[34] Diakopoulos, N. (2014) Algorithmic Accountability. *Digital Journalism*, **3**, 398-415. https://doi.org/10.1080/21670811.2014.976411

[35] Chapdelaine, C. (2020) Bayesian Iterative Reconstruction Methods for 3D X-Ray Computed Tomography. Université Paris Saclay.

[36] Chen, K., Zha, Y., Alwan, L.C. and Zhang, L. (2019) Dynamic Pricing in the Presence of Reference Price Effect and Consumer Strategic Behaviour. *International Journal of Production Research*, **58**, 546-561. https://doi.org/10.1080/00207543.2019.1598592

[37] Rotemberg, J.J. (2005) Customer Anger at Price Increases, Changes in the Frequency of Price Adjustment and Monetary Policy. *Journal of Monetary Economics*, **52**, 829-852. https://doi.org/10.1016/j.jmoneco.2005.03.004

[38] Danziger, S., Hadar, L. and Morwitz, V.G. (2014) Retailer Pricing Strategy and Consumer Choice under Price Uncertainty. *Journal of Consumer Research*, **41**, 761-774. https://doi.org/10.1086/677313

[39] Martin, W.C., Ponder, N. and Lueg, J.E. (2009) Price Fairness Perceptions and Customer Loyalty in a Retail Context. *Journal of Business Research*, **62**, 588-593. https://doi.org/10.1016/j.jbusres.2008.05.017