



Machine Learning for Dynamic Pricing in e-Commerce

Maria Cristina ENACHE*

ARTICLE INFO

Article history:

Accepted November 2021

Available online December 2021

JEL Classification

K22, M21

Keywords:

dynamic pricing, e-commerce,
machine learning

ABSTRACT

Dynamic pricing is a long-term pricing model that can increase the conversion rates of your e-commerce store. You can use A.I applications to offer different prices for the same product to different customers, depending on unique personal factors. Advanced applications should take into account many other factors, such as the prices charged by competitors that buyers have previously sponsored, the current demand for the product, cross-price elasticity, halo ratios, and so on. Some AI-based dynamic pricing models can also implement in-depth learning capabilities to deduce the prices that each customer will be willing to pay for a product or service at some point.

© 2021 EAI. All rights reserved.

1. Introduction

In 2021, customizing websites, products, offers, and content recommendation services to help retailers and other companies customize their proposal to support potential and increase conversions is becoming mandatory. The opportunities to apply customization are now much wider than the initial retail recommendations. Personalizing the digital experience is the dynamic delivery of personalized content, products, or promotional offer recommendations to website visitors or application users based on their characteristics and intended behavior to support long-term conversion and engagement. Although many of us will have experienced customization through retail product recommendations, the definition shows the relevance of personalization for all types of companies. For example, even B2B companies that do not sell online can use personalization to recommend relevant "best content" offers to support the potential interest of a business and thus fuel them for a sale.

The limitations of physical interactions around the world have reshaped the lives and habits of buyers. While the pandemic has affected most industries, e-commerce has thrived. Dynamic pricing helps retailers refine their pricing strategies to increase profitability and boost customer engagement and loyalty.

For e-merchants, it is vital to keep up with price movements. Overloading your products can lead to losing customers to your competitors, while overloading can lead to lower revenue. In 2019, online shopping generated revenue of \$ 3.53 trillion for e-merchants. In addition, by 2040, it is expected that approximately 95% of all global purchases will be made online.

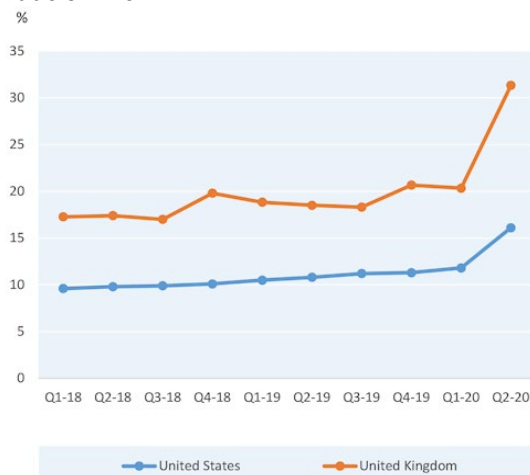


Figure 1. Share of e-commerce in total retail sales, UK and USA - 2018-2020 (source [8])

Source OECD

For the United States, data provides estimates for e-commerce as a percent of total retail sales, based on data from the Monthly Retail Trade Survey and administrative records. Data for the second quarter 2020 are preliminary estimates. For the United Kingdom, data provides Internet sales as a percentage of total retail sales.

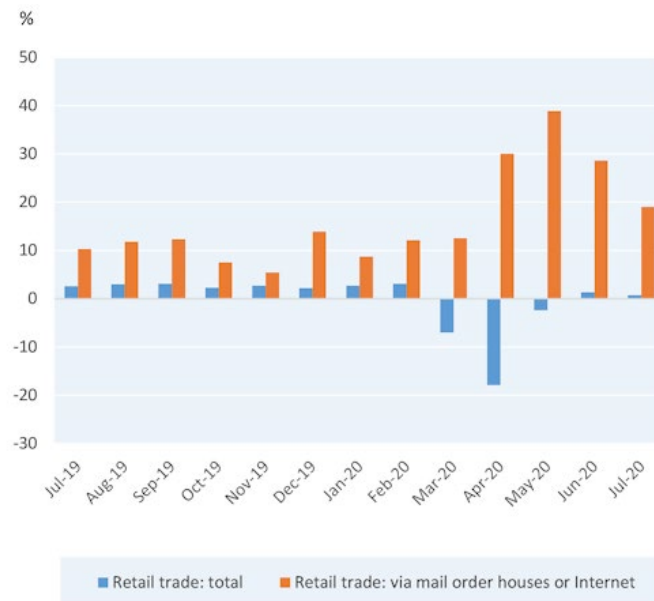


Figure 2. Retail trade in 2019-2020 (source [8])

2. Web customization

When web personalization services first appeared, they were part of expensive analytics solutions available only to the largest companies, but today there are many services suitable for small businesses. These are two of the original services that are available today in a new form.

- Adobe Target is one of the most established customization engines evolving from the original Touch Clarity in 2004 and then integrated into the Omniture analysis suite as Test and Target
- IBM Product Recommendations - The Coremetrics smart offering has been widely used by retailers for analysis, but since its acquisition by IBM it has been offered as a separate product.
- Google Optimize 360 - This is the latest analytics service offering added to this page's most recent update. Optimize is available for free as an AB test for all GA users, with some customization features, but the full version of this customization option is only available to enterprise subscribers today
- Google AI recommendations - Officially launched in January 2020, it is designed to serve retail recommendations. It's based on Google's experience of applying AI to their search engine. Recommendations AI allows Google Cloud customers to apply rules to adjust what buyers see and to diversify the products displayed, filtering by product availability and custom labels. Accepts international product catalogs in multiple geographic areas and offers recommendations anywhere on a customer's journey, whether on a homepage, when confirming an order, or in a shopping cart. Once the initial data import is complete, Recommendations AI users can choose the type of model and the optimization goal. Model training and adjustment takes between two and five days, says Google, and model recommendations can be previewed before being offered to customers. Google is introducing a new price structure with three volume-based price levels for predictions and a separate fee for training and adjusting the model. All new customers will receive a credit in addition to the free general credit for new Google Cloud customers, which is usually enough to train a model and test its performance in production through a two-week A / B test. Google's AI recommendations compete with Amazon Personalize, which similarly uses machine learning to provide suggestions for websites, SMS, email, and apps. According to Amazon. Personalize addresses issues such as creating recommendations for new users or products without historical data through API calls that automate the tasks needed to build, train, adjust, and implement a recommendation model.

3. Dynamic Pricing using machine learning

Dynamic pricing is the practice of adjusting prices according to market and customer data. E-commerce business such as eBay and Amazon, leverage different types of dynamic pricing to attract more customers and increase profitability.

Dynamic pricing is a process of automatically adjusting prices for products or services in real time to maximize revenue and other indicators of economic performance. To define the optimal price, a dynamic pricing strategy considers the current state of the market as a basis, including the company's previous price, changes in competitors' prices, consumer tastes, time frame and other external factors.

Pricing strategies are applied in many business contexts and are used by airlines, railway companies, concert venues, theaters, car rental companies, accommodation providers and retail companies to respond promptly to market fluctuations. For example, Amazon monitors and changes the prices of its products every 10 minutes, once big data is updated and processed. Uber also uses a flexible pricing strategy in the event of high demand caused by bad weather or a particular event pushing prices up.

Any application that has a dynamic pricing component based on machine learning will need a company's sales and transaction data to calculate demand for each product in your range. This forms the basis for each AI pricing decision. At least all sales information is required, e.g., what items were sold at what price.

Every e-commerce business will look for real tangible ways to increase their business success. One way would be to consider changing the look of the store or hiring a copywriter to write compelling product descriptions. But a method increasingly used by new e-commerce store owners is the use of artificial intelligence and dynamic pricing. For some people, the terms "artificial intelligence" and "dynamic price" may simply be fashionable words without real practical meaning.

You no longer must spend hours looking at competing prices and deposit prices to determine the best price you should use. Now you can use a combination of machine learning, AI, and algorithms to predict prices and take care of the most important thing: your customers. This article helps you understand what the two ideas mean and gives you a framework for starting to implement them in an e-business.

The benefits of using dynamic pricing are increased profits and revenues, as e-commerce business owners can remain competitive and price their products in line with sales volumes, competition, and market trends.

Today, in any e-commerce business, many merchants use flexible pricing to stay competitive. Here are some key benefits of dynamic e-commerce pricing:

- Competitive advantage Automatic monitoring of competitors' prices allows you to quickly adapt to the dynamic environment and gain market leadership.
- Profits increase After the implementation of dynamic prices; Best Buy recorded a 25% increase in sales. By analyzing the market, you can adjust the price of a product to generate more revenue. If the demand for a product is low, you can increase it by lowering the price, and if it is a peak season for a product, you can increase the price without changing the sales volume.
- Get market information. Ongoing market monitoring allows you to keep abreast of prevailing market trends and gain information about consumer behavior, which can lead to better decision making.

In e-commerce, retailers generally look at their own sales data as well as external factors to constantly change their prices when the market fluctuates. But more than that, it is not only an approach that focuses on price changes, but also on the analysis of competition. The analysis of the competitors starts by defining them first. Without a doubt, the most popular place to promote an e-commerce business is Google. Not only is it just a means of promotion, but potential customers are starting to buy there for the first time. So, it would be a wise start for competition analysis and mapping to start on Google.

Dynamic e-commerce prices move away from static prices (where items have a fixed cost) and instead use data to set the price of items. Therefore, the more data that can be analyzed, the better the optimal prices will be displayed. This means that the price no longer depends only on how much stock there is. It uses a series of advanced analyzes about the product, the buyer, and the competitors to determine the best price at a given time.

The strategy itself cannot completely eliminate uncertainty about consumer responses to different prices, although there are many advantages to setting dynamic prices. In practice, addressing this issue requires the efficient use of sales data. Sales data are data in time series that contain prices, along with those sales and other features that could be useful in boosting sales (such as inventory, product seasonality, listing, etc.). It is an input that a company should provide to build a dynamic pricing engine.

Because it is difficult to measure the performance of agents in real life, in this article we present an artificial example, along with theoretically optimal prices for comparison. There are many different approaches for training agencies to choose the optimal price for a certain period. We begin the process of building a dynamic pricing system by building a sales prediction model that takes market status as input and produces estimated sales. This model is trained on sales data by exploiting time series analysis and machine learning methods. An important note here is that the price must be in a set of input features for a prediction model. In addition, the characteristics should be of sufficient importance.

There are several possible approaches to defining a pricing strategy when using a forecast model:

- Optimization approach. This is a simple one-step optimization. Using the forecast model, you can set different prices and see how they will affect sales and revenue. This is an optimization problem with a

single variable over a continuous interval, which is defined by a minimum and maximum price. A typical solution is to discretize a continuous range into a countable number of possible prices and choose the price that leads to the highest income or another goal. An additional advantage of this method is that it naturally avoids the problem of falling to a local minimum.

The disadvantage of this approach is that it only considers the income from a current time stamp, rather than the cumulative income over a longer period, which is a better choice for maximization.

- Reinforcement learning (RL) is an alternative approach and one that solves the problem specified above. It considers the associativity between the stages of setting succulent prices, thus being greedy in terms of current time-marked revenues, but greedy in terms of cumulative income. For example, it might be beneficial to set a lower price in the current time frame, lowering the potential income to later reach a better market condition.

4. Reinforcement learning

Reinforcement learning, or RL, is one of the three main areas of machine learning, alongside supervised learning, and unsupervised learning. Its main task is to develop algorithms that allow agents to maximize their accumulated rewards while operating in an unknown environment. RL learns what to do (politics) and how to map situations into action.

The idea of learning through interaction with an environment is very natural and, in some respects, biologically inspired. As human beings, we continually interact with the world around us, trying to maximize our reward (satisfaction, recognition, money, etc.).

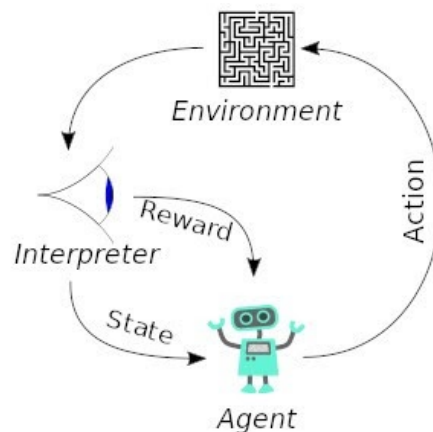


Figure 3. How RL works (source [10])

In Reinforcement Learning (RL), the agent is rewarded for the right moves and punished for the wrong ones. By doing this, the agent tries to minimize the wrong movements and maximize the right ones. In setting dynamic prices, an agent should set optimal prices based on market conditions. In terms of RL concepts, stocks are all possible prices and conditions, market conditions, except for the current price of the product or service.

In fact, it is quite difficult to train an agent in an interaction with a real-world market. The reason is that an agent should get a lot of samples from an environment, which means that it will take a long time as it is a lengthy process. An agent should analyze a representative subset of the entire data set, trying different actions. As a result, the company could lose a lot of money while training the agent, which would work sub optimally.

An alternative approach is to use an environmental simulation. Using a forecast model, the reward (e.g., income) can be calculated based on market conditions, and the stock is the current price. So, transitions between states should only be modeled. The main disadvantage of the RL approach is that it is extremely difficult to accurately simulate a market.

For instance, in the e-commerce dynamic pricing problem, we could map these concepts to:

- *environment*: marketplace
- *state*: lowest price in the market, day of the week, inventory levels, shipping values to a location, and many others.
- *agent*: dynamic pricing algorithm
- *action*: to increase or to lower prices
- *reward*: total profit generated by the *agent's* decisions

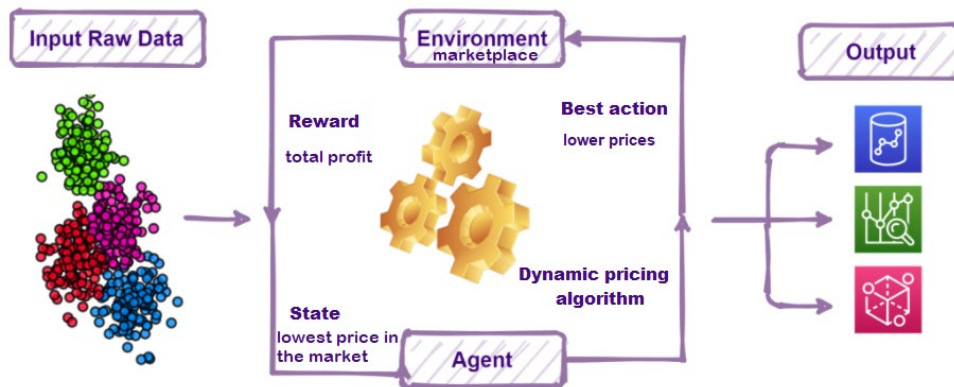


Figure 4. E-commerce dynamic pricing problem map

To implement a dynamic pricing strategy in an e-commerce platform, an e-business owner must:

- Collect market data: The first step in implementing a dynamic pricing strategy is to collect market data, including competitor prices, customer reviews of similar products, and buying trends over time.
- Choose the right dynamic price module: There are different dynamic price modules for different product categories. Some modules are based on the type of data available and customer perceptions and expectations.
- Choose the right type of dynamic pricing: There are also different types of dynamic pricing, which differ depending on the season, competitors, stock availability, etc. Companies can choose to apply one or more types of dynamic pricing depending on their needs.
- Apply dynamic price algorithms to collected data: A dynamic price algorithm analyzes the collected data and offers prices or price ranges for different products accordingly. Old dynamic pricing algorithms are based on classical statistical methods, such as Bayesian strategies, while newer algorithms use ML methods, such as deep learning or consolidation learning for more accurate results.
- Update data: Prices change frequently, so price data needs to be collected frequently. Companies can use web crawlers to automate the extraction of price data to get real-time data.

Advantages of reinforcement learning

- It can solve complex and higher order problems, the solutions obtained will be very precise, being very similar to the human learning technique.
- This model will go through a rigorous training process that can take time, which can help correct any errors.
- Due to its learning ability, it can be used with neural networks. This can be called deep consolidation learning.
- Because the model is constantly learning, a mistake made earlier would be unlikely to occur in the future.
- Various problem-solving models can be built using reinforcement learning.
- The best part is that even when there is no training data, you will learn from the experience you have from processing the training data.
- For various problems, which may seem complex, it offers the perfect models to solve them.

Conclusions

E-business owners, in today's competitive environment, face the challenge of adapting to market changes, as lagging can mean losing leadership and revenue. Applying consolidation learning to dynamic pricing can become an approach that brings an important change in the hierarchy of competitors, to be a game changer for retail. Dynamic pricing can help retail business owners stay ahead of the market, and consolidation learning can overcome dynamic pricing challenges. Amazon is without a doubt one of the largest e-commerce platforms in the world, with over 300,000,000 active users. Amazon changes its prices more than 2.5 million times a day to set prices lower than competitors. Since 2016, dynamic prices have helped Amazon increase profits by 25%.

References

1. *Reinforcement learning for fair dynamic pricing*. Roberto Maestre, Juan Duque, Alberto Rubio, and Juan Arévalo - arXiv preprint arXiv:1803.09967, 2018.
2. *Dynamic pricing and energy consumption scheduling with reinforcement learning* - Byung-Gook Kim, Yu Zhang, Mihaela Van Der Schaar, and Jang-Won Lee. *IEEE Transactions on Smart Grid*, 2016
3. *Dynamic pricing on e-commerce platform with deep reinforcement learning: a field experiment* - Jiayi Liu, Yidong Zhang <https://arxiv.org/pdf/1912.02572.pdf>
4. *Data-Driven Automated Dynamic Pricing for E-commerce*, Jiří Moravčík https://dspace.cvut.cz/bitstream/handle/10467/94420/F3-BP-2021-Moravcik-Jiri-data_driven_automated_dynamic_pricing_for_e_commerce.pdf

5. *Reinforcement Learning for Fair Dynamic Pricing* Roberto Maestre, Juan Duque, Alberto Rubio, Juan Arevalo *Intelligent Systems Conference 2018* <https://arxiv.org/pdf/1803.09967.pdf>
6. <https://techvidvan.com/tutorials/reinforcement-learning/>
7. <https://www.techradar.com/news/google-cloud-is-launching-an-ai-recommendation-engine-for-online-retailers>
8. <https://www.oecd.org/coronavirus/policy-responses/e-commerce-in-the-time-of-covid-19-3a2b78e8/>
9. <https://www.namogoo.com/resources/report/ecommerce-promotion-insights-survey-2021-shoppers-edition/>
10. https://en.wikipedia.org/wiki/Reinforcement_learning