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Optimization Project 1 Report
Group 4

1. Introduction

The report delves into the criticality of effective marketing, underlined by the variance in marketing success across firms like P&G and Netflix, as observed from recent surveys. With marketing budgets constituting a notable portion of company expenditures, the effectiveness of these allocations significantly impacts business outcomes. This variance is partially attributed to the methods of budget allocation across different advertising platforms. Through the utilization of linear programming, this project aims to devise a simplified marketing budget allocation strategy to enhance marketing effectiveness and business performance, drawing inspiration from data-driven approaches like that of Netflix. This exploration seeks to foster better-informed marketing budget decisions, paving the way for improved marketing and business results.

2. Problem Statement

Our company wants to allocate a marketing budget of $10 Million to various marketing channels, and the data science team is tasked with optimizing the budget allocations. The rates of return (ROI) for all marketing channels are obtained by consulting external firms, to decrease reliability issues on the data, different data is acquired from 2 different consulting firms independently.
Additional constraints that are to be taken into consideration while optimizing allocations are as follows:

1. Print and TV budgets combined should not exceed budgets allocated for Facebook and Email.
2. Social Media spend should be at least twice the spend on SEO and AdWords.
3. Amount for each channel is limited to $3M.

3. Linear Modeling

3.1 Firm 1's ROI

We use Gurobi to model this problem using Firm 1's ROI and obtain the optimal allocations. Based on the results obtained from this linear optimization model, the optimal budget allocation across various channels for maximizing the ROI is as follows:

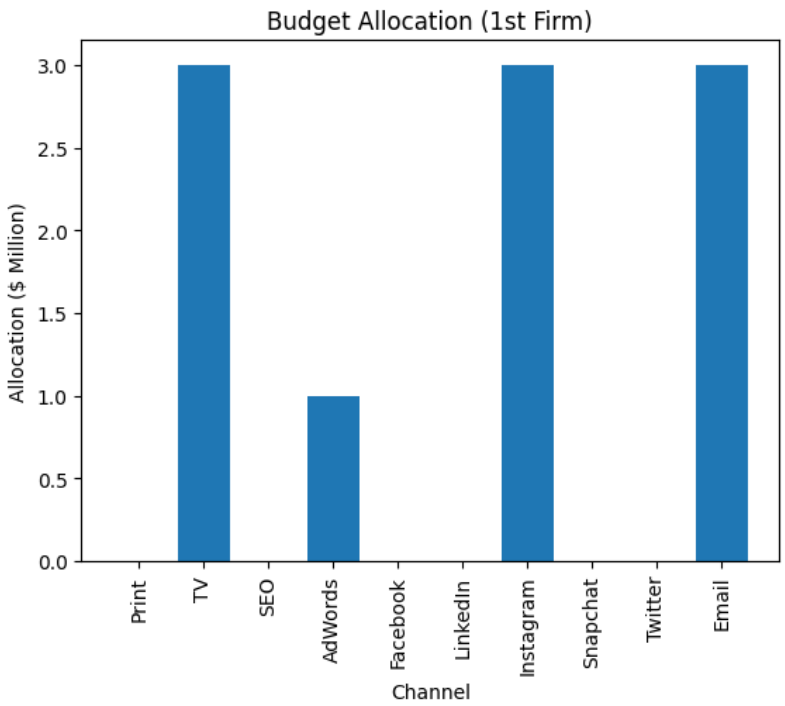

Figure 1. Marketing Budget Allocation basis Firm-1's ROI projections

Unsurprisingly all the allocations are suggested to be done in channels which have the four highest ROI projections. TV, Instagram and Email hit their limits of $3M and the remaining $1M is suggested to be invested in AdWords based on ROI projections from the first firm.

Channels such as Print, SEO, Facebook, LinkedIn, Snapchat, and Twitter have not been allocated any budget in the optimal solution, suggesting that, under the given circumstances and data, these channels might not be as effective in contributing to higher ROI.

If this allocation is followed, we expect an ROI of $0.456 million. This optimized budget allocation is aimed at maximizing the ROI by distributing the budget across the channels in a manner that yields the highest return and not breaking any constraints specified earlier.

3.2 Firm 2's ROI

Based on the results obtained from using second firm's ROI, an alternative optimal budget allocation across marketing channels has been obtained shown as follows:

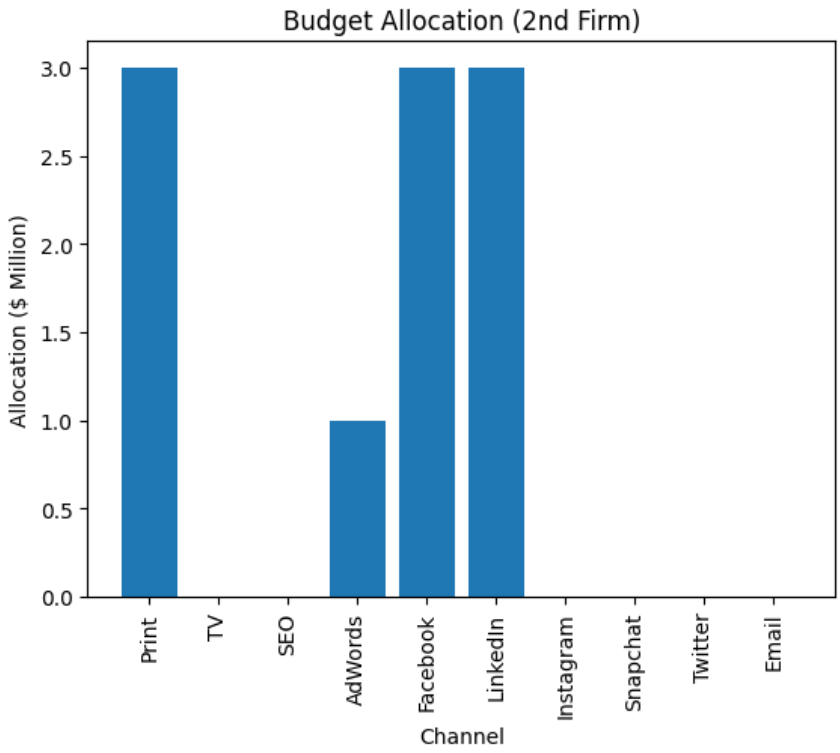

Figure 2. Marketing Budget Allocation basis Firm-2's ROI projections

The pattern of allocation is the same but the channels differ this time. Print, Facebook and Linkedin to be allocated $3M and the remaining $1M be invested in AdWords based on ROI projections from the second firm.

The channels of Television, SEO, Instagram, Snapchat, Twitter, and Email have not been allocated any budget in this scenario, suggesting that these channels might not contribute as efficiently towards a higher ROI according to the second firm's model. The total budget allocation remains at $10.0 million with an expected total ROI of $0.456 million, identical to the ROI from the first firm's model. However, the allocation across channels varies notably between the two models. This optimized budget allocation from the second firm redirects funds towards Print, Facebook, and LinkedIn advertising while moving away from TV, Instagram, and Email marketing as seen in the first firm's model.

3.3 Comparison of allocation

We compare the two firms allocation and get a summary of differences in budget allocations and ROI estimations between the two firms across various marketing channels:

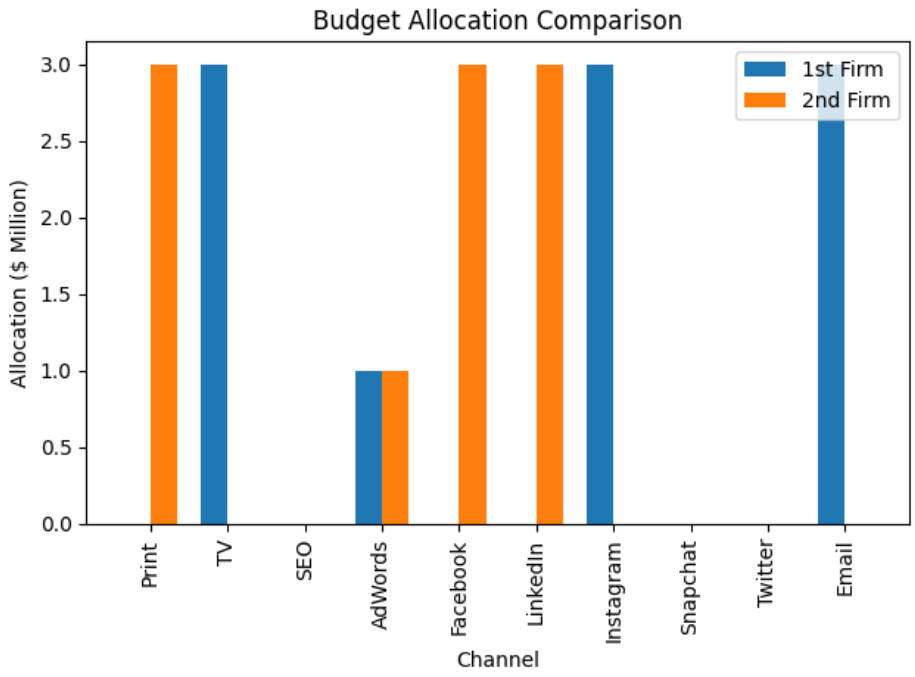

Figure 3. Marketing Budget Allocation comparison

1. Print, Facebook, and LinkedIn:
    - The 2nd firm allocates a significant budget of $3.0 million to each of these channels, while the 1st firm allocates no budget to them.
    - The 2nd firm estimates higher ROIs for these channels compared to the 1st firm.
2. TV, Instagram, and Email:
    - The 1st firm allocates a substantial budget of $3.0 million to each of these channels, in contrast to the 2nd firm which allocates no budget to them.
    - The 1st firm sees higher ROI potential in TV and Instagram, while the 2nd firm estimates a lower ROI for these channels. Conversely, the 2nd firm estimates a lower ROI for Email compared to the 1st firm.
3. AdWords:
    - Both firms agree on a budget allocation of $1.0 million to AdWords, indicating a shared view on its moderate importance.
4. SEO, Snapchat, and Twitter:
    - Both firms allocate no budget to these channels, reflecting a consensus on their lower ROI potential in this scenario.

The differences in budget allocations reflect diverging ROI estimations and possibly varying strategies or beliefs regarding the effectiveness of these marketing channels. Based on two different sets of ROI data we summarize observed outcomes below:

- Scenario 1 - 1st Firm's ROI Data is Correct: If use the 2nd Firm's budget allocation (modeled using 2nd firm's ROI data), the ROI would be $0.252M as opposed to the optimal ROI of $0.456M, which is a **reduction of $0.204M** in marketing return.

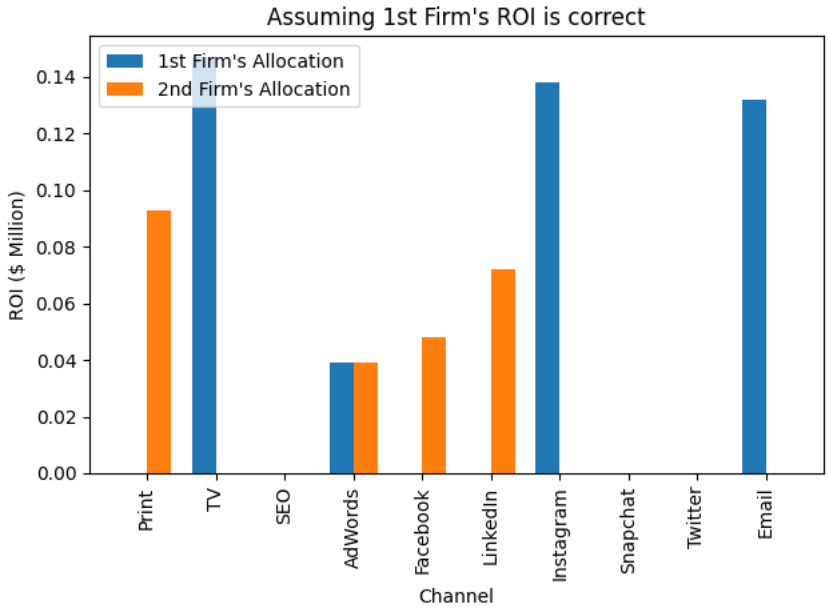

Figure 4. Scenario 1 - 1st ROI is correct and 2nd allocation in use

- Scenario 2 - 2nd Firm's ROI Data is Correct: If we use the 1st Firm's budget allocation (modeled using 1st firm's ROI data), the ROI would be $0.264M as opposed to the optimal ROI of $0.456M, which is a **reduction of $0.192M** in marketing return.

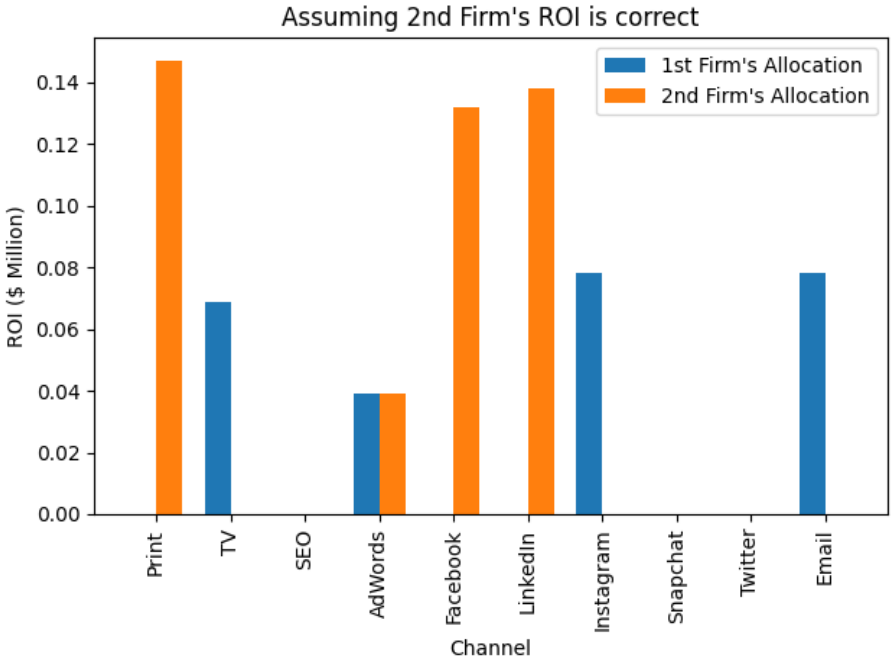

Figure 5. Scenario 2 - 2nd ROI is correct and 1st allocation in use

3.4 Usefulness of 3rd constraint

The third constraint based on boss's experience (at most $3 Million invested in one marketing medium) is useful, because ROI is an expected value and we can't be sure in the real world of getting exactly what the 1st firm has predicted, with the third constraint that the boss has advised, we ended up diversifying budget allocation across 4 different channels which would make marketing performance less dependent on particular channels. The marginal gain in ROI as depicted in Figure 6 is only $9,000 ($465,000 vs $456,000), which isn't a considerable amount, however we are going from 4 marketing mediums to 2 marketing mediums which is quite risky.

1st Firm's Optimal Budget Allocation

	Channel	Budget Alloc ($M)	Allocation without 3rd constraint
0	Print	0.0	0.0
1	TV	3.0	5.0
2	SEO	0.0	0.0
3	AdWords	1.0	0.0
4	Facebook	0.0	0.0
5	LinkedIn	0.0	0.0
6	Instagram	3.0	0.0
7	Snapchat	0.0	0.0
8	Twitter	0.0	0.0
9	Email	3.0	5.0
Total Budget		$10.000M	
Total ROI		$0.465M	

Table 1. Optimal Allocation removing 3rd constraint

4. Sensitivity Analysis

Table 1 below shows the minimum, current, and maximum ROI for different advertising channels, based on an analysis where the first firm's ROI data is used as a reference point for optimal budget allocation. Observations are explained below:

Channel	Min ROI	Curr ROI	Max ROI
Print	-inf	0.031	0.049
TV	0.039	0.049	0.062
SEO	-inf	0.024	0.039
AdWords	0.033	0.039	0.046
Facebook	-inf	0.016	0.029
LinkedIn	-inf	0.024	0.039
Instagram	0.039	0.046	inf
Snapchat	-inf	0.026	0.039
Twitter	-inf	0.033	0.039
Email	0.029	0.044	inf

Table 2. ROI sensitivity table

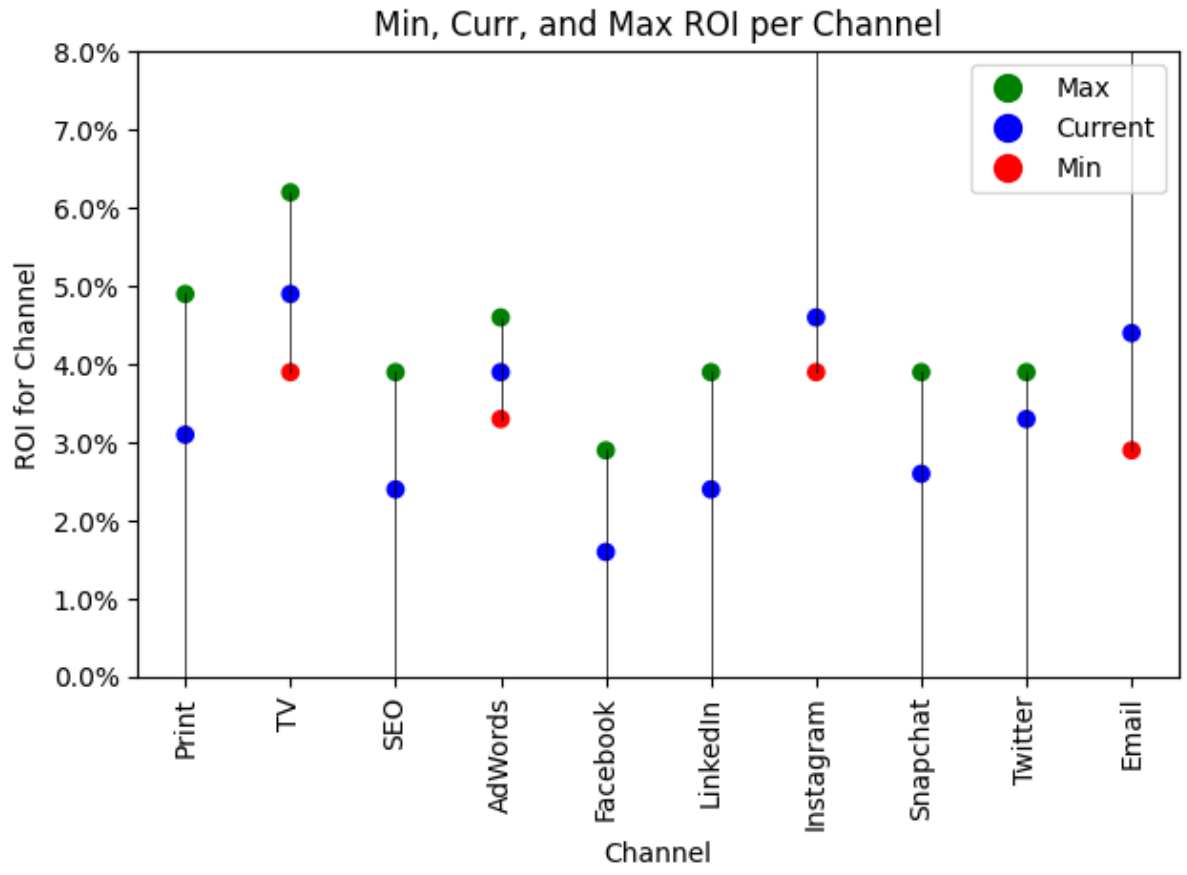

Figure 6. ROI sensitivity visualization

1. Fixed ROI Channels:
   - TV and AdWords have specific min and max ROI values, indicating that there's a finite range within which the ROI for these channels can fluctuate while still maintaining the optimal allocation.

2. Unbounded ROI Channels:
   - Instagram and Email have no upper bound (inf) on the maximum ROI, suggesting that an increase in ROI for these channels might still maintain the current optimal allocation.
   - Similarly, Print, SEO, Facebook, LinkedIn, Snapchat, and Twitter have no lower bound (-inf) on the minimum ROI, indicating that a decrease in ROI for these channels might also retain the current optimal allocation.

3. Significance of ROI Bounds:
   - The defined ROI bounds for each channel indicate the degree of ROI variability that can be tolerated without altering the optimal budget allocation derived from the initial ROI data.
   - Channels with bounded ROI values (like TV and AdWords) have a defined range of ROI variability, while those with unbounded values might have a higher tolerance for ROI changes while keeping the budget allocation optimal.

4. Implication for Budget Allocation:
   - The optimal budget allocation is sensitive to changes in ROI values. Understanding the range within which ROI can fluctuate without affecting the optimal allocation helps in better planning and adjusting the marketing budget across different channels.

5. ROI Variability Tolerance:
   - The data suggests that the budget allocation for channels like TV and AdWords might be more susceptible to changes in ROI as they have defined bounds. In contrast, channels like Instagram and Email may have higher flexibility as they have an unbounded maximum ROI.

5. Monthly Optimal Budget Allocation

Figure 7. shows the monthly allocation for each marketing medium. The initial amount available to invest in January is $10 Million, after the end of January, half of the returns from January ($373,000/2) are available along with the $10 Million to invest in February. This process is repeated every month, taking half of the returns from the previous month along with $10M. By looking at the heatmap below, it is clear that there is some randomness in the allocation from month to month, this is to be expected as each

month, the marketing allocation is treated as a standalone optimization problem and there are changing conditions, namely

- The total budget for marketing investment.
- The ROI for each medium.

However, we do see some mediums being favored across the months when compared to other mediums, for example, Adwords, Email, Instagram, Twitter and Print. Similarly, there are mediums which are avoided in general, for example, Snapchat and SEO.

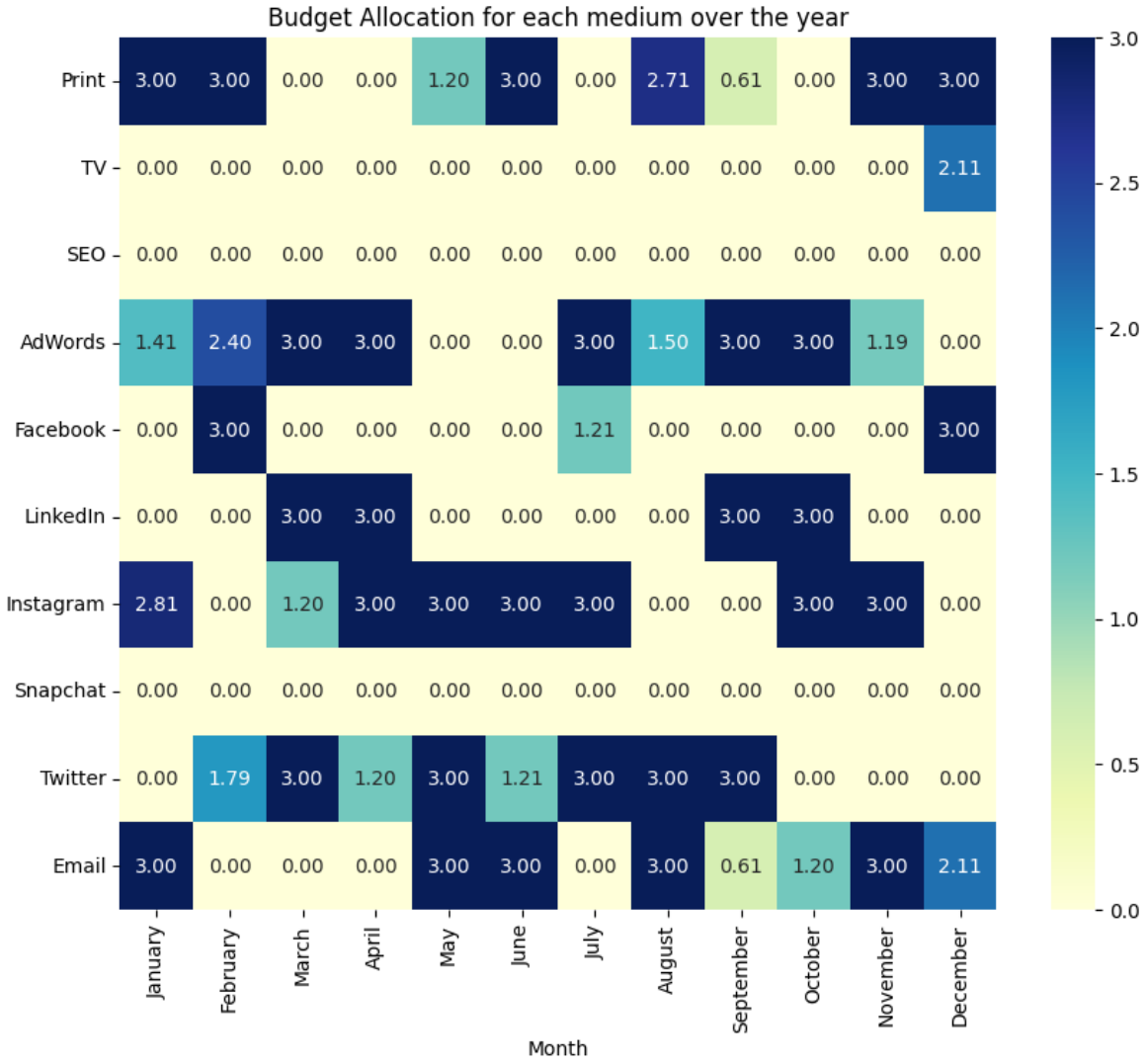

Figure 7. Monthly allocation heatmap

Figure 8 below, shows the total allocation across all months. We see that the most amount invested is in Adwords, followed by Email, Print, Instagram and Twitter at a relatively similar level. LinkedIn, Facebook and TV end off the investment list, with the least amount invested in TV. No amount was invested in SEO and Snapchat.

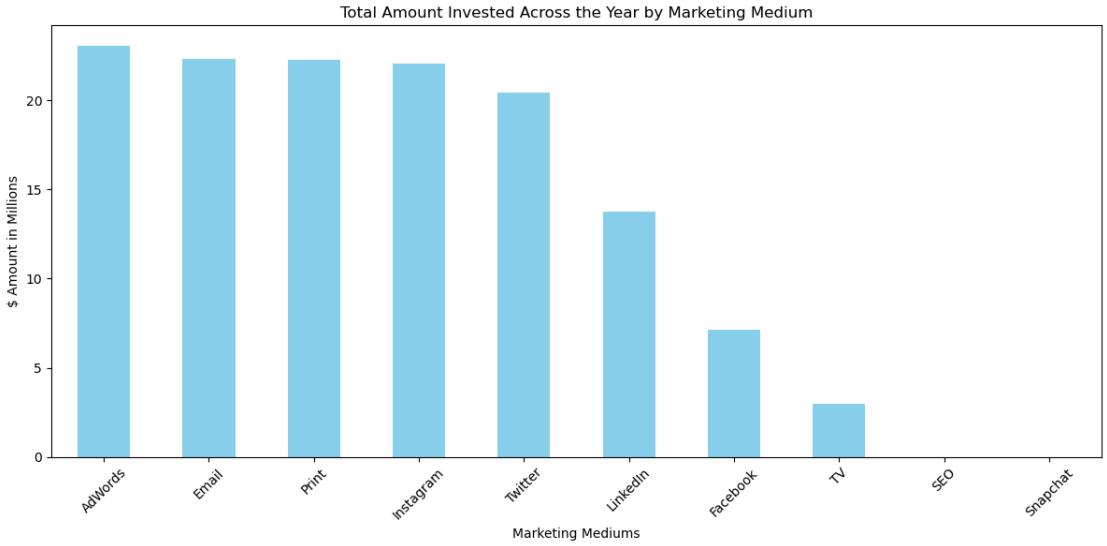

Figure 8. Total Allocations for the year

5.1 Budget variation

As seen in Table 3, there are several instances where the budget changes by more than ± $1 Million. Therefore, it is an unstable budget. The way to make the budget stable would be -

- No changes required for the allocation in January.
- From February onwards, the allocations need to be given upper and lower bound constraints corresponding to ± $1 Million of the preceding month's allocation.

This will constrain the allocations to be stable.

Month	January	February	March	April	May	June	July	August	September	October	November	December
Print	0	0.000	-3.000	0.000	1.804	1.196	-1.876	1.876	-1.637	-1.363	3.000	0.000
TV	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.000
SEO	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AdWords	0	1.063	0.604	0.000	-3.000	0.000	3.000	-1.173	1.173	0.000	-0.944	-1.628
Facebook	0	3.000	-3.000	0.000	0.000	0.000	1.124	-1.124	0.000	0.000	0.000	3.000
LinkedIn	0	0.000	3.000	0.000	-3.000	0.000	0.000	0.655	2.345	0.000	-1.887	-1.113
Instagram	0	-2.667	1.390	1.610	0.000	0.000	0.000	-3.000	0.000	3.000	0.000	-3.000
Snapchat	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Twitter	0	1.791	1.209	-1.403	1.403	-0.980	0.980	0.000	0.000	-3.000	0.000	0.000
Email	0	-3.000	0.000	0.000	3.000	0.000	-3.000	3.000	-1.637	1.592	0.045	0.000

Table 3. Monthly allocation change

6. Conclusions and Final Recommendation

After an extensive examination of marketing budget allocations based on different ROI projections from two distinct firms, several key conclusions are drawn:

1. Changing Recommendations:
The two consulting firms present differing recommendations on optimal allocations. Firm 1 recommends allocations to TV, Instagram, and Email, whereas Firm 2 places emphasis on Print, Facebook, and LinkedIn. This disparity highlights the necessity for accurately finding out the optimal channels for marketing investments.

2. Common Ground on Certain Channels:
Despite variances, there is common ground, as seen in AdWords where both firms agree on a $1M allocation, reflecting a shared perspective on its moderate importance. Similarly, no budget allocation to SEO, Snapchat, and Twitter by either firm implies consensus on their lesser ROI potential.

3. Diversification Benefits:
The third constraint, limiting investments in one medium to $3 million, enforces diversification, mitigating risks related to overdependence on single channels and yielding to a more balanced, secure marketing strategy.

4. ROI Sensitivity and Stability:
The findings underscore the importance of acknowledging ROI sensitivity and the significance of stability in budget allocation, particularly in channels like Instagram, which demonstrates relative stability.

5. Monthly Variations:
Monthly allocations reveal inherent randomness in the optimization of channels with some mediums being persistently favored, such as Adwords and Email, implying consistent performance in certain platforms.

Final Recommendation -

Based on the conclusions drawn from the analysis, the following recommendations are made to optimize the marketing budget allocation effectively:

1. Precision in ROI Predictions:
It is imperative to prioritize precision in ROI predictions. A meticulous evaluation of the accuracy of ROI projections is crucial to preempt significant revenue discrepancies arising due to incorrect allocations.

2. Balanced Diversification:
Upholding a diversified portfolio by avoiding overreliance on a single channel is pivotal. Ensuring allocations are spread across multiple channels will aid in risk mitigation and balance dependencies, enhancing overall marketing resilience.

3. Incorporate Stability Constraints:
To curb abrupt variations in budget allocations month over month, it's recommended to instate upper and lower bound constraints. These constraints will add more stability and fortify the allocation strategy against sudden market shifts or changes in ROI.

4. Reinvestment Strategy:
Evaluate and adjust the reinvestment strategies consistently to harness positive outcomes effectively. The results showcase the benefit of dynamic reinvestment in advertising platforms, and this aspect requires continuous assessment to maintain optimization.

5. Continuous Review:
Given the dynamic nature of marketing ROI, it's vital to conduct periodic reviews and adjustments of the budget allocations. Regular assessments will align the allocation strategies with evolving market conditions and channel performances.

6. Strategic Flexibility:
Lastly, maintaining flexibility in allocations is essential. While adhering to initial constraints is important, embracing adaptability in reallocating budgets from less effective to high ROI yielding platforms, when necessary, can be instrumental in optimizing overall returns.

In conclusion, a harmonious balance between accurate ROI predictions, diversified allocations, strategic flexibility, and continuous assessment is the key to optimizing marketing budget allocations, ensuring maximum returns and minimal discrepancies.