




Timing Matters: How pre- and post-holiday promotions affect fresh and frozen product sales in grocery retail

Farzaneh Darbanian^{a,b}, Patrick Brandtner^{a,b,*} , Taha Falatouri^{a,b}, Mehran Nasserri^{a,b}, Sina Mirshahi^{a,b,c}

^a University of Applied Sciences Upper Austria, Department for Logistics, Steyr, Austria

^b Josef Ressel Center for Predictive Value Network Intelligence (JRC PREVAL), Steyr, Austria

^c Department of Informatics and Artificial Intelligence, Faculty of Applied Informatics, Tomas Bata University in Zlín, Czech Republic

ARTICLE INFO

Keywords:

Promotions
Promotional timing
Perishable products
Fresh produce
Frozen products

ABSTRACT

This study investigates the impact of promotional timing on fresh and frozen product sales during holiday periods within the supermarket sector. Using a comprehensive dataset from an Austrian retail chain, spanning six years and over 19 million transaction lines, the research highlights the critical interplay between promotional strategies, consumer purchasing behavior, and product perishability. The findings reveal that pre-holiday promotions are particularly effective for fresh products such as fruits, vegetables, meat, and fish, leveraging consumer urgency due to store closures and perishability. In contrast, frozen products exhibit more stable sales patterns, with less pronounced effects from promotional timing due to their suitability for stockpiling. The analysis emphasizes the importance of tailored promotional strategies. Five key implications emerge: the necessity of timing promotions for fresh products to capitalize on consumer urgency, the reduced sensitivity of frozen products to promotional timing, the effectiveness of promotions for high-frequency items in driving sales and traffic, the importance of customizing promotions by product type and leveraging deal intensity, and the critical role of accurate forecasting to minimize waste, particularly for frozen goods. These insights contribute to both theoretical understanding and practical strategies, offering retailers actionable recommendations to enhance sales performance, optimize inventory management, and reduce wastage during holiday periods. The study also highlights avenues for future research, including product-level analyses and the exploration of consumer behavior across different holiday types.

1. Introduction

Sustainable growth in the competitive retail market requires a profound understanding of sales dynamics, influenced by both internal and external factors. While external conditions such as market trends and public holidays shape consumer behavior, internal factors like pricing and promotional strategies are under a retailer's control and critical for maximizing revenue (Bolton and Shankar, 2003). Among these strategies, price promotions and holiday-related shopping behaviors have been identified as key levers for driving sales performance (Oh and Kwon, 2009; Dede suleman et al., 2024). Promotions such as price discounts or bundled offers have demonstrated significant potential to encourage spontaneous purchases, boost store traffic, and increase revenue (Bhatt et al., 2024). They account for over a quarter of total revenue for many consumer goods companies (Gauri et al., 2017). At the

same time, these strategies can influence consumption patterns and help retailers manage inventory, particularly for perishable goods, by reducing waste and increasing product turnover (Calvo-Porrall et al., 2017). Therefore, retailers usually use a range of in-store promotions, such as temporary price reductions or multiunit discounts, to bring customers into their stores (van et al., 2017). These promotions are not only designed to increase store traffic but also to convert them into actual sales (Buyukdag et al., 2020) While most research highlights the positive impact of promotions on sales, certain conditions can lead to unintended negative effects, where price promotions may actually hinder sales performance (Kim, 2024).

However, the timing of promotions adds complexity to this approach, especially during public holidays when shopping behaviors shift dramatically due to store closures and heightened demand for essentials (Jiang et al., 2021; Zhang et al., 2020). Public holidays present

* Corresponding author. University of Applied Sciences Upper Austria, Department for Logistics, Austria.

E-mail address: patrick.brandtner@fh-steyr.at (P. Brandtner).

<https://doi.org/10.1016/j.jretconser.2025.104317>

Received 13 January 2025; Received in revised form 1 April 2025; Accepted 30 April 2025

Available online 6 May 2025

0969-6989/© 2025 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

both opportunities and challenges for retailers. On the one hand, these periods typically see a surge in sales as consumers stock up for store closures or festive celebrations (Hirche et al., 2021). On the other hand, the unpredictable nature of holiday demand – further driven by external factors such as seasonal trends and promotional campaigns - requires accurate sales forecasting and strategic promotional planning (Moraes et al., 2020). Timing promotions effectively can make the difference between a successful sales boost and suboptimal results. Promotions during peak shopping periods, such as the days leading up to a holiday, can result in significant sales increases, as consumers' routines and behaviours shift during these periods, leading to increased demand and making pre-holiday promotions an effective retail strategy (Fritz et al., 2010; Du et al., 2024). In contrast, promotions during off-peak times may need more effort to achieve the same effect (Keller et al., 2019). Hence, the strategic placement of promotions around holidays can improve their effectiveness (Hansen et al., 2018). Understanding the optimal timing for discounts requires analyzing customer behavior patterns and sales data across different periods (Johnson et al., 2013).

The role of promotional timing becomes even more pronounced when considering product perishability. Fresh products, such as fruits, vegetables, meat, and fish, face unique challenges during holidays due to their shorter shelf lives and increased demand associated with store closures (Chung et al., 2013; van Donselaar et al., 2016). Pre-holiday promotions for such products can significantly influence consumer behavior, as shoppers tend to purchase more in preparation for periods when stores are inaccessible (Hirche et al., 2021; Fritz et al., 2010). Conversely, frozen goods, with their extended shelf lives, follow different consumer purchase patterns, often driven by stockpiling behavior regardless of promotional activity (van et al., 2017; van Donselaar et al., 2016). Understanding these divergent dynamics is essential for retailers to tailor their strategies effectively.

While prior research has examined the impacts of discounts and holiday shopping patterns individually (e.g. (Zhang et al., 2020; Bolton and Shankar, 2003)), limited attention has been given to the interaction between these two factors. Furthermore, the differential effects of promotional timing on fresh versus frozen products remain underexplored (Calvo-Porrall et al., 2017; Chung et al., 2013). Addressing this gap is crucial not only for maximizing sales performance but also for minimizing waste and optimizing inventory management, particularly during high-demand periods like holidays (Teller et al., 2018; Moraes et al., 2020).

The central research question driving this study is: "How does the timing and intensity of promotions around public holidays influence consumer purchasing behavior and sales outcomes for fresh and frozen products in the supermarket sector?" This question addresses the critical interplay between promotional strategies, consumer behavior, and product perishability, focusing on the unique dynamics of holiday-related shopping periods. Our analysis emphasizes not only the differences in consumer behavior across product types but also the strategic importance of aligning promotional timing with shopping patterns during critical periods like public holidays. This research focuses on the Austrian retail context, where supermarkets remain closed on public holidays and Sundays, creating unique consumer behaviors around stockpiling and pre-holiday purchases. To address these questions, the study utilizes a robust dataset comprising daily sales records from a leading supermarket chain in Austria, spanning from 2016 to 2021. The data covers two key product categories - fruits and vegetables, and meat and fish - further divided into fresh and frozen subcategories. By examining promotional effectiveness across these categories, the study highlights actionable insights for retailers to optimize their strategies during holiday periods.

The remainder of the paper is structured as follows: Section 2 provides an overview of the relevant research background, detailing the theoretical and empirical foundations of promotional strategies and holiday effects. Section 3 outlines the research methodology, including the data collection, cleaning, and analytical approaches. Section 4

presents the results, showcasing how promotional timing and product perishability impact sales outcomes. Finally, Section 5 discusses the implications of the findings, offering practical recommendations for retailers and theoretical contributions to the field.

2. Background

The study of pricing and promotional strategies in retail markets has garnered significant attention due to their profound impact on consumer behavior and sales performance. Promotions are a powerful tool for businesses to boost sales (Buyukdag et al., 2020). They not only attract customers by offering incentives but also help build loyalty, generate interest, and involve intermediaries in the value chain (Alexandrescu and Milandru, 2018). Despite their critical role in influencing consumer purchasing behavior (van et al., 2017) poorly framed promotional offers can backfire, leading to distrust and reduced purchase intentions (Bhatt et al., 2024). The effectiveness of promotions varies across businesses and market conditions (Hitsch et al., 2021). Retailers typically adopt one of two approaches: either aggressively responding to competitors' price changes or ignoring them altogether. These pricing practices often differ across product categories. For instance, perishable products like meat are more influenced by direct supermarket competition, while frozen or dry groceries are shaped by broader market factors (Binkley and Connor, 1998). Historically, grocery retailers have employed pricing strategies such as Every Day Low Pricing (EDLP) or High-Low Pricing at the store or chain level (Bolton and Shankar, 2003). However, shifts in consumer behavior, intensifying competition, and advancements in technology have led to more sophisticated approaches. This evolution is particularly evident among online grocers, who increasingly adopt algorithmic pricing to automate their strategies, a method traditionally used in industries like airlines, ride-hailing, and online marketplaces for durable goods (Aparicio et al., 2024). To navigate these challenges, retailers increasingly rely on category management, treating product groups as distinct business units. A deep understanding of consumer behavior and the shopper journey is now critical for crafting effective strategies and maintaining competitiveness (Pascucci et al., 2022). Recent advancements in data analytics and machine learning have provided retailers with tools to optimize promotional strategies, offering new opportunities to align promotions with consumer behavior during high-demand periods (Jiang et al., 2021; Falatouri et al., 2022; Nasseri et al., 2023).

The literature on promotions explores various dimensions. Johnson et al. (2013) developed an optimization model for temporal discounts, which increased profits by 18–40 % compared to traditional discounting methods. Buyukdag et al. (2020) found that specific discount patterns enhance purchase intentions by creating perceptions of value, though their effectiveness varies across consumer segments and product types. Similarly, Hitsch et al. (2021) revealed that the effectiveness of price reductions and promotions depends on market conditions, with product quality often moderating these effects (Setiawan and Warganegara, 2024). Research has also highlighted the relative effectiveness of different promotion types, with discounts generally outperforming other methods in influencing purchasing decisions (Suleman et al., 2024). Furthermore, while increasing the overall frequency of promotional events can enhance profitability, tailored pricing strategies for specific SKUs allow for customized promotions that leverage their unique attributes (Phumchusri et al., 2024).

Other studies have examined the timing of promotions. For example, Julian et al. (2024) analyzed e-commerce discount strategies and showed that consumer behavior is influenced by product type, timing, and individual preferences (Julian et al., 2024). Timing becomes particularly critical during holidays, which represent a unique opportunity for retailers to increase sales. Especially in markets like Austria, where public holidays and Sunday store closures significantly impact consumer shopping patterns, understanding the role of promotional timing is particularly crucial. Holidays disrupt the structured routines of the workweek (Huttenlocher et al., 1992) and encourage non-work

activities that affect emotional and behavioral patterns (Fritz et al., 2010). This weekend effect impacts consumption habits, with mood shifts altering decision-making and leading to distinct shopping behaviors (Du et al., 2024), as well as online shopping habits (Yao et al., 2023). Strategically timed promotions during these periods can significantly boost household spending (Oh and Kwon, 2009). Hirche et al. (2021) found that external factors like temperature variations and holidays correlate with increased sales, such as higher alcoholic beverage sales during warmer holiday periods. Similarly, Ramasami et al. (2023) demonstrated that factors like fuel prices, holidays, and weather significantly impact Walmart sales (Ramasami et al., 2023).

Over the years, various theoretical frameworks have tried to clarify how business strategies, such as promotional timing, shape consumer decision-making and purchase intentions, offering distinct yet complementary insights into the effectiveness of pre- and post-holiday promotions. Cialdini's (2001) scarcity principle proposed that perceived rarity enhances desirability, suggesting that pre-holiday promotions for fresh products like fruits, vegetables, meat, and fish succeed because store closures and perishability create urgency, driving significant sales increases. In contrast, Prospect Theory (Kahneman and Tversky, 1979) argued that consumers evaluate outcomes relative to a reference point, with greater sensitivity to losses than gains, this explains why the potential loss of not securing fresh goods before holidays outweighs the gain of discounted frozen items, which consumers can store up later, resulting in weaker promotional responses. Mental Accounting Theory (Thaler, 1985) complemented this by emphasizing "transaction utility," where the psychological pleasure of a deal boosts pre-holiday product sales. Temporal Construal Theory (Liberman and Trope, 1998) further refines this, proposing that near-future events, like imminent holidays, amplify the immediate appeal of fresh product promotions and future-oriented frozen purchases. Conversely, the Model of Focusing on Economic Choice (Kőszegi and Szeidl, 2013) suggests consumers fixate on standout features like discounts, which may explain promotion success across both categories on normal days, though its effect is less pronounced for frozen items pre-holiday due to stockpiling tendencies. Finally, the Framework of Family Responses to Resource Scarcity (Hosany and Hamilton, 2022) highlights how situational scarcity, such as holiday closures, shifts consumption priorities, reinforcing fresh product demand before holidays but stabilizing frozen sales regardless of timing. Comparing these frameworks, scarcity and temporal construal dominate for fresh products, where urgency and immediacy align with holiday-driven behavior, while prospect theory and mental accounting better explain the muted response of frozen goods, where Loss sensitivity and deal perception are tempered by longer shelf life. Together, these theories provide a multidimensional lens, revealing why pre-holiday promotions are particularly effective for perishable items, while frozen products exhibit resilience to timing due to differing consumer motivations. Based on this theoretical foundation, we expect that pre-holiday promotions will be especially effective for fresh products, driven by urgency and perceived scarcity, while frozen products may show more stable purchase behavior, less affected by timing. Furthermore, transaction utility and promotion visibility may play a stronger role on regular days, regardless of perishability. These frameworks therefore offer valuable interpretive guidance for understanding potential differences in consumer reactions across product categories and holiday contexts, which we will explore in the empirical analysis.

Despite substantial research on the individual effects of discounts and holiday shopping behavior, a significant gap remains in understanding how promotional timing around holidays influences sales. Most studies focus on either discounts or holidays but rarely explore their interplay. Additionally, there is limited research comparing the effectiveness of promotions across different periods - before and after holidays versus regular days - or examining how product perishability affects consumer responses to promotions. Addressing this gap is vital as it provides actionable insights for optimizing promotional strategies to enhance sales and reduce waste. Several studies highlight the

importance of timing in promotions. Chung et al. (2013) used simulation models to show that early discounts on perishable goods can boost sales and reduce waste when supply exceeds demand. Similarly, van Donseelaar et al. (2016) analyzed a large dataset of perishable products and found that substitution effects, where consumers switch between similar items, are critical. Franckle et al. (2023) conducted randomized controlled trials for a 2-for-1 price incentive on fruits and vegetables, demonstrating its feasibility and high consumer adoption (Franckle et al., 2023). These findings underscore the importance of aligning promotional strategies with consumer behavior and product characteristics. An overview of literature relevant to this study is summarized in Table 1.

Despite extensive research on various aspects of pricing and promotional strategies, significant gaps remain in understanding the nuanced dynamics of promotional effectiveness, particularly when factoring in timing and product perishability. Most studies focus on either promotions or external events, such as holidays, but rarely examine their interaction or the impact of temporal factors on sales performance. Moreover, research comparing the effectiveness of promotions across different periods—before holidays, after holidays, and regular shopping days—remains scarce. The influence of product characteristics, especially perishability, on consumer responses to promotions is similarly underexplored. Addressing these gaps is vital for optimizing promotional strategies to improve sales outcomes and minimize waste. This study builds on existing literature by analyzing the role of promotional timing for fresh and frozen goods during holiday periods. The context of Austrian retail operations, where public holidays and Sunday closures strongly influence shopping behavior, provides a unique opportunity to examine how these dynamics shape consumer purchasing patterns. By exploring the interplay between promotional timing, product characteristics, and consumer behavior, this research offers actionable insights that can inform more targeted, effective, and sustainable retail practices.

3. Research methodology

The dataset utilized in this study consists of sales data from January 2016 to June 2021 for two main groups of products, including "Fruit and Vegetables" and "Meat and Fish." each group is divided into two categories fresh and freezer types. To be more precise, we analyze the differences in customer purchase behavior among "Freezer Fruits and Vegetables," "Fresh Fruits and Vegetables," "Freezer Meat and Fish," and "Fresh Meat and Fish." The data was obtained from the respective company and represents over 19 million customer receipt lines, detailing individual product purchases and daily sales transactions across 63 stores. These data encompass daily sales figures, promotion status, and holiday status. To have a better understanding of the data, Fig. 1 displays the daily store value share across all product categories. Each bar represents the proportion of sales for a particular category as a percentage of the store's total daily quantity. This figure shows that dairy, "Fresh Fruits and Vegetables" and "Snacking" are the sales leaders; the four selected categories in this research (highlighted bars) contribute to 20 % of the total daily sale value of stores.

Prior to analysis, the sales data underwent thorough cleaning processes. Negative sale values (returned items) and sales data related to tourist areas occurring on federal holidays and Sundays were removed to ensure data accuracy and consistency. We also removed the sale value related to March 13–14, 2020, when Austria's first lockdown was announced, because it caused an abnormal jump in sales.

Then, we aggregated store sales data on the level of product. to standardize the data for comparative analysis for products with different scales (kilogram or pieces), normalization procedures were applied based on formulas (1).

$$\text{Normalized value} = \frac{(x - \text{Min})}{(\text{Max} - \text{Min})} \quad (1)$$

Table 1
Literature background overview.

Paper	Focus	Scope	Features	Product group	Method	Holiday/Event type	Promotion type	Data
Oh and Kwon (2009)	Effect of promotion during a holiday season.	Online & offline retail	Promotions, consumer characteristics, spending in store and internet channels	Holiday merchandise	Statistical analysis	Christmas season	Discounts, markdowns	Survey
Waterlander et al. (2012)	Effect of promotion on healthy foods and the saved money on less healthy foods.	Grocery retail	Price, discounts, product category, participants characteristic, expenditure	Fruits and vegetables	Simulation	–	Discounts	Simulation
Chung et al. (2013)	Effect of promotion timing on sales volume, wastage and inventory aging	Grocery retail	Dynamic pricing, inventory levels and shelf-life durations	Dairy, Baked Goods, Fresh Meat, Seafood	Simulation	–	Discounts	Simulation
Johnson et al. (2013)	Customized temporal discounts model to maximizes profits for retailers/ manufacturers	Grocery retail	Household purchase timing, brand choice, discounts, coupons	Laundry detergent, ketchup, yogurt	Optimization	–	Discounts, Coupons	Stores sale data
van Donselaar et al. (2016)	Effect of promotion on sales and forecast promotional demand	Grocery retail	discounts, time-to-consume, sales, categorization of products	Desserts, dairy drinks, cold cuts and salads	Moving average, regression models	–	Discounts	Weekly stores sales in Netherland
Gauri et al. (2017)	Effect of promotion on store traffic, sales, and profits	Grocery retail	percentage discount (depth), number of items discounted (breadth), store traffic, sales, profit, category characteristics	FMCG	Regression	MemorialDay, Independence Day, Labor Day, Thanksgiving	Discounts	Weekly stores sales in USA
Keller et al. (2019)	Promotion response difference between event and non-event times	Grocery retail	Category-event fit, brand equity, advertising, clutter, price promotion response	Food, beverages, personal care, household care	Hierarchical linear model	Skating, soccer, summer & winter Olympics, Eurovision, Christmas, Easter	Discounts	Retail sales in Netherland
Buyukdag et al. (2020)	Effect of promotion on consumers	Cloth retail	Survey based data	Sports footwear	Manipulation check test	–	Discounts	Survey
Hirche et al. (2021)	Effect of holiday and daily temperature on sales	off-trade retail	Holiday, daily temperature, beverage type, sale	Alcoholic beverages	SARIMAX	Events like New Year's Day, Super Bowl, Valentine's Day, etc.	–	Weekly retail sales in USA
Kirci et al. (2022)	Effect of promotion, inventory, direct delivery, order variations, order cycle, case size cover, quality issues and sales on spoilage of product	Grocery retail	Inventory, promotions, direct delivery, order variations, order cycle, case size cover, quality issues, sales	Fresh fruits and vegetables	Fixed effects, random effects, and ordinary least squares	–	Discounts	Daily stores sales in Netherland
Franckle et al. (2023)	Effect of 2-for-1 price incentive implementation on sales	Grocery retail	Sales, participant & retailer perceptions, use of loyalty card, redemption	frozen and canned fruits and vegetables	Randomized controlled trial	–	2-for-1 price promotion	Survey, sales data
Ramasami et al. (2023)	Effect of holidays, Average temperature, fuel price and unemployment rate on customer behavior and forecast	Grocery retail	Sales data, temperature, fuel price, unemployment rate, and holiday	FMCG	Visualization	Events like New Year's Day, Super Bowl, Valentine's Day, etc.	–	Weekly stores sales in USA
Bhatt et al. (2024)	Effect of promotion on consumers reactions	Consumer goods	Promotion-induced reactance, transaction value, acquisition value, purchase intention	Shirts, blenders, body wash, pencils	Experiments	–	Must buy x, bundle of x	Survey
Suleman et al. (2024)	Effect of promotion on consumer purchase behavior	Grocery retail	Promotions, consumer purchase behavior	FMCG	Linear regression, statistical test	–	2-for-1 price, discounts free samples, coupon	Survey
Setiawan and Warganegara (2024)	Effect of price, promotion and product quality on sales	Cloth retail	Price, promotion and product quality, sales volume	Textile	Linear regression, statistical test	–	–	Textile company sales, Survey
Thies et al. (2024)	Effect of promotion and color preferences on consumer willingness to pay for beef	Grocery retail	Beef color levels, prices, survey, discount stickers	Beef steaks	Discrete Choice Experiment, Mixed Logit	–	Discounts	Survey

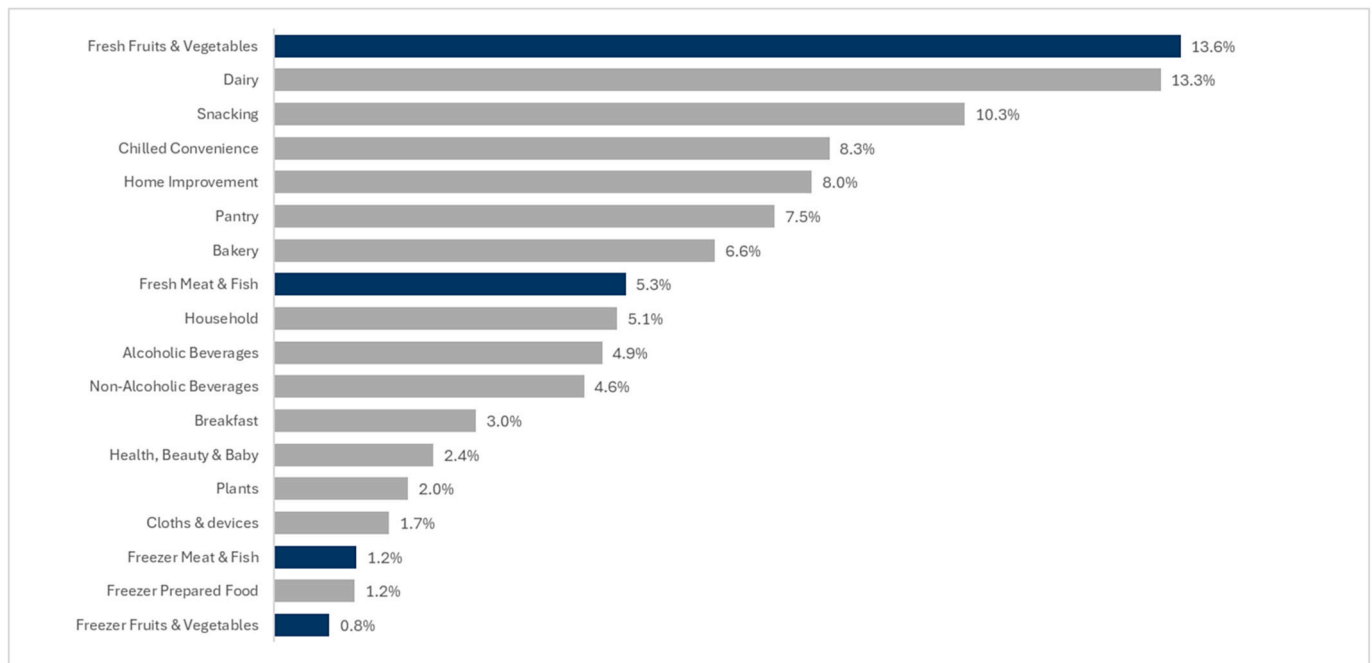


Fig. 1. Daily store sale value distribution by category.

Finally, we calculated the average of normalized daily sales on the level of four product categories, including “Freezer Fruit and Vegetables,” “Fresh Fruit and Vegetables,” “Freezer Meat and Fish,” and “Fresh Meat and Fish.” Fig. 2 displays data collection procedure.

Each date has a status label based on promotion availability on that day as well as its holiday status. Promotion status can be either 0, without promotion, or 1, with promotion. Holiday status can have three values, which can be a normal day, before the holiday, and after the holiday (0,-1,1, respectively). Therefore, the data is categorized with the following status tags: Before Holiday without Promotion (-10), Before Holiday with Promotion (-11), Normal Day without Promotion (00), Normal Day with Promotion (01), After Holiday without Promotion (10), and After Holiday with Promotion (11).

For the purpose of this article, we compare the product categories pairwise for two groups “Fruit and Vegetables” and “Meat and Fish”. In each group, fresh and freezer types will be compared with each other.

Table 2 provides key summary statistics, including the average, count, standard deviation (STDV), and median on six status levels for each category.

Fig. 3 displays a graphical representation of the distribution of the dataset, where a boxplot of normalized sales of selected categories by their status is provided. This boxplot illustrates a visual summary of the spread and central tendency of product sales, while also highlighting any potential outliers. As it is shown, boxes related to status with promotions in almost all categories are less compact, indicating that sales figures are more spread out, with a broader range of values. This suggests that sales during promotion campaigns may fluctuate significantly, with larger differences in sales volumes from one period to another. For the category Fresh Fruits and Vegetables, the difference is not as visible as for others. However, there is a significant difference between the

median of the boxes with discounts (status: -11, 01, 11) versus others, which shows that sales tend to be relatively stable with the higher median for days with discounts during all time periods.

Fig. 4 provides a line chart of daily sales for each category. the x-axis represents the days, from January 2016 to June 2021, while the y-axis shows the normalized average daily sales. The chart depicts the seasonal variations in sales, especially in the Fruit and vegetable categories, with notable peaks at different times of the year.

We have conducted a pairwise comparison of the effect of promotion and holidays for fresh and freezer product types. The p-values of the one-way ANOVA for all product categories are less than the significance level of 0.05 (p-value = <2e-16), we can conclude that there are significant differences between the groups. However, in a one-way ANOVA test, a significant p-value indicates that some of the group means are different, but we don’t know which pairs of groups are different. Hence, we performed multiple pairwise comparisons to determine if the mean difference between specific pairs of groups is statistically significant. This analysis was conducted using the function pairwise.t.test in Rstudio to calculate pairwise comparisons between group levels with corrections for multiple testing. The results are provided in the section 4.

4. Results

Section 4 presents the main empirical findings of the study. It begins with validation and reliability checks to confirm the robustness of the data and methods (4.1), followed by detailed pairwise comparisons across conditions (4.2), an inter-category analysis between fresh and frozen products (4.3), and a final examination of how promotions affect both sales and waste (4.4).

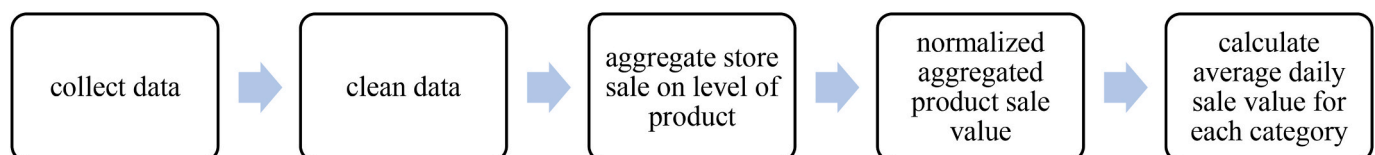


Fig. 2. Data Collection and preparation process.

Table 2
Summary statistics by product category and status.

Product category	Status	Status description	Ave	Count	STDV	Mean
Freezer Fruits and Vegetables	00	Normal day without Promotion	0.24	1019	0.07	0.22
	01	Normal day with Promotion	0.28	58	0.23	0.22
	10	After holiday without Promotion	0.27	325	0.06	0.26
	-10	Before holiday without Promotion	0.35	309	0.07	0.35
	11	After holiday with Promotion	0.35	12	0.37	0.17
	-11	Before holiday with Promotion	0.32	19	0.24	0.27
Fresh Fruits and Vegetables	00	Normal day without Promotion	0.2	1019	0.05	0.19
	01	Normal day with Promotion	0.42	1018	0.12	0.41
	10	After holiday without Promotion	0.22	325	0.05	0.22
	-10	Before holiday without Promotion	0.26	309	0.06	0.26
	11	After holiday with Promotion	0.49	325	0.13	0.47
	-11	Before holiday with Promotion	0.53	309	0.12	0.53
Freezer Meat and Fish	00	Normal day without Promotion	0.26	1019	0.06	0.24
	01	Normal day with Promotion	0.28	86	0.32	0.2
	10	After holiday without Promotion	0.27	325	0.04	0.26
	-10	Before holiday without Promotion	0.33	309	0.04	0.33
	11	After holiday with Promotion	0.29	31	0.35	0.17
	-11	Before holiday with Promotion	0.38	29	0.34	0.21
Fresh Meat and Fish	00	Normal day without Promotion	0.25	1019	0.07	0.22
	01	Normal day with Promotion	0.44	154	0.22	0.42
	10	After holiday without Promotion	0.26	325	0.06	0.24
	-10	Before holiday without Promotion	0.4	309	0.06	0.39
	11	After holiday with Promotion	0.43	25	0.26	0.35
	-11	Before holiday with Promotion	0.54	74	0.26	0.52

4.1. Reliability and validity results

Before conducting pairwise comparison, to ensure that our statistical approach correctly captured the effects of promotions and holidays, we performed additional validation checks. We implemented a one-way ANOVA separately for each year (2016–2021) to determine whether promotion and holiday effects remained statistically significant across different periods. The results confirmed that sales differed significantly by status (promotion and holiday) in all years ($p < 0.001$), with strong effect sizes (η^2 ranging from 0.25 in 2016 to 0.55 in 2019). Although

statistical significance remained consistent (F-values: 107.6–409.1), the variation in η^2 indicates that the practical impact fluctuated over time.

To assess the reliability of sales across different status categories (Holiday and Promotion) and date (aggregated monthly), we employed a linear mixed-effects model (LMM) with random intercepts for status and date to partition the variance attributable to status and date and estimate the intraclass correlation coefficient (ICC) as a measure of reliability. The adjusted ICC was 0.825, suggesting a high degree of consistency in sales within groups. This indicates that a significant portion of the observed variability in normalized sales is structured by status and date rather than arising from random fluctuations. The model was fitted using restricted maximum likelihood (REML), and variance components were extracted to evaluate the proportion of total variability explained by group-level factors. The results showed that the variance attributed to status and date was 0.0134 and 0.0015 respectively with residual variance of 0.0032. This suggests that most of the variability in sales is due to differences between groups rather than measurement error. A likelihood ratio test confirmed the statistical significance of the random effects ($p < 0.001$ for both).

In addition, we split the dataset into pre-COVID (2016–February 2020) and post-COVID (March 2020–June 2021) periods to check the robustness of our results. One-way AONVA is used to examine the impacts of sales and the presence of promotions and holidays during both periods. As it is provided in Table 3 the p-value for all categories is statistically significant ($p < 0.001$). This shows that promotions and holidays consistently influenced sales across both timeframes. These results indicate that although the magnitude of effects fluctuated slightly over time, the core influence of promotions and holidays on sales remained stable, which strengthen the reliability of our findings.

4.2. Pairwise comparison results

As it is provided in Table 4, all pairwise comparisons for fresh fruit and vegetables have p-values less than 0.05, indicating significant differences between these conditions.

In the case of freezer fruit and vegetables, as provided in Table 5, most pairwise comparisons showed p-values less than 0.05, indicating significant differences between these conditions. However, some exceptions were found. For instance, the comparison between “Before holiday without promotion” and “Before holiday with promotion” had a p-value of 0.3465, which suggested no significant difference between these two conditions. Similarly, the comparisons between “Before holiday with Promotion” and “Normal day with Promotion” (p-value = 0.0948), and between “Before holiday with Promotion” and “After holiday with Promotion” (p-value = 0.4724) also showed no significant differences.

Similarly, most pairwise comparisons for fresh meat and vegetables (see Table 6) have p-values less than 0.05, indicating significant differences between these conditions. However, the comparison between “After holiday without Promotion” and “Normal day without Promotion” (p-value = 0.6562) and between “After holiday with Promotion” and “Normal day with Promotion” (p-value = 0.65049) showed no significant differences.

The results of pairwise comparison for freezer meat and fish is provided in Table 7. Surprisingly for this group, the significant differences between only less than half of the pairwise comparisons were observed (p-values <0.05) and most comparisons did not reach significance. For instance, the comparison between “Before holiday with/without promotion” (p-value = 0.5169), and the comparisons involving “Normal day With/without Promotion” (p-value = 0.05169) and “After Holiday With/without Promotion” (p-value = 0.40845), as well as “After holiday with Promotion” and “Normal day with Promotion” (p-value = 0.73606), showed no significant differences.

Many comparisons show highly significant differences, indicating that sales or consumption patterns in most categories are significantly affected by time periods and promotions. Timing appears to play a

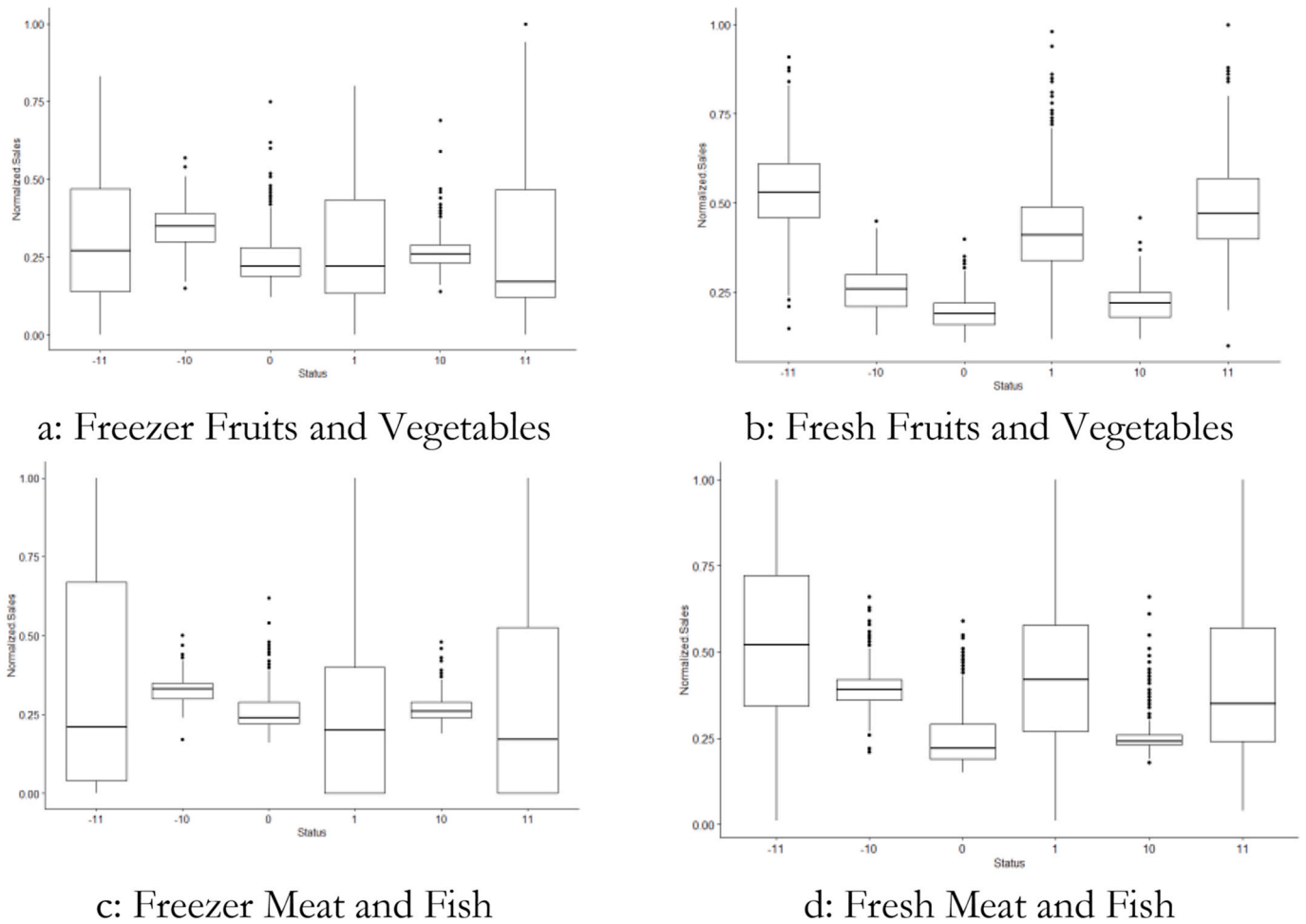


Fig. 3. Distribution of dataset by product category by status.

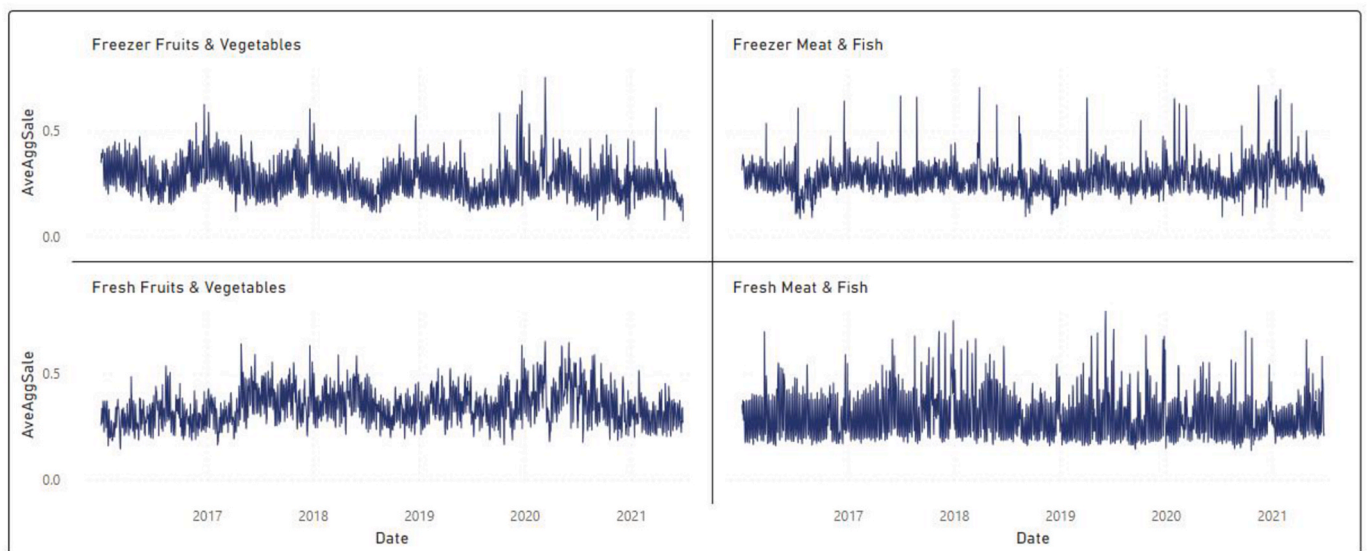


Fig. 4. Daily distribution of average sale value by product category.

crucial role, as the effects of promotions and holidays may differ depending on whether they occur before, during, or after holiday periods. The impact may also vary depending on the product category, therefore a detailed overview for each category is provided as follows.

4.2.1. Fresh fruits and vegetables

All pairwise comparisons are statistically significant with p-values <0.05, indicating that promotions, regardless of their time, have a significant effect on sales. Also, considering the increase in average sales by

Table 3
ANOVA p-values: Effect of 'Status' Before and After Covid.

Category	Before Covid (p-value)	After Covid (p-value)
Fresh Fruits & Vegetables	<2e-16	<2e-16
Freezer Fruits & Vegetables	<2e-16	1.12e-05
Fresh Meat & Fish	<2e-16	<2e-16
Freezer Meat & Fish	7.42e-11	4.23e-09

applying for promotions, we can say that scheduling promotions on normal days, before and after holidays, can significantly boost fresh fruits and vegetables sales.

4.2.2. Freezer fruits and vegetables

Although sales are highest before holidays with or without promotion, with average sales of 0.35 and 0.32 respectively, promotion during this time is not significantly different from other periods, indicating that promotions may not be as effective before holidays, potentially due to customers' tendency to stock up regardless of promotions. Moreover, without promotion, the differences between pre-holidays and normal days or post-holidays are statistically significant (p-values < 2e-16), indicating that sales naturally increase before holidays. Therefore,

Table 4
Pairwise comparison for "Fresh fruit and vegetable" category.

	Before holiday with Promotion	Before holiday without Promotion	Normal day without Promotion	Normal day with Promotion	After holiday without Promotion
Before holiday without Promotion	<2e-16				
Normal day without Promotion	<2e-16	<2e-16			
Normal day with Promotion	<2e-16	<2e-16	<2e-16		
After holiday without Promotion	<2e-16	2.40E-07	7.00E-06	<2e-16	
After holiday with Promotion	2.50E-08	<2e-16	<2e-16	<2e-16	<2e-16

P value adjustment method: BH.

Table 5
Pairwise comparison for "Freezer fruit and vegetable" category.

	Before holiday with Promotion	Before holiday without Promotion	Normal day without Promotion	Normal day with Promotion	After holiday without Promotion
Before holiday without Promotion	0.3465				
Normal day without Promotion	5.50E-05	<2e-16			
Normal day with Promotion	0.0948	1.70E-06	0.0004		
After holiday without Promotion	0.0091	<2e-16	1.30E-06	-0.2693	
After holiday with Promotion	0.4724	0.8937	3.90E-05	0.0241	0.0026

P value adjustment method: BH.

Table 6
Pairwise comparison for "Fresh Meat and Fish" category.

	Before holiday with Promotion	Before holiday without Promotion	Normal day without Promotion	Normal day with Promotion	After holiday without Promotion
Before holiday without Promotion	<2e-16				
Normal day without Promotion	<2e-16	<2e-16			
Normal day with Promotion	4.00E-11	0.00043	<2e-16		
After holiday without Promotion	<2e-16	<2e-16	0.06562	<2e-16	
After holiday with Promotion	8.90E-06	0.23447	4.00E-16	0.65049	1.60E-13

P value adjustment method: BH.

sales are already high before holidays without the need for promotions, and promotions do not significantly increase sales. It may be more cost-effective to reduce promotional efforts during this period or focus on other marketing strategies.

On the other hand, promotion on normal days is effective and slightly increased sales. Promotion after holidays has a high statistical significance, suggesting that promotions are more effective after holidays and lead to higher average sales (Ave = 0.35) compared to no promotions (Ave = 0.27). Therefore, offering discounts during these periods is most effective and leads to a significant increase in freezer fruits and vegetables sales.

In general, promotions around holidays are more effective for fresh products compared to freezers. Although applying for promotions on normal days or post-holidays is effective for freezer fruits and vegetables, for freezer products, sales patterns are significantly affected by time periods rather than promotions.

4.2.3. Fresh meat and fish

Most comparisons show significant differences, indicating that promotions and timing have a substantial effect on sales. Sales during normal days and after holidays exhibit similar statistical patterns. Average sales on normal days doubled from 0.25 without promotion to

Table 7
Pairwise comparison for “Freezer Meat and Fish” category.

	Before holiday with Promotion	Before holiday without Promotion	Normal day without Promotion	Normal day with Promotion	After holiday without Promotion
Before holiday without Promotion	0.05169				
Normal day without Promotion	1.60E-08	<2e-16			
Normal day with Promotion	0.00012	0.0005	0.05169		
After holiday without Promotion	1.50E-06	2.30E-11	0.05169	-0.42085	
After holiday with Promotion	0.00364	0.05687	0.11272	0.73606	0.40845

P value adjustment method: BH.

0.44 with promotion, accompanied by increased variability (STDV 0.22). Similarly, after holidays, average sales increased from 0.26 to 0.43 with considerable variability (STDV 0.26) when discounts were offered. The comparisons between “after holiday without promotion” and “normal day without promotion” (p-value 0.06562) and between “after holiday with promotion” and “normal day with promotion” (p-value 0.65049) are not significant, confirming that sales are comparable in these periods. However, fresh meat and fish sales increased before holidays without promotions compared to normal days, with an average of 0.4. Offering promotions at this time boosted sales to the highest observed average (0.54).

These results show that applying for promotions in all periods can affect sales, and implementing regular promotional campaigns on normal days and post-holidays is essential to maintaining higher sales levels. Though, Pre-holidays promotions have the highest impact on sales and are therefore more effective.

4.2.4. Freezer meat and fish

For the freezer meat and fish group, fewer significant differences were observed in pairwise comparison, which suggests less impact from holidays and promotion for this category.

Similar to fresh meat and fish, sales for freezer meat and fish during normal days and post-holiday periods exhibit similar behavior. The average sales value is moderate, at 0.26 on normal days and 0.27 after holidays without promotion. These values slightly increase to 0.28 and 0.29, respectively, when discounts are offered, although both periods show high variability. Some comparisons, such as “after holiday with promotion” versus other periods, are not statistically significant, suggesting that post-holiday promotions may not have high impact. Similarly, regular promotions during normal days might not yield significant overall increases.

However, average sales before holidays without promotion are higher (0.33) compared to normal days without promotion. Sales reach their highest average with promotion before holidays (0.38), but with high variability (STDV 0.34). There is no significant difference between pre-holiday with and without holiday, which means that similar to freezer fruit and vegetables, people tend to purchase more freezer meat and fish before holidays regardless of discounts. However, significant differences between “before holiday with promotion” and other periods indicate that pre-holidays promotions are more effective than normal days or post-holiday periods.

4.3. Fresh and freezer comparison

This section provides an inter category comparison between fresh and frozen type within each category (“Fruits and Vegetables” and “Meat and Fish”), and highlights trends in consumer demand across various time periods.

4.3.1. Fruits and vegetables category

Fig. 5 shows monthly sale distribution of fresh and freezer fruit and

vegetables. This chart illustrates that “Fresh Fruits & Vegetables” consistently have higher normalized sales than “Freezer Fruits & Vegetables”. For certain periods opposing trends are noticed, when fresh items increase in sales, freezer items tend to decrease, and vice versa. This could indicate a seasonal or consumer preference shift between fresh and frozen options depending on availability or seasonality. In addition, during certain times, like the pandemic year 2020, both fresh and freezer fruits & vegetables showed increases in sales, which could show that external factors like the pandemic influenced demand for both categories similarly. However, sales for both categories declined in 2021, which can be due to a return to more typical demand levels after the pandemic surge.

Fig. 6 shows the comparison of normalized sale distribution between fresh and freezer fruits and vegetables. This distribution chart for both groups indicates that the majority of sales are concentrated in the lower range (0.15–0.2). “Fresh Fruits & Vegetables” have higher and more consistent normalized sales across different levels, while “Freezer Fruits & Vegetables” show a sharp peak in lower sales values, followed by a rapid decline. The distribution chart for “Freezer Fruits and Vegetables” shows a steeper and rapid decline in sales as the normalized values increase. This pattern suggests that the bulk of sales for freezer items occurs at lower levels, with minimal sales across the higher range, indicating potentially less consistent demand compared to fresh items. The fact that freezer items show a concentrated peak followed by a quick drop-off could suggest that any external effect like promotion is limited or short-lived, leading to high sales in the lower ranges without much lasting impact on higher sales levels. For “Fresh Fruits & Vegetables” the distribution gradually declines, with some fluctuations in the mid-range which may possibly be influenced by factors like seasonal demand or promotional impact.

To investigate the potential contribution of promotion for the fluctuations, Fig. 7 is provided. This chart illustrates the frequency distribution of normalized sales for “Fresh Fruits and Vegetables,” comparing periods with and without promotion. The figure shows that the distribution peaks for days without promotion (dashed line) have a higher frequency with a lower normalized sale value (0.15), indicating that sales tend to be higher in frequency but lower in volume when there is no promotion. On the other hand, The distribution shifts towards higher normalized sale values, with a peak around 0.4 on the periods with promotion (solid line). This suggests that promotions increase the overall sales volume, but with a broader distribution. This explains the fluctuation on normalized sale distribution for “Fresh Fruits and Vegetables” and suggests that promotional efforts effectively boost sales for this category but may result in more variable purchasing behavior among customers.

4.3.2. Meat and fish category

Fig. 8 illustrates monthly sale distribution of fresh and freezer fish and meat. Similar to Fruit and Vegetables category, fresh items in Meat & Fish category have generally higher sales than freezer items but the overall difference is less here. Although there are moments of

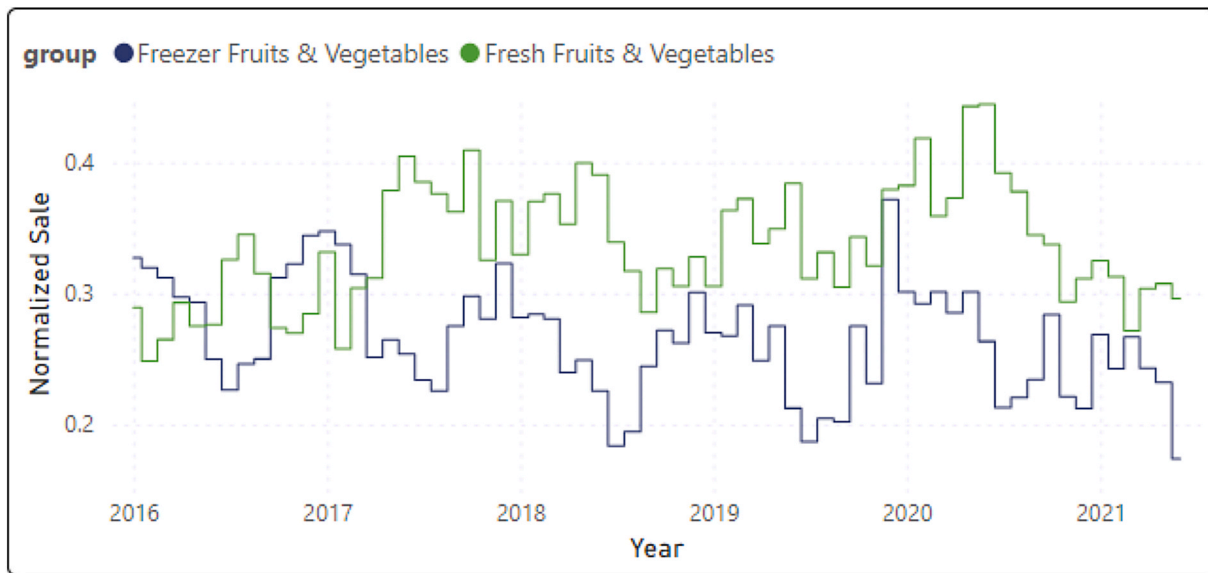


Fig. 5. Monthly sale distribution of fresh and freezer fruit and vegetables.

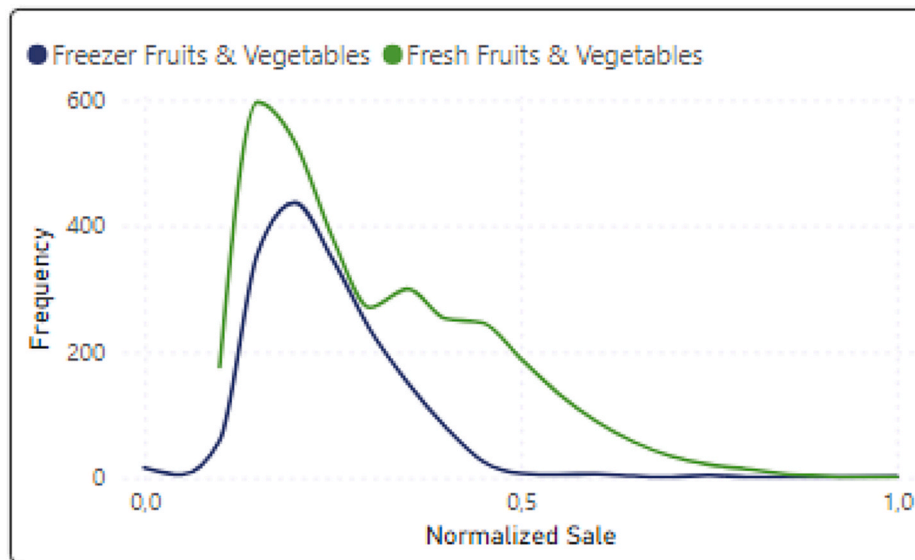


Fig. 6. Normalized sale distribution of fresh and freezer fruit and vegetables.

divergence, the overall trend isn't strictly inverse; instead, it seems that both categories generally fluctuate with seasonality and external factors, but with occasional opposite movements.

Fig. 9 shows the comparison of normalized sale distribution between fresh and freezer meat and fish.

This chart is quite similar to fruit and vegetables with concentration in the lower range for both fresh and freezer type. However, despite the fruit and vegetables, for meat and fish, fresh and freezer type have close peak value. The sharp peak in freezer products and small fluctuation for fresh products are noticed in meat and fish distribution as well. Which could suggest that fresh products in meat and fish category are more influenced by other factors such as seasonality or promotions.

To explore potential factors that influence fluctuation in sale distribution for "Fresh Meat and Fish", Fig. 10 is provided. This chart shows the frequency distribution of normalized sales for "Fresh Meat and Fish," comparing sales on days before holidays with those on normal days and the days after holidays (labelled as "Regular days"). The distribution for "Regular days" (dashed line) has a high peak at lower normalized sale

values (around 0.2), indicating that on regular days, sales of fresh meat and fish are frequent but with lower normalized volumes. Though, the distribution shifts rightward, peaking around 0.35 for days before holidays (solid line), suggesting that sales volumes increase as people buy more fresh meat and fish in preparation for holidays. The frequency distribution is also broader, showing a wider range of normalized sale values, indicating more substantial purchasing behaviour in anticipation of holidays.

4.4. Promotion impact on sales and waste

Monitoring both sales and waste can provide a fuller picture of promotion effectiveness, helping businesses balance inventory with demand while reducing financial and environmental costs associated with overstock. Therefore, a comparison of promotion impact on sale and waste of products is provided in Fig. 11. This chart shows that promotions effectively boosted sales across all categories, however the relationship between sales increase and waste reduction wasn't

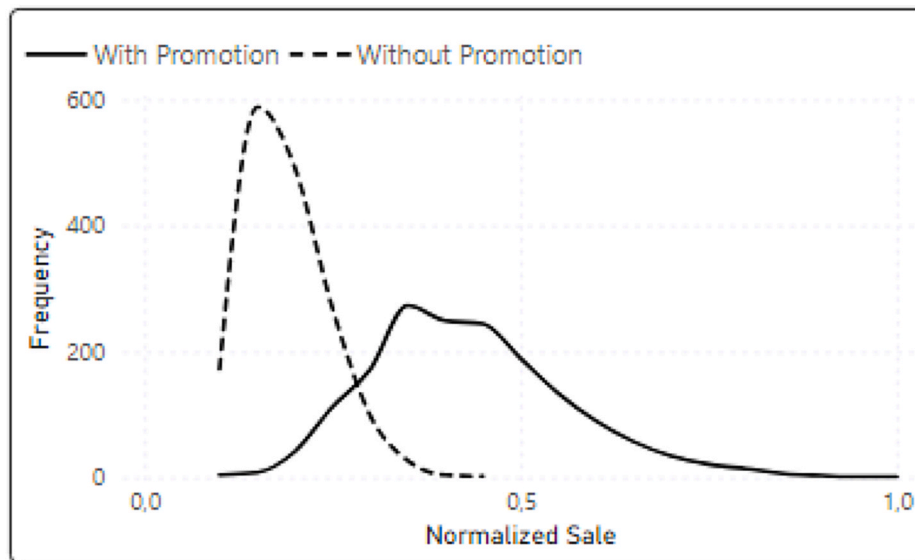


Fig. 7. Normalized sale distribution for fresh fruits and vegetables with and without promotion.

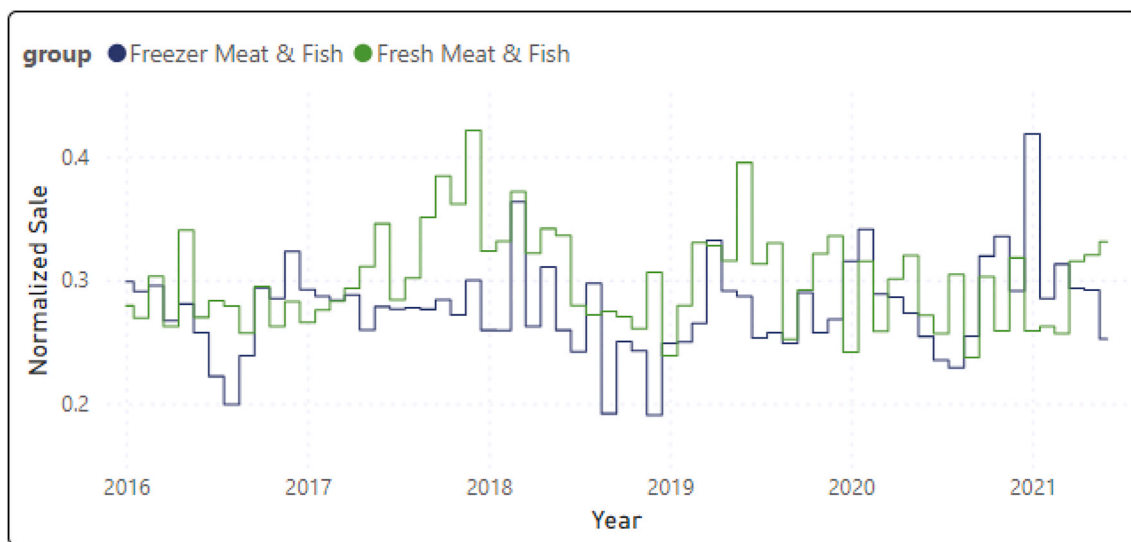


Fig. 8. Monthly sale distribution of fresh and freezer fish and meat.

consistent. For perishable categories (“Fresh Fruits and Vegetables” and “Fresh Meat and Fish”), we can say that promotions may effectively balance demand and stock. For example, for “Fresh Fruits and Vegetables”, we saw a significant sales increase (+122 %) with a slight decrease in waste (−2 %). Though, for freezer products, promotions also increased sales but led to a large rise in waste, which can suggest overstock and inefficient management despite the sales boost.

5. Discussion

Our work analyses the specific timing of promotions - particularly before and after holiday periods - and the differential impact this timing has on fresh versus frozen products. Our findings suggest that, especially for fresh fruits, vegetables, meat, and fish, the timing of promotions (e. g., before holidays) significantly affects sales, much more than what the general effectiveness of promotions would suggest. For example, fresh produce promotions before holidays show strong sales effects, likely because of consumer preparation for holiday closures, while freezer products exhibit different patterns, indicating that consumers may

stockpile regardless of promotions. The broader implication of our study is that promotion strategies must be context-specific. We assessed the stability of sales patterns across years using one-way ANOVA and ICC analyses, which showed excellent reliability and low within-category variation. Similarly, a pre-vs. post-COVID split confirmed consistent effects of promotions and holidays, further supporting the robustness and stability of the data over time. Our work shows that timing around holidays is a critical variable that affects not only the magnitude of sales but also how different types of perishables respond to promotions. This nuanced understanding allows retailers to better plan promotional strategies around key calendar events rather than applying a one-size-fits-all approach. Therefore, we argue that during holiday periods, the urgency associated with fresh product perishability and store closures becomes a dominant driver of consumer behavior. This temporal dimension adds complexity to promotional strategies, as retailers must consider not only the discount itself but also how the timing relative to holidays influences consumer motivations.

In a study by van Donselaar et al. (2016), the authors analyze the impact of price discounts on perishable products and emphasize the

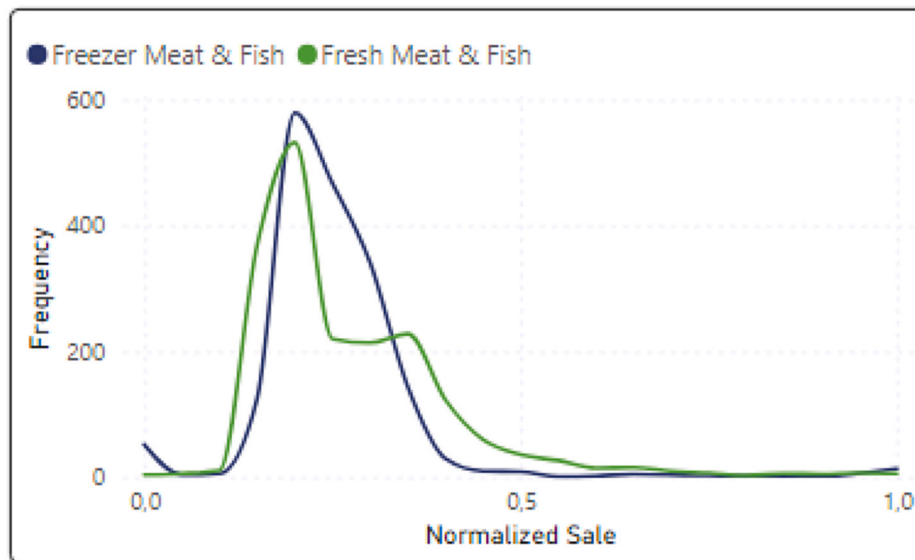


Fig. 9. Normalized sale distribution of fresh and freezer meat and fish.

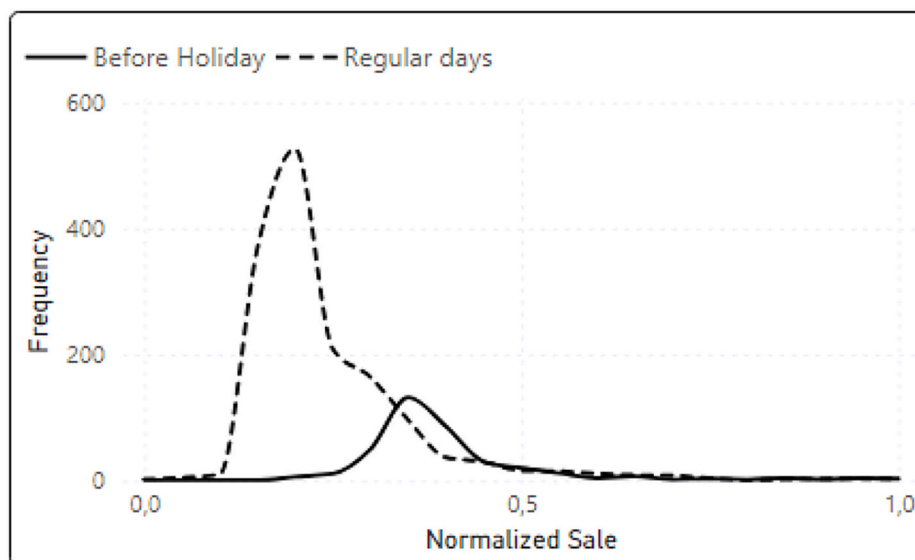


Fig. 10. Normalized sale distribution for fresh meat and fish before holiday vs other days.

substitution effect, where consumers switch between similar products rather than stockpiling during promotions. They found no clear evidence for threshold or saturation levels for discounts, suggesting that the success of promotions might depend more on consumer behavior within the category, rather than on the perishability of the products. Our research builds on this by adding a temporal dimension, specifically focusing on how the timing of promotions around holidays affects supermarket sales. While [van Donselaar et al. \(2016\)](#) focus on the general effectiveness of promotions, our work explores how promotions before and after holidays interact with consumer behavior, particularly with respect to perishable products. We find that fresh products, especially fruits, vegetables, meat, and fish, experience significant sales increases when promotions are strategically timed before holidays. This is likely due to consumer behavior patterns, such as preparing for store closures, which differs from the substitution effects [van Donselaar et al. \(2016\)](#) observed during regular promotion periods. Furthermore, our results for freezer products indicate that timing plays a less significant role compared to fresh products, as customers tend to stock up on frozen goods regardless of promotional timing. This contrasts with van

[Donselaar's](#) findings, where the success of promotions was more universally tied to substitution effects across product categories. By integrating the timing factor, particularly around holidays, we demonstrate that promotional strategies need to account not only for discount levels but also for when these discounts are applied. One possible explanation for the differences between our findings and those of [van Donselaar et al. \(2016\)](#) lies in the nature of consumer behavior around holiday periods. During holidays, consumer shopping patterns shift as customers often anticipate store closures, leading to increased demand for fresh products before holidays as part of their preparation, which can prove the idea of the different behavior related to the weekends ([Du et al., 2024](#)). This behavior contrasts with regular shopping periods, where substitution effects might dominate and influence the success of promotions. In holiday contexts, consumers are less likely to substitute products within the same category because they are focused on stocking up for the closure, particularly for fresh items that cannot be stored long-term. This explains why our results show that pre-holiday promotions on fresh products yield significant sales increases compared to other periods. Customers are not simply responding to discounts but are also motivated

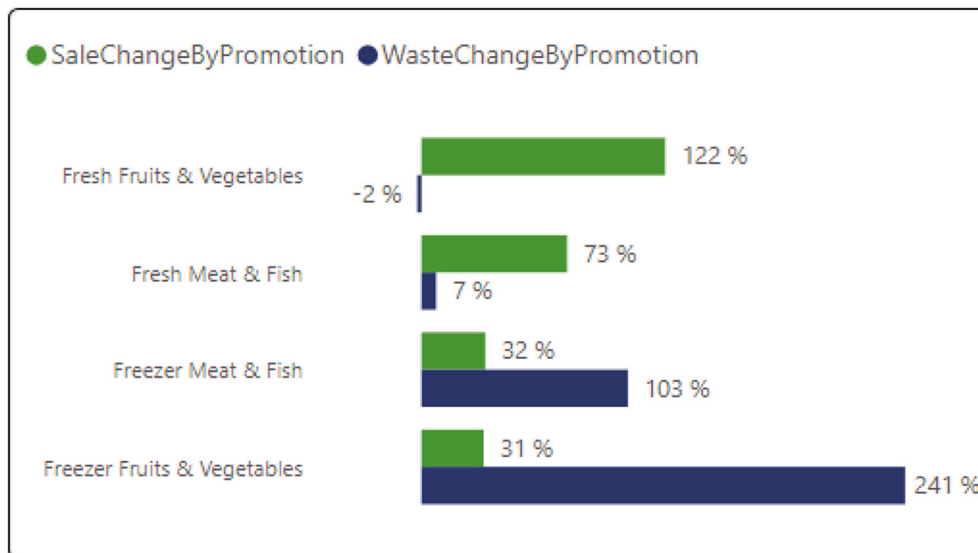


Fig. 11. Impact of promotions on sales and waste by product category.

by the need to purchase fresh products before holidays when they anticipate higher demand and limited availability. In contrast, for frozen products, the time-to-consume is not a pressing issue, and customers might already engage in stockpiling regardless of promotions. This explains the relative ineffectiveness of holiday promotions for frozen goods in our study. The flexibility of frozen products allows consumers to stockpile when convenient, reducing the need for promotions to drive sales during specific periods like holidays.

In comparing our results with those of (Wolters and Huchzermeier, 2021), we observe both similarities and differences in how promotional timing affects sales, particularly around holiday periods. Both studies find that well-timed promotions result in significant sales increases. In our case, pre-holiday promotions for fresh products (e.g., fruits, vegetables, meat, and fish) show the largest sales uplift, while Wolters and Huchzermeier emphasize seasonal cycles and the importance of forecasting demand across both promotional and non-promotional periods. A key difference lies in the response of frozen products. While Wolters and Huchzermeier account for post-promotion dips in out-of-season periods due to stockpiling, we find that frozen products (such as frozen vegetables and meat) show less impact from pre-holiday promotions. This is explained by consumers' tendency to stockpile frozen goods ahead of holidays, reducing the necessity for promotional incentives during these periods. In contrast, fresh products, which are highly perishable, require timely purchases, and therefore respond more sharply to promotions immediately before holidays. This difference highlights the role of perishability in shaping consumer behavior and underscores the need for differentiated promotional strategies based on product type and timing.

In comparing our study with Gauri et al. (2017), which examines the impact of promotional discounts on store performance, a key similarity emerges: promotions for high-penetration, high-frequency items are particularly effective in driving store traffic and sales (Gauri et al., 2017). This aligns with our findings for fresh products, where pre-holiday promotions significantly boost sales due to high demand and perishability, creating a sense of urgency among consumers. In both cases, the timing of promotions is crucial, as it aligns with established purchasing habits for high-frequency items or the urgency to purchase perishable goods before they spoil or become unavailable during store closures. This synergy between product necessity and time-sensitive demand explains the strong impact of promotions on sales. However, as Alexandrescu and Milandru (2018) note, the effects of promotional sales are typically short-lived, failing to establish long-term sales trends, a limitation also observed in our findings (Alexandrescu and Milandru,

2018).

Our findings on the differential impact of promotional timing on fresh versus frozen product sales align with and extend several theoretical frameworks. In particular, they illustrate the interplay of urgency, perishability, and consumer decision-making during holiday periods. The significant sales uplift observed for fresh products like fruits, vegetables, meat, and fish before holidays supports Cialdini's (2001) Scarcity Principle: store closures and perishability create a perceived scarcity that drives urgency. This dynamic is less evident for frozen goods, which are more suitable for stockpiling. Consumers seem more sensitive to the potential loss of fresh product availability than to the gain from discounted frozen items, which may explain the muted promotional response for the latter. Temporal Construal Theory (Liberman and Trope, 1998) also helps explain the success of pre-holiday promotions for fresh goods, as consumers tend to focus more concretely on near-future needs, prioritizing immediate consumption over more abstract, long-term planning—such as stocking up frozen items. Mental Accounting Theory (Thaler, 1985) suggests that the psychological benefit of a good deal should apply to all categories; however, our findings indicate that this effect is stronger for fresh products, possibly due to the enhanced transaction utility when urgency is present. The Model of Focusing on Economic Choice (Kőszegi and Szeidl, 2013) predicts that standout discounts drive purchases. This appears to be more relevant for normal-day promotions in both fresh and frozen categories than for frozen products before holidays, where stockpiling behaviour may overshadow price sensitivity. Finally, the Framework of Family Responses to Resource Scarcity (Hosany and Hamilton, 2022) supports our observation that holiday-related situational scarcity increases demand for fresh items, while demand for frozen products remains more stable, as families tend to plan long-term and stock up in advance. Together, these comparisons suggest that scarcity and temporal immediacy are key drivers of promotional effectiveness for fresh products, whereas frozen goods appear more resilient to timing effects due to lower urgency and reduced sensitivity to losses or deals.

These findings highlight two critical implications: first, the timing of promotions is essential for fresh products, as pre-holiday promotions capitalize on consumer urgency and preparation for store closures (Implication I); second, the impact of promotional timing is less pronounced for frozen goods, where consumer behavior favors stockpiling regardless of discounts, reducing the effectiveness of pre-holiday promotions (Implication II):

Implication I: Timing of promotions is crucial for fresh products, particularly before holidays, due to perishability and consumer urgency.

Implication II: Frozen products are less sensitive to promotion timing, as consumers naturally stockpile these items ahead of holidays.

Another study by Ailawadi et al. (2009) provides a comprehensive review of communication and promotion strategies in retailing, with a focus on how both retailers and manufacturers allocate promotional budgets and optimize promotional strategies for short-term and long-term performance (Ailawadi et al., 2009). This aligns with our focus on understanding how timing and perishability influence the effectiveness of promotions, particularly around holiday periods. One notable similarity between our findings and those of Ailawadi et al. is the emphasis on how promotions drive consumer behavior, especially for frequently purchased or time-sensitive products. Ailawadi et al. discuss the importance of loss leader promotions, where deeply discounted items, often perishable and hence high-frequency goods, are used to drive store traffic. This concept mirrors our findings, where pre-holiday promotions for fresh products significantly boost sales due to the urgency and perishability of these items. Both studies underline the effectiveness of using promotions strategically to meet consumer needs and increase store performance. These findings highlight that promotions are particularly effective for high-frequency products, as their regular necessity aligns well with consumer behavior, driving sales and increasing store traffic (Implication III):

Implication III: Promotions are highly effective for high-frequency products because they align with regular consumer shopping habits, increasing the likelihood of purchase.

When comparing our study with a study by Bolton and Shankar (2003), which investigates various retailer pricing and promotion strategies, several important insights emerge. Their research identifies five distinct pricing strategies at the brand-store level—Exclusive, Moderately Promotional, Hi-Lo, EDLP, and Aggressive pricing - showing that retailers do not follow a one-size-fits-all approach (Bolton and Shankar, 2003). In our study, we similarly emphasize the importance of customizing promotions, especially around holidays, for different product types (e.g., fresh versus frozen items). A key similarity lies in the understanding that deal intensity and support play a crucial role in driving consumer behavior. Bolton and Shankar identify deal depth, frequency, and support (features, displays) as critical dimensions of a retailer's pricing strategy, which align with our findings that timing of promotions is equally important in influencing consumer purchases, especially around holiday periods. For fresh products, pre-holiday promotions significantly increase sales due to perishability, reflecting the effectiveness of targeted promotions, similar to Bolton and Shankar's identified deal intensity and support components. These findings underscore the importance of tailoring promotional strategies to product types and leveraging deal intensity and support to maximize consumer response and sales (Implication IV):

Implication IV: Customizing promotions by product type and leveraging deal intensity and support is essential for maximizing consumer response and sales.

The issue of product wastage at the retail level, often shaped by consumer preferences, has become a focal point in sustainability discussions. Addressing food waste is essential for creating sustainable food systems, especially in the face of rising global food demand and the environmental constraints of planetary resources. Although retail contributes only 12 % of total food waste, it remains a critical point for intervention, particularly through improved forecasting and inventory management, which are key drivers of product wastage (Thies et al., 2024). In this context, the literature presents contrasting perspectives on how promotions affect forecasting accuracy and effort, and, consequently, product wastage. Both Van Donselaar et al. (2016) and Kirci et al. (2022) agree that forecasting during promotions is more challenging, yet they differ in their conclusions. Van Donselaar et al. emphasize that this difficulty leads to higher waste and stock-outs, as forecasting inaccuracies hinder efficient inventory management (van Donselaar et al., 2016). Conversely, Kirci et al. argue that promotional periods see greater managerial effort and collaboration in forecasting,

utilizing historical promotion data and coordination between DCs and stores, which could theoretically enhance accuracy and reduce waste (Kirci et al., 2022).

Our findings suggest a nuanced reality: for fresh products, increased managerial effort during promotions appears to effectively balance demand and stock, resulting in significant sales increases (+122 %) and slight waste reduction (−2 %). However, for frozen products, the same effort does not yield similar benefits, as promotions lead to both higher sales and significant increases in waste, likely due to overstocking. This highlights the importance of addressing the challenges of forecasting during promotions, as inaccuracies can significantly impact product wastage, particularly for frozen goods (Implication V):

Implication V: Effective forecasting during promotions requires careful attention, as challenges in accuracy can influence product wastage, especially for frozen goods.

6. Conclusion, limitations and future work

This study examines the impact of promotional timing on fresh and frozen categories of meat, fish, fruits, and vegetables, providing insights into how these products respond to promotions before, during, and after holiday periods. Our findings reveal that fresh products are highly sensitive to promotional timing, with pre-holiday promotions generating the most significant sales increases. This is particularly true for fresh meat, fish, fruits, and vegetables, where perishability and consumer urgency drive purchasing behavior. In contrast, frozen products show less responsiveness to pre-holiday promotions due to their suitability for stockpiling, resulting in more stable sales patterns across promotional periods. These differences emphasize the need for tailored promotional strategies that account for both product type and timing.

The study highlights five key implications. First, the timing of promotions is critical for fresh products, as pre-holiday promotions capitalize on consumer urgency and preparation for store closures. Second, frozen products are less sensitive to promotion timing, as consumers tend to stockpile these items regardless of discounts. Third, promotions for high-frequency products are particularly effective because they align with regular consumer shopping habits, increasing sales and driving store traffic. Fourth, customizing promotional strategies by product type and leveraging deal intensity and features is essential to maximize consumer response and sales. Lastly, forecasting challenges during promotions significantly influence product wastage, with fresh products benefiting from increased forecasting efforts, while frozen goods often experience overstocking and waste. These findings underscore the importance of developing tailored forecasting and promotional strategies to optimize sales and minimize waste.

From a theoretical perspective, this study extends the literature by emphasizing the role of timing, perishability, and urgency in shaping consumer responses to promotions. While much of the existing research focuses on discount depth and deal frequency, our findings demonstrate the critical importance of timing relative to holidays and its interaction with product perishability. By distinguishing between fresh and frozen products, we reveal the moderating effect of stockpiling behaviors on promotional outcomes, contributing to a more nuanced understanding of promotion theory. These insights provide a framework for integrating timing and perishability into promotional and forecasting models, offering practical value for retailers and supply chain managers.

Practically, the results highlight several actionable strategies for retailers. Pre-holiday promotions for fresh products should be prioritized to leverage consumer urgency, while post-holiday promotions for frozen goods can optimize sales and reduce waste. Tailoring promotional efforts to specific product categories and adjusting deal intensity based on perishability and demand patterns are critical to maximizing outcomes. Enhanced forecasting models that account for the unique sales dynamics of fresh and frozen products are necessary to minimize waste and improve inventory alignment. Retailers should also focus on high-frequency items as they drive sales and traffic, especially when

coupled with strategic timing and promotional features.

One of the primary limitations of this study is the variability of products within each category. For example, different types of tomatoes (e.g., organic, cherry, and standard) may differ in quality, price, or packaging, potentially leading to distinct consumer demand patterns that could influence the overall results. Additionally, our dataset contains more promotional data for fresh product categories than for frozen ones, as retailers tend to offer more discounts on fresh items to reduce waste. This imbalance likely reflects real-world retail practices but may also limit the comparability across categories and affect the robustness of statistical inferences—particularly for frozen products, where promotional sample sizes are smaller. While we applied rigorous statistical methods and confirmed result consistency through ANOVA and ICC tests, the unequal distribution may result in more conservative estimates of promotion effects in frozen categories. Future studies could address this limitation by using sampling techniques, matched designs, or weighting approaches to balance promotional exposure across product types and enable stronger causal inference. Additionally, as the study is based on the Austrian retail context - where supermarkets are closed on Sundays and public holidays - consumer behaviour patterns such as pre-holiday stockpiling may differ from other countries. This limits the generalisability of our findings and calls for comparative studies across different regulatory and retail environments.

For future research, it would be valuable to consider the price or quality type of individual products to analyze how they interact with promotional effectiveness. For instance, it would be interesting to investigate whether promotions are more or less effective for expensive or organic products. Furthermore, examining different types of holidays could reveal how various cultural or regional holidays influence shopping behavior. More analyses are needed to determine whether customers exhibit similar shopping patterns before occasional holidays like Christmas and Sundays. Additionally, a deeper investigation into product cannibalization - where sales of one product may decrease due to the promotion of another - could provide valuable insights for optimizing promotional strategies across different product categories. Other promising avenues include exploring the effects of collaborative forecasting and improved forecasting methods on reducing spoilage and optimizing inventory management. Future studies could also examine the role of multiple daily deliveries in minimizing waste and ensuring better stock alignment during promotions. Furthermore, future research could investigate how different customer segments—such as frequent shoppers, large-basket buyers, or loyalty card users—respond to promotions, provided that individual-level data is available. This would offer deeper insights into heterogeneity in promotional effectiveness. Finally, analyzing how promotions on substitute products impact spoilage in the days-fresh category could yield practical insights for designing more efficient promotional strategies and inventory systems.

CRedit authorship contribution statement

Farzaneh Darbanian: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Patrick Brandtner:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Taha Falatouri:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Mehran Nasser:** Formal analysis, Data curation. **Sina Mirshahi:** Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This research has been funded by the Christian Doppler Research Association as part of the Josef Ressel Centre for Predictive Value Network Intelligence (PREVAIL), Austria, and the Government of Upper Austria as part of the Excellence Network Logistics - Logistikum. RETAIL, Austria.

Data availability

The data that has been used is confidential.

References

- Ailawadi, Kusum L., Beauchamp, J.P., Donthu, Naveen, Gauri, Dinesh K., Shankar, Venkatesh, 2009. Communication and promotion decisions in retailing: a review and directions for future research. *J. Retailing* 85 (1), 42–55. <https://doi.org/10.1016/j.jretai.2008.11.002>.
- Alexandrescu, Mihai-Bogdan, Milandru, Marius, 2018. Promotion as a form of communication of the marketing strategy. *Land Forces Academy Review* 23 (4), 268–274. <https://doi.org/10.2478/raft-2018-0033>.
- Aparicio, Diego, Metzman, Zachary, Rigobon, Roberto, 2024. The pricing strategies of online grocery retailers. *Quant. Market. Econ.* 22 (1), 1–21. <https://doi.org/10.1007/s11129-023-09273-w>.
- Bhatt, Siddharth, Swaminathan, Srinivasan, Suri, Rajneesh, 2024. Restrictively framed promotions hurt retailers: the role of promotion induced reactance. *J. Promot. Manag.* 30 (1), 77–109. <https://doi.org/10.1080/10496491.2023.2251472>.
- Binkley, James K., Connor, John M., 1998. Grocery market pricing and the new competitive environment. *J. Retailing* 74 (2), 273–294. [https://doi.org/10.1016/S0022-4359\(99\)80096-7](https://doi.org/10.1016/S0022-4359(99)80096-7).
- Bolton, Ruth N., Shankar, Venkatesh, 2003. An empirically derived taxonomy of retailer pricing and promotion strategies. *J. Retailing* 79 (4), 213–224. <https://doi.org/10.1016/j.jretai.2003.09.005>.
- Buyukdag, Naci, Soysal, Ayse Nur, Kitapci, Olgun, 2020. The effect of specific discount pattern in terms of price promotions on perceived price attractiveness and purchase intention: an experimental research. *J. Retailing Consum. Serv.* 55, 102112. <https://doi.org/10.1016/j.jretconser.2020.102112>.
- Calvo-Porrall, Cristina, Medín, Andrés Faiña, Losada-López, Chema, 2017. Can marketing help in tackling food waste?: proposals in developed countries. *J. Food Prod. Market.* 23 (1), 42–60. <https://doi.org/10.1080/10454446.2017.1244792>.
- Chung, Jaekwon, Choi, Daeheon, Park, Iljin, 2013. The impacts of scheduling price discounts for perishable foods on retailer performance. *J. Channel Retail* 18 (4), 107–125. <https://doi.org/10.17657/jcr.2013.10.31.5>.
- Cialdini, Robert B., 2001. The science of persuasion. *Sci. Am.* 284 (2), 76–81. Available online at: <http://www.jstor.org/stable/26059056>.
- Du, Jiangang, Zhu, Liya, Ma, Yuanning, Zhang, Yu, 2024. Beyond weekdays: the impact of the weekend effect on eWOM of hedonic product. *J. Retailing Consum. Serv.* 77, 103624. <https://doi.org/10.1016/j.jretconser.2023.103624>.
- Falatouri, Taha, Darbanian, Farzaneh, Brandtner, Patrick, Udokwu, Chibuzor, 2022. Predictive analytics for demand forecasting – a comparison of sarima and lstm in retail scm. *Procedia Comput. Sci.* 200, 993–1003. <https://doi.org/10.1016/j.procs.2022.01.298>.
- Franckle, R.L., Boulos, R.J., Thorndike, A.N., Moran, A.J., Khandpur, N., Blue, D., et al., 2023. Implementation of a 2-for-1 price incentive for fruits and vegetables in a grocery retail setting. *Health Promot. Pract.* 24 (4), 728–739. <https://doi.org/10.1177/15248399221086880>.
- Fritz, Charlotte, Sonnentag, Sabine, Spector, Paul E., McInroe, Jennifer A., 2010. The weekend matters: relationships between stress recovery and affective experiences. *J. Organ. Behav.* 31 (8), 1137–1162. <https://doi.org/10.1002/job.672>.
- Gauri, Dinesh K., Ratchford, Brian, Pancras, Joseph, Talukdar, Debabrata, 2017. An empirical analysis of the impact of promotional discounts on store performance. *J. Retailing* 93 (3), 283–303. <https://doi.org/10.1016/j.jretai.2017.06.001>.
- Hansen, Benjamin, Kendall, Houghton, Keaton, Miller, Caroline, Weber, 2018. Price promotion holidays: theory and evidence. Available online at: <https://www.keatonmiller.org/s/price-promotion-holidays-2.pdf>.
- Hirche, Martin, Haensch, Juliane, Lockshin, Larry, 2021. Comparing the day temperature and holiday effects on retail sales of alcoholic beverages – a time-series analysis. *Int. J. Wine Bus. Res.* 33 (3), 432–455. <https://doi.org/10.1108/IJWBR-07-2020-0035>.
- Hitsch, Günter J., Hortaçsu, Ali, Lin, Xiliang, 2021. Prices and promotions in U.S. retail markets. *Quant. Market. Econ.* 19 (3–4), 289–368. <https://doi.org/10.1007/s11129-021-09238-x>.
- Hosany, A. R. Shaheen, Hamilton, Rebecca W., 2022. Family responses to resource scarcity. *J. Acad. Market. Sci.* 1–31. <https://doi.org/10.1007/s11747-022-00882-7>.
- Huttenlocher, J., Hedges, L.V., Prohaska, V., 1992. Memory for day of the week: a 5 + 2 day cycle. *J. Exp. Psychol. Gen.* 121 (3), 313–325. <https://doi.org/10.1037/0096-3445.121.3.313>.
- Application of machine learning model and hybrid model in retail sales forecast. In: Jiang, Haichen, Ruan, Jiatong, Sun, Jianmin (Eds.), 2021. 2021 IEEE 6th International Conference on Big Data Analytics (ICBDA). IEEE, Xiamen, China, 05-08 March 2021.

- Johnson, Joseph, Tellis, Gerard J., Ip, Edward H., 2013. To whom, when, and how much to discount? A constrained optimization of customized temporal discounts. *J. Retailing* 89 (4), 361–373. <https://doi.org/10.1016/j.jretai.2013.08.002>.
- Julian, Anitha, Maheswar, Challa, Ramyadevi, R., Murali Dhar, M.S., Selvi, S. (Eds.), 2024. Analysis and Estimation of Discounts on Product Prices in E-Commerce Sites. 2024 IEEE International Conference on Computing, Power and Communication Technologies (IC2PCT). Greater Noida, India, 09-10 February 2024: IEEE (5).
- Kahneman, Daniel, Tversky, Amos, 1979. Prospect theory: an analysis of decision under risk. *Econometrica* 47 (2), 263. <https://doi.org/10.2307/1914185>.
- Keller, Wiebke I.Y., Deleersnyder, Barbara, Gedenk, Karen, 2019. Price promotions and popular events. *J. Market.* 83 (1), 73–88. <https://doi.org/10.1177/0022242918812055>.
- Kim, Rae Yule, 2024. Price promotion does not always work: online reviews, price-quality heuristics, and risk aversion. *Electron. Commer. Res.* <https://doi.org/10.1007/s10660-024-09894-7>.
- Kirci, Mervegül, Isaksson, Olov, Seifert, Ralf, 2022. Managing perishability in the fruit and vegetable supply chains. *Sustainability* 14 (9), 5378. <https://doi.org/10.3390/su14095378>.
- Kőszegi, Botond, Szeidl, Adam, 2013. A model of focusing in economic Choice. *Q. J. Econ.* 128 (1), 53–104. <https://doi.org/10.1093/qje/qjs049>.
- Liberman, Nira, Trope, Yaacov, 1998. The role of feasibility and desirability considerations in near and distant future decisions: a test of temporal construal theory. *J. Pers. Soc. Psychol.* 75 (1), 5–18. <https://doi.org/10.1037/0022-3514.75.1.5>.
- Moraes, Camila Colombo de, Oliveira, Costa, de, Flávio Henrique, Roberta Pereira, Carla, Silva, Da, Lago, Andrea, Delai, Ivete, 2020. Retail food waste: mapping causes and reduction practices. *J. Clean. Prod.* 256, 120124. <https://doi.org/10.1016/j.jclepro.2020.120124>.
- Nasseri, Mehra, Falatouri, Taha, Brandtner, Patrick, Darbanian, Farzaneh, 2023. Applying machine learning in retail demand prediction—a comparison of tree-based ensembles and long short-term memory-based deep learning. *Appl. Sci.* 13 (19), 11112. <https://doi.org/10.3390/app131911112>.
- Oh, Hyunjoon, Kwon, Kyoung-Nan, 2009. An exploratory study of sales promotions for multichannel holiday shopping. *LJRD* 37 (10), 867–887. <https://doi.org/10.1108/09590550910988048>.
- Pascucci, Federica, Nardi, Lorenzo, Marinelli, Luca, Paolanti, Marina, Frontoni, Emanuele, Gregori, Gian Luca, 2022. Combining sell-out data with shopper behaviour data for category performance measurement: the role of category conversion power. *J. Retailing Consum. Serv.* 65, 102880. <https://doi.org/10.1016/j.jretconser.2021.102880>.
- Phumchusri, Naragain, Chewcharat, Thiti, Kanokpongsakorn, Supawish, 2024. Price promotion optimization model for multiperiod planning: a case study of beauty category products sold in a convenience store chain. *J. Revenue Pricing Manag.* 23 (2), 164–178. <https://doi.org/10.1057/s41272-023-00438-6>.
- Exploratory data analysis of Walmart outlets sales using data analytics techniques. In: Ramasami, Meaga Varsha, Thangaraj, Rajasekaran, Manoj Kumar, S., Eswaran, Sivaraman (Eds.), 2023. 2023 International Conference on Digital Applications, Transformation & Economy (ICDATE). Miri, Sarawak, Malaysia, pp. 14–16. July 2023: IEEE.
- Setiawan, Ferdi, Warganegara, Tri Lestira Putri, 2024. The influence of prices, promotions and product quality on sales volume in trimoda textile in pringsewu. *Int. J. Econ. Bus. Innovat. Res.* 3 (2), 709–727.
- suleman, Dede, Sabil, Sabil, Haryati, Raden Ati, Wianti, Wiwin, Sofyanty, Devy, 2024. Analysis influence various types of promotions sale to behavior purchase consumers : case study at niaga supermarket, lombok. *DIJMS* 5 (4), 770–780. <https://doi.org/10.31933/dijms.v5i4.2352>.
- Suleman, Dede, Sabil, Sabil, Haryati, Raden Ati, Wianti, Wiwin, Sofyanty, Devy, 2024. Analysis influence various types of promotions sale to behavior purchase consumers: case study at niaga supermarket, lombok. *Dinasti Int. J. Manage. Sci. (DIJMS)* 5 (4).
- Teller, Christoph, Holweg, Christina, Reiner, Gerald, Kotzab, Herbert, 2018. Retail store operations and food waste. *J. Clean. Prod.* 185, 981–997. <https://doi.org/10.1016/j.jclepro.2018.02.280>.
- Thaler, Richard, 1985. Mental accounting and consumer Choice. *Mark. Sci.* 4 (3), 199–214. <https://doi.org/10.1287/mksc.4.3.199>.
- Thies, Annika J., Altmann, Brianna A., Countryman, Amanda M., Smith, Colton, Nair, Mahesh N., 2024. Consumer willingness to pay (WTP) for beef based on color and price discounts. *Meat Sci.* 217, 109597. <https://doi.org/10.1016/j.meatsci.2024.109597>.
- van Donselaar, K.H., Peters, J., Jong, A. de, Broekmeulen, R.A.C.M., 2016. Analysis and forecasting of demand during promotions for perishable items. *Int. J. Prod. Econ.* 172, 65–75. <https://doi.org/10.1016/j.ijpe.2015.10.022>.
- van, Heerde, Harald, J., Neslin, Scott A., 2017. Sales promotion models. In: Wierenga, Berend, van der Lans, Ralf (Eds.), *Handbook of Marketing Decision Models*, vol. 254. Springer International Publishing, Cham, pp. 13–77 (International Series in Operations Research & Management Science).
- Waterlander, Wilma E., Steenhuis, Ingrid H.M., Boer, Michiel R. de, Schuit, Albertine J., Seidell, Jacob C., 2012. The effects of a 25% discount on fruits and vegetables: results of a randomized trial in a three-dimensional web-based supermarket. *Int. J. Behav. Nutr. Phys. Activ.* 9, 11. <https://doi.org/10.1186/1479-5868-9-11>.
- Wolters, Jannik, Huchzermeier, Arnd, 2021. Joint in-season and out-of-season promotion demand forecasting in a retail environment. *J. Retailing* 97 (4), 726–745. <https://doi.org/10.1016/j.jretai.2021.01.003>.
- Yao, Wang, Zhao, Hongying, Liu, Luning, 2023. Weather and time factors impact on online food delivery sales: a comparative analysis of three Chinese cities. *Theor. Appl. Climatol.* 153 (3–4), 1425–1438. <https://doi.org/10.1007/s00704-023-04542-w>.
- Zhang, Mu, Huang, Xiao-nan, Yang, Chang-bing, 2020. A sales forecasting model for the consumer goods with holiday effects. *JRACR* 10 (2), 69. <https://doi.org/10.2991/jracr.k.200709.001>.