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Analysis and forecasting of demand during promotions for perishable items

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ABSTRACT

This study examines promotions for perishable products in a retail environment. We analyze the impact of relative price discounts on product sales during a promotion and shed light on how to build models to forecast promotional demand for perishable products. Preliminary analyses, based on regression models and a large dataset from a retailer, do not reveal conclusive evidence for the presence of threshold and/or saturation levels for price discounts for perishable products. A potential explanation comes from the observation that, although products like desserts on average allow 1,5 weeks time-to-consume, their sales during promotions on average are equal to 14 weeks of regular sales. This suggests that the success of a promotion is not so much determined by the restriction to stockpile (due to the short time-to-consume) but by the emergence of substitution effects (consumers switching between different products of the same category). We develop and test different models to forecast the demand during a promotion, including a moving average forecast and several regression models. Within the class of regression models we find that modeling threshold and saturation effects leads to worse forecasting performance than modeling price reductions linearly or quadratically. The largest improvements in forecast accuracy are gained by distinguishing between routine and non-routine product categories. Routine categories with routine demand processes and a large number of observations perform best when applying a regression based on direct observations of the product category, whilst non-routine categories benefit from a regression which also uses observations from other product categories.

1. Research objectives and relevance

There are two research objectives in this paper. The first objective is to gain a more in-depth understanding of the impact of temporary price discounts on the sales of perishable items. The second is to use this knowledge and additional ideas to develop a model to assist retailers in making a forecast for the demand during a promotion for a perishable item.

The first objective directly responds to a key issue in sales promotion research addressed by Blattberg et al. (1995). In their paper, they call for more empirical results on the shape of the so called 'Deal Effect Curve'. This curve shows how the promotional sales depend on the relative price discount. Since then, only a few empirical studies on the Deal Effect Curve have paid attention to the presence of threshold and saturation effects for price discounts. The threshold level is the minimum value of a temporary price discount needed to change the consumer's purchases (Gupta and Cooper, 1992). The saturation level is the level of a temporary price discount from which the consumer no longer increases its purchases if the discount further increases. Despite the fact that perishable products are core items for grocery retailers, little is known about the effect of price discounts on promotional sales for perishable products. According to Blattberg et al. (1995), the limit in stockpiling is one of the reasons for saturation effects. This makes perishable items, with their short time-to-consume from the moment they are sold, especially interesting to investigate. This is the first study which analyzes threshold and saturation effects for perishable items specifically, based on a large empirical dataset with a variety of perishable items.

The second research objective responds to the increased awareness, worldwide, that food waste should be reduced. For example in early 2012 the European Parliament has called for urgent measures to halve food waste by 2025 and to improve access to food for needy EU citizens. Moreover, they called for 2014 to be designated as "European year against food waste". (European Parliament, 2012). Retailers who can improve their demand forecast accuracy will be better able to match supply with demand. By doing so, they will not only reduce food waste but also benefit from increased product availability for their customers and an

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improved customer's perception of their food quality. Heller (2002) indicated that the quality of perishable items is a core reason for customers to visit a specific store. Furthermore, according to Thron et al. (2007), the sale of perishable items is of vastly increasing importance to grocery retailers; around 50% of the total turnover can be accounted to perishable items. On the other side, Thron et al. (2007) state that, due to their limited life span, perishable items also account for the majority of product losses; around 15% is lost due to damage, spoilage, and expiry.

Hence, how to better control inventories for perishable items constitutes a major challenge for retailers. van Donselaar et al. (2006) and Broekmeulen and van Donselaar (2009) provide several solutions to improve the control of inventories for perishable items if those items are not on promotion. Promotions however have become more and more important. Fierce competition among supermarket chains has led to a significant increase (already since the 1970s) in the number, frequency, and depth of promotions (Srinivasan et al., 2004). Promotions are also responsible for a large part of the waste and the out-of-stock situations for perishable items since, as pointed out by Gruen et al. (2002), Corsten and Gruen (2003) and Ettouzani et al. (2012) emphasize that the demand for promotional products is notoriously difficult to forecast and manage. The latter authors end their paper with a call for research on new forecasting models for demand during promotions.

In conclusion, the sale of perishable items being of vastly increasing importance for grocery retailers, the growing awareness worldwide that food waste should be reduced substantially in the next decade, the importance of price promotions as a marketing tool for retailers and the fact that promotions for perishable items are responsible for a large part of the waste and the out-of-stock situations in a store makes it all more than worthwhile to focus on the analysis and forecasting of demand during promotions for perishable items.

The paper is organized as follows. In section 2 we describe the research environment and the empirical data. In Section 3 we review the literature related to threshold and saturation levels as well as the literature dealing with forecasting models for promotional demand. The focal model will be described in Section 4. In Section 5 the results on the threshold and saturation levels for perishable items are presented. The different forecasting models for promotional demand and the associated forecasting accuracies are discussed in Section 6. In Section 7 we present the conclusions and discuss several options for future research.

2. Research environment and data description

The empirical data needed for the analyses and tests in this paper were provided by a Dutch grocery retail chain. They operate more than 100 supermarkets in The Netherlands and have a strategic focus on providing good quality fresh products to their customers. With this strategy they want to differentiate themselves from their competitors. In this retail chain each store is supplied by one DC.

The data provided by this retailer include: data on sales quantities, prices, product information, weight or volume per consumer unit, timing of promotions, additional promotion action (like a Saving Action where consumers can save credits/points for buying special products at reduced prices), and information whether the product was on display in the store or included in the store flyer. The promotions typically run one week (simultaneously in all stores) and the sales data are also weekly data (from week 2 in 2010 till week 35 in 2011) with each sales week covering exactly one promotion week (Sunday to Saturday). The data were weekly SKU data aggregated on national level (i.e. summed over all stores). We use sales data rather than demand data assuming that out-of-stocks make little difference. This assumption is motivated by the flexibility in the supply chain. For example, both the retailer's DC and the manufacturer carry safety stock to prevent out-of-stocks as much as possible. At the end of the week preceding the promotion week the stores receive the majority of the products for the entire promotion week. Thanks to the safety stocks at the DC and at the manufacturer, the stores are able to order additional products on a daily basis during the week if the promotion is very successful. Due to the flexibility in this replenishment process, the forecasting (in) accuracy at the national and weekly aggregation level is a good first indicator of the potential to reduce total waste due to poor forecasting. In future research, the forecasting (in) accuracy can also be measured at the daily store aggregation level, which will give an even better indication.

The products from the following four product categories were included in this dataset: Desserts (like vanilla custard and yoghurt), Dairy Drinks (like drink yoghurt or milk with a flavor), Cold Cuts (like ham and liver pate) and Salads (e.g. Russian salad and Egg salad). All products are prepackaged. Fig. 1 shows some examples of the four product categories.

Table 1 reports a summary of the descriptive statistics for this dataset.

The dataset contains 407 different perishable items. The Dairy Drinks category contains the largest number of items (182 SKU's), the Cold Cuts category the lowest (48 SKU's). In total, there were 1447 promotions in 86 weeks for 407 perishable SKU's. So on average there were 16.8 SKU's on promotion in a week and an individual SKU is promoted on average once every 24.2 weeks. The average regular price per item was close to €1.50. When an item was on promotion, the median price discount was close to 30%, but could vary between 0% (no discount) and 60%. The price discount is calculated by comparing the price during the promotion with the regular sales price in the week preceding the promotion week.

The success of a promotion was measured by the Lift Factor, which was defined as the Sales during a promotion divided by the baseline sales. Baseline sales were measured by taking the average weekly sales of the non-promotional weeks during the five weeks preceding a promotion. The average Lift Factor was highest for Desserts (13.8) and approximately equal for Dairy Drinks, Cold Cuts and Salads (5.6, 6.2 and 7.5). The Range for the Lift Factor was very large: it varied from 1.1 to 59.5. The average Shelf Life was close to 10 days for Desserts and Dairy Drinks, while it was 25.2 days for Cold Cuts and 16.1 days for Salads. The average baseline sales, i.e. the average total number of consumer units (per SKU) sold in all stores together, ranged from 718 (Desserts) to 1010 (Cold Cuts) consumer units per week.

Fig. 1. Examples of products in the categories Desserts, Dairy Drinks, Cold Cuts and Salads.