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Dynamic Two-Part Pricing and Bidding for Display Ad Campaigns

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The digital advertising industry has experienced remarkable growth, enabling businesses to effectively engage their target audiences. A significant proportion of digital advertising is done through display advertising. Despite all of its advantages, managing such campaigns operationally continues to be a major challenge for campaign managers at ad agencies, who manage such campaigns on behalf of advertisers. New campaigns, with differing characteristics, arrive at the agencies in an unpredictable manner, and must be appropriately priced. Because of significant uncertainties in both the rate at which these campaigns arrive and the target users visit web sites, as well as the outcomes of real time auctions for these viewers on ad exchanges, ensuring that the campaigns proceed according to plan is a difficult challenge. In this research, we have developed an optimization methodology that ad agencies can use to price ad campaigns and bid for viewers in a profitable manner while ensuring expected outcomes for their clients. Specifically, we formulate the problem as a Markov decision process to maximize profits in both finite horizon and steady-state contexts, and determine dynamic strategies for real time bidding for acquiring impressions, allocating impressions to campaigns, and two-part pricing for the newly arriving campaigns. We show optimality of our approach and characterize the optimal solution. We also develop a heuristic that is easy to compute and implement at scale. Finally, managerial insights based on the analysis of a numerical case study are also illustrated.

Optimizing Inventory Availability Disclosures for Brick-and-Mortar Stores

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Many retailers display inventory information of their brick-and-mortar stores on their website, which could impact customers' choices to visit the store. For example, if a consumer wants to buy three units of a product in a store and online information indicates that three units are available, she may go to the store because there is sufficient inventory. However, she might also be concerned that there won't be sufficient stock available when she visits because of inventory inaccuracies. Our paper aims to understand how inventory disclosure on a website affects consumers' decisions to visit a store, and how retailers can adjust the displayed inventory to maximize their profit. We first conducted an empirical study to investigate the elements that influence customers' go-to-store decisions considering inventory inaccuracy. The study showed that the subjects' decision to go to the store is significantly affected by the difference between desired demand and displayed inventory, the magnitude of inventory error, and the cost of disappointment associated with a failed purchase. We then developed a formula to determine the optimal go-to-store threshold for a customer. The respondents' decisions deviate slightly from the optimal decisions, indicating that they make rational decisions but are influenced by personal factors. We also developed a formula to determine the optimal inventory level for displaying on the website, which will help retailers maximize their profits. This formula takes into account the customer's go-to-store threshold, display inventory, system inventory, inventory error, potential profit, complaint cost, and lost sale cost.

Partial Demand Information Exchange between a Seller and an Online Platform

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Many sellers offer products directly through their own sales channels and indirectly through online platforms. As such, the total demand information for a certain product resides in different sales channels, and each entity has partial information about the underlying demand uncertainty. As those uncertain demands prevent the sellers and the platform from making better pricing and commission rate decisions, respectively, capturing more information about such market dynamics to better forecast the demands is of importance for both parties. For instance, it is common for the seller to conduct market research to gauge seasonal trends and fluctuating consumer preferences toward certain types of products. At the same time, in order for the platform to set its commission rate, the platform is keen to learn more about the uncertain market. We analytically study the incentive to exchange partial demand information between a seller and a platform under a game theoretic framework. We examine under which conditions the seller and the online platform exchange their private information under two settings: 1) the platform's commission fee is exogenously given; hence, the platform is passive except for sharing his demand information, and 2) the commission fee is endogenized by the platform under information exchange. We present an equilibrium price and a commission rate for the seller and the platform, respectively. Our results show that if the commission fee is exogenous, the information exchange leads to a win-win for both players. When the platform decides on the commission rate, the information exchange benefits both players if the seller's information is precise. However, under a moderate precision of the platform's information, both players' incentive to exchange information reduces.

Performance Rankings and the Big-or-Small-Fish Dilemma

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In some jobs, workers must strategize between pursuing high-reward, low-probability (``big-fish'') payoffs or low-reward, high-probability (``small-fish'') payoffs. We demonstrate that implementing performance rankings in the workplace causes workers to strategize poorly, as they tend to overfocus on risky, big-fish outputs at the expense of reliable, small-fish outputs. In a field experiment involving 18 footwear stores and 230 sales agents, we equipped agents in some stores with smartwatches displaying live sales rankings of all co-workers. Additionally, we collected high-frequency data to observe how the salespeople interacted with customers, both with and without the rankings. We show that the rankings prompted agents to fixate on customers browsing for luxury items---or to push customers towards buying such goods---while neglecting bargain-hunting shoppers. As a result, sales of low-value items plummeted, causing storewide revenue to drop. This obsession with big-fish sales was pronounced among bottom-ranked agents, who attempted to make grandiose sales out of every customer to quickly ``resurrect'' themselves in the rankings.

Where Do Promotion Leaflets Work? – An Accidental Experiment

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At grocery retailers, weekly promotion leaflets continue to be widely used as a marketing instrument and means of communicating special offers. Furthermore, surveys indicate that 60% of German consumers read leaflets on a weekly basis and rely on them to decide where and what to buy. At the same time, paper prices are rising and customers become more aware of the environmental impact of distributing millions of brochures. Kaufland, a German-based discount supermarket chain, has a comparatively larger share of price-conscious customers and should be particularly sensitive to reduced advertisement. Despite some competitors reducing or discontinuing leaflet distribution, Kaufland currently has no plans to cut back on leaflet usage. Accidentally and without prior notice, we at Kaufland conducted a large scale "real-world experiment" for four weeks in December 2022 due to distribution issues. In this presentation, we provide insights into how we reacted to this problem, our containment efforts, and present the results of our ex post analysis. Specifically, we examine the impact of the sudden absence of leaflets on store performance and identify the customer and store groups that are most affected. Additionally, we highlight potential research questions that arise within the industry.

Understanding the impact of the adoption of digital ordering solutions on the ordering behavior of nanostores

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The traditional retail channel is undergoing a rapid digital transformation around the world. Accelerated by the Covid-19 pandemic, both large CPG (Consumer Packaged Goods) companies and startups have started to digitize the sales and distribution process for small and medium-sized retailers in developing countries. Goods in the traditional retail channel are typically distributed using the presales strategy or van sales strategy. The introduction of digital ordering solutions creates a third sales strategy, which does not require the visit of a sales agent. Moreover, it allows placing an order directly at a desired moment in time, increasing order flexibility and convenience for nanostores. Prior research studying the adoption of new sales channels in developed countries has shown that adding a new sales channel can increase the purchase frequency, can result in customers buying a larger number of items, and can result in customers returning more items, more frequently. In this paper, we collaborate with a Moroccan digital-enabled distributor. Using transactional data, we study the adoption and differential impact of different order collection methods on the ordering behavior of nanostores. More specifically, we focus on three order collection methods: the traditional sales agent, orders placed via a call center, and orders placed via an application. In this way, we provide insights into the impact of new sales channel introductions on ordering behavior in the traditional retail channel in developing countries.

The impact of online sales on perishable product waste in grocery retail

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The COVID-19 pandemic has simultaneously caused an increase in overall sales volumes in grocery retail and a shift from in-store to online shopping. We consider an omnichannel retailer who satisfies

demand from in-store and online consumers from the same in-store inventory. When satisfying online orders for perishable products of deteriorating quality over time, the retailer has to decide which units of inventory to select: should they select the oldest units in an attempt to reduce waste or the freshest units in order to maximize consumer satisfaction? We consider two possible fulfilment methods: First-Expired-First-Out (FEFO) and Last- Expired -First-Out (LEFO) with an age threshold beyond which units can no longer be used to satisfy online orders. The retailer maximizes expected profit which includes a disposal cost for unsold expired inventory and a staleness penalty, which is increasing in the average age of the units purchased by consumers. We study the impact of the optimized online demand policy on waste and find that the optimized age threshold and the waste are lower when the fulfilment method is FIFO. We also study the impact on waste of an increase in the proportion of online sales and find that, when the fulfilment method is LIFO, the two effects of the COVID-19 pandemic have opposite impact on waste. We also evaluate the value of eliciting product freshness preferences from online consumers as well as the benefits of pooling inventory across both streams of demand.

A simple estimator for food waste in retail.

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Eindhoven University of Technology

In this research project we develop a simple estimator for food waste in retail. The main goal is not to find the most accurate estimator, but rather to find an estimator which can be used to assist managers in both commercial and replenishment departments in retail companies and which is easy to understand. In this way the estimator can be the basis for discussions on how to make assortment and replenishment decisions like determining the assortment depth, the case pack size, the shelf life and the target product availability. The new estimator is based on the Fresh Stock Cover. The Fresh Stock Cover is an extension of the Fresh Case Cover (equal to the case pack size divided by the average demand during the shelf life), which is a rough indicator for the amount of waste. The Fresh Stock Cover is a more accurate estimator since it not only takes into account the impact of the case pack size but also the impact of the safety stock on the amount of waste. Simulation and regression are used to develop and test the new estimator for food waste.

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Store delivery planning for peak seasons in grocery retailing

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Public holidays present significant challenges for grocery retailers, leading to a loss of delivery days and increased pressure on the supply chain due to higher consumer demand and costumer traffic. Retailers address these challenges by adjusting their weekly delivery patterns, adding extra shifts at distribution centers, and/or advancing order quantities from peak weeks to earlier weeks. The paper takes an integrative perspective, considering the cost implications and capacity constraints of all relevant stages of the intern supply chain of a grocery retailer, i.e., the distribution centers, transportation system and stores. We formulate the problem as a mixed integer program (MIP) that aims to minimize overall costs by orchestrating the aforementioned adjustment options during peak seasons. We solve the MIP model with Gurobi for instances of a large European retail chain. The results achieved offer valuable insights into the added value of tailored planning approaches for non-standard delivery periods.

Managing Surplus Food in Grocery Retail

Lena Riesenegger, Alexander Hübner

Technical University of Munich

It is nearly impossible to decrease food waste in retail grocery stores to zero purely by optimizing planning processes. Customers have high requirements for freshness and availability, forcing store managers to provide full shelves throughout the day. Maintaining excess inventory to fulfill these needs leads to expiring or spoiling products before they can be sold. To prevent overstock near expiration from discarding, grocery retailers have two major options: discounting and donating. Discounts offer the possibility of still achieving a salvage value but also entail the risk that the products remain on the shelf. Furthermore, it might lead to cannibalization. At the same time, donating is an ethical way to reduce food waste, but it results in lost profits. Current procedures applied in grocery retail follow simple rules of thumb and do not allow adjustments to actual demand, product characteristics, and surplus quantity. The available literature, in turn, lacks approaches with multiple re-use options and either determines the best discounting strategy or donation time. We study the combination of these two options and simulate different scenarios in a store environment while demand is stochastic and dependent on price and product freshness. We develop a tailored solution approach to determine combined discount and donation policies to reduce food waste and maximize profit.

Joint shelf design and space planning problem with placement options and varying display orientation

Sandra Zajac

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In grocery retail, shelf space is a valuable asset in both food and non-food area wherefore it is essential to manage it efficiently. Literature focuses on the space planning in the food segment where products are traditionally placed on shelf boards. In the non-food area, however, some products are placed on shelf boards while others are hung on the perforated back wall of the shelf rack. For practical reasons,

the display orientation of the product may change if a product is placed on a shelf board instead of being hung up. In that case, the width and height of a product facing depends on the chosen placement type. In this talk, the joint shelf design and space planning problem with placement options and varying display orientation is introduced. The objective is to maximize the total profit taking space-elastic demand into account. The shelf design is determined by defining the required number and position of shelf boards and hence the space allocated to floor and hanging placements. For each listed product, space and placement type have to be assigned. Lastly, the products have to be positioned both vertically and horizontally on the shelf rack. In our talk, we present a linear mathematical program for this innovative problem. The problem is solved for both random test instances and a realistic case study and some insights are shared.

A bi-objective model for delivery pattern planning considering pollution

Sara Joosten, Alexander Hübner

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In grocery retail, scheduling the delivery of stores from a distribution center affects all logistics subsystems: warehousing, transportation and instore logistics. Therefore, the planning of repetitive delivery patterns has many advantages along the retail chain. In this study, we do not only consider the potential of total cost savings but also aim for reducing the greenhouse gas emission due to the corresponding transportation routes. We propose a novel bi-objective model to minimize total costs in the retail distribution subsystems as well as to minimize the greenhouse gas emissions due to transportation. Therefore, this model constitutes a main tool to shed light on the trade-off between minimizing total costs and minimizing greenhouse gas emission in last-mile delivery.

Scheduling store deliveries from an automated distribution center

Rob Broekmeulen

Eindhoven University of Technology

We consider a distribution center (DC) using order picking robots with an inflexible capacity to collect orders from grocery stores. Each store orders daily and gets its order delivered in the same time slot every day. The objective is to minimize the transportation costs, while respecting the required lead-time for the stores, the capacities of the DC and the delivery trucks. To solve the scheduling problem, we decomposed the problem in two subproblems. First, we cluster the stores into trips. This clustering results for each trip in a time window for leaving the DC, such that the delivery time windows of the stores in the trip are respected. The second subproblem sequences the clusters on the order picking robots, such that the timing and capacity constraints are respected. We applied the developed model to a case study of an European retailer and were able to produce feasible delivery schedules.

A reparametrization approach to improve store-level demand forecasts in retailing

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We propose a semiparametric store sales model with dynamic price effects that allows for both functional flexibility in own price response and generalized forms of heterogeneity. We assume a brand's sales to depend on its own price, prices of substitute brands, promotional activities, seasonality, as well as the brand's one-period lagged sales to separate price dynamics from other relevant consumer dynamics like stockpiling or customer holdover effects. Functional flexibility is accomplished in the main equation of the model via Bayesian P-splines in order to be able to capture complex nonlinearities in own price response. The flexibly estimated own price effect is further reparametrized via a second equation to accommodate store-specific own price effects, both with respect to unobserved cross-sectional store heterogeneity and price dynamics (time heterogeneity). The price dynamics are operationalized following managers' beliefs that a price change of at least 15 percent must be necessary to alter the purchasing behaviour of consumers. In an empirical study for a frequently purchased consumer good, we demonstrate that the new reparametrization approach can provide more accurate sales predictions compared to more parsimonious models that either ignore both store and time heterogeneity, or allow for cross-sectional heterogeneity only (and not for price dynamics). Importantly, ignoring price-change effects in the model would in particular lead to a strong underestimation of consumers' price sensitivity in weeks with substantial price cuts, and to an overestimation of their price sensitivity in weeks with prices at the upper bound of the observed price range.

A comparison of the Minimum Life On Receipt (MLOR) rule in centralized and decentralized inventory management systems

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The Minimum Life On Receipt (MLOR) rule specifies the maximum age a retailer is willing to receive food products from a supplier. In practice, this rule is usually fixed and imposed to avoid product expiration at the stores, based on the claim that consumers seek the freshest products. However, the rule imposes a burden on producers who have a limited time to produce and send the freshest products to retailers. Those products that do not commit to the MLOR rule at arrival have to be disposed, resulting in a surplus for the supplier. As a result, suppliers need to make small production batches, requiring many setup operations. Thus, the supplier needs to find a balance between production efficiency, product surplus and the service level. While in a Vendor Managed Inventory System the MLOR rule may be redundant, as the supplier bears the disposal costs of the retailer, it may be strategically set by the supplier. In the decentralized system, as each entity manages their own inventory, the MLOR rule can be seen as a quality standard. Even so, a flexible rule may be beneficial for both entities. This work analyses the MLOR rule impact on centralized and decentralized inventory management systems. Single and bilevel mathematical models are developed to represent the

centralized and decentralized problems, respectively. To deal with demand uncertainty, a robust optimization approach is embedded in both models. The trade-offs between production efficiency, waste generation and lost sales will be examined.

A heuristic for large-scale dynamic assortment planning problem

Lijue Lu, Mozart Menezes, Hamed Jalali

NEOMA Business School

Single-period dynamic assortment planning refers to the retailer's problem of deciding the set of products to offer and their initial inventory levels with stochastic demand and dynamic substitution. The goal of the retailer is to maximize its expected revenue subject to a capacity constraint on the total number of items offered. This problem is notoriously difficult to solve. We propose an efficient heuristic for this problem considering an online retailer that has hundreds of possible SKUs to choose from and has the possibility to stock thousand units in total. We impose no assumptions on preference lists and substitution patterns. Compared to the most recent heuristic, our algorithm is competitive in the average revenue obtained but it is significantly faster especially for large instances. We show that our approach performs well in a variety of settings.

Incorporating Promotional Effects in Sales Planning of Retail Industry Using Geometric Programming

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The growing popularity of promotions in boosting total profit has sparked retailers' interest. Managers in the FMCG industry attempt to jointly decide the schedule of promotion vehicles as well as the promotion prices of multiple items in the presence of several business requirements which complicates the decision-making process. This paper addresses the analytical problem of jointly optimizing the promotion prices and promotion vehicle schedules when the total demand is affected by several promotional effects. Using actual sales data from an online meal delivery company, we implement the proposed model into practice. In this study, we propose a general class of multiplicative demand function incorporating post-promotion deep effects, cross-item effects, promotion vehicle effects, and cross-term effects of promotion vehicles. Then, we formulate the problem of planning sales promotion simultaneously using price discounts and promotion vehicles. Our formulation considers several business rules as constraints. To optimally solve the proposed mixed-integer nonlinear program, we reformulate the problem as a convex optimization form by exploiting the multiplicative structure of the demand function, and the concept of geometric programming. Furthermore, to reduce the running time of the large-scale problems, we develop a Lagrangian decomposition algorithm, dividing the original model into a geometric program and an integer program. Generating realistic instances inspired by previous studies, we show that the Lagrangian decomposition algorithm reduces the running time from 8318 to 6 seconds for large-scale instances. Furthermore, employing actual sales data from a meal delivery company, we demonstrate that applying the convex promotion model allows the company to increase the profit by roughly 31% compared to not using either. The proposed optimization model serves as a decision-support lever for retailers, assisting them in automating the promotion planning process.

Keynote
22nd September

Assortment Curation in Online Marketplaces

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The majority of online sales worldwide take place in online marketplaces that connect sellers and buyers. The presence of numerous third-party sellers leads to a proliferation of options for each product, making it difficult for customers to choose between the available options. Online marketplaces adopt algorithmic tools to curate how the different options in an assortment are presented to customers. Using various examples, this talk will discuss some of the key differences between retailers and marketplaces, and different mechanisms for algorithmic assortment curation in marketplaces. We will do a deep dive on one specific tool for assortment curation (the "buybox") that algorithmically chooses one option to be presented prominently to customers, and we will explore consequences for customers, sellers, and the marketplace operator.

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Analyzing and modelling the customer willingness to wait for their online orders

Stefan Voigt, Markus Frank, Heinrich Kuhn

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Online retailing is characterized by ever shorter delivery times, which are usually accompanied by higher logistics costs and negative impacts on the environment. Longer order fulfillment times generally improve cost and ecoefficiency. The aim of the paper is twofold. It first presents the results of an online survey that analyze to what extent consumers are willing to accept a greater flexibility in the delivery of their online orders if they are granted cost advantages and/or information on the environmental impact of a home delivery. The results show that consumers are willing to make trade-offs in delivery time and underline previous findings on the relevance of informing consumers about the ecological impacts of the delivery. However, customers respond differently to incentives depending on their personal characteristics, e.g., gender, age, environmental awareness, and urgency of online ordering. Based on these empirical findings we formulate in the second part of the paper a new last-mile delivery problem that considers delivery costs and CO_2 emissions reductions by allowing some flexibility in the speed at which customer orders are served assuming a stochastic-dynamic order arrival process. Customers can choose from several delivery options when placing an order. We model the related static-deterministic problem as a mixed-integer linear program. We develop a dynamic solution method that solves prize collecting VRP subproblems. We show how a slower delivery option can lead to cost reductions without increasing the average waiting time significantly.

Food Waste in Grocery Retail: The Impact of Store Characteristics

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Technical University of Munich

Despite the well-established influence of certain characteristics of brick-and-mortar retail stores, like shelf-space and assortment planning or the size of the aisles, influencing customer behaviour, little is known about the effect of various store attributes on food waste. Additionally, food waste remains a severe sustainability issue for retailers since empirical evidence about its root causes is scarce, resulting in higher carbon emissions and increased costs due to expired products. Thus, our research uses proprietary transaction data and geo data from a European retail chain partner company to investigate the relationship between store-specific characteristics and in-store waste levels. The data covers 174 retail stores in urban and rural areas. By applying Double Machine Learning models for hypothesis testing, our initial findings indicate that store-specific characteristics such as grocery store density, city size and the number of households nearby, significantly impact food waste levels relative to its revenues. Our study fills a gap in literature on food waste in grocery retail by providing empirical evidence on the store characteristics that lead to higher food waste levels. Furthermore, this study creates awareness and offers novel managerial insights for practitioners considering food waste when planning strategic store locations.

Lowering the environmental impacts of fashion retail assortments: balancing profit maximization and impact minimization

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There is an increasing call for the fashion industry to lower its environmental impacts. However, many fashion brands argue that customers are unwilling to pay a premium for less impactful products, and consequently, have little incentives to switch to less impactful assortments. Those brands willing to change struggle to decide which level of attributes (e.g., recycled materials, increased durability, circularity) to offer, considering the uncertain customer willingness-to-pay (WTP) for those attributes and the often-costly investments required to offer them. A popular practice in the industry is to offer a few products with low(er) environmental impacts but retain the status quo for nearly all of the assortment. We use a choice-based conjoint (CBC) approach, in combination with a Becker-DeGroot-Marschak (BDM)-based incentive-aligned (IA) mechanism, to accurately characterize customers' WTP for specific attributes that can lower environmental impacts of sweatshirts. Moreover, our survey includes a manipulation to study the effect of prior education on respondents' WTP by showing half of the respondents a short video explaining how some attributes make a difference in lowering environmental impacts. The estimated WTP from the IA-CBC survey responses are used in an assortment and pricing optimization problem. We derive the optimal decisions when maximizing for profits versus minimizing for environmental impacts, revealing the trade-offs resulting from these contrasting objective functions. Our analyses provide insights into how brands can shift to a lower baseline of environmental impacts for the entire assortment, in addition to highlighting how educating customers can enable this switch.

Navigating the Future of Online Grocery: Labor, Pricing, and the E-commerce Paradox

Marshall Fisher, Santiago Gallino

Wharton School

This article explores the challenges and opportunities in the evolving landscape of online grocery retail. Through an in-depth study involving grocery retail managers and global executives, the article uncovers two primary challenges: staff recruitment and retention, and the struggle to make online operations profitable. The labor-intensive nature of online grocery exacerbates these challenges, while pricing strategies often fail to account for the additional labor involved. The article highlights a significant disconnect between the costs of online grocery operations and current pricing policies, raising questions about fairness and the need for subsidies. Despite the temporary surge during the COVID-19 pandemic, online grocery's market share remains modest, urging retailers to refocus efforts on physical stores and in-store labor. Prioritizing loyal in-store customers and investing in innovation can unlock benefits, drive profits, and adapt to changing consumer behaviors.

Store-Specific Assortments in the Presence of Product Constraints

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When allocating products to brick-and-mortar stores, retailers face product availability constraints which force them to balance product offerings across stores. Moreover, this allocation decision has to be made simultaneously for the entire store network. In contrast to prevalent assumption in the literature, it is not realistic to assume homogeneous product attractiveness across stores. Hence, we offer an integer programming model to allocate products to multiple stores in the network respecting the availability constraints. We show that this problem is NP-complete under the multinomial logit (MNL) type demand assumption. We develop a tractable continuous relaxation of the problem, which provides an upper bound, and most importantly yields to a unimodular constraint matrix. Consequently, we build a solution algorithm that finds the optimum of the relaxation in polynomial time, on the basis of which we provide near-optimal approximation algorithms for the integer programming model. We then apply our algorithms to mixed-MNL and nested-MNL type demand structures, and conduct extensive numerical analyses on their performances. We further provide a case study using extensive data from a large multinational apparel retailer where we first estimate the initial model parameters using an MNL regression, and run the approximation algorithms. We identify a significant potential for revenue increase by matching the right products with the right stores.

Inventory dynamics at the retailer - An economic and environmental analysis of packaging fresh produce

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The use of packaging materials for food products and the associated environmental impact has received increasing attention in public discourse over recent years. At the same time, packaging solutions provide functional properties that help to preserve fresh produce and protect food from external damage. Given these trade-offs, it can be very challenging for retailers to make the right decisions, lowering their environmental impact. This is further complicated by the complex nature of inventory dynamics in the case of perishable products, as multiple factors can impact food waste and the environmental impact at the retailer. This research proposes a simulation model to investigate the effect of packaging as well as a variety of other factors on profit, waste and the environmental impact of products. For this purpose, the environmental impacts of three different products and their corresponding packaging solutions were quantified using a life cycle approach, and a number of experiments considering different demand patterns, service level requirements, batch sizes and order policies were carried out. The findings of this research are manifold, highlighting the importance of considering inventory and packaging decisions within an integrated framework. Moreover, while the shelf life extension obtained from the use of packaging has clear economic benefits due to the resulting lower waste levels, the environmental impact varies depending on the considered products, packaging material and environmental indicator.

Multi-criteria optimization of inventory decisions in an omni-channel grocery setting

Martin Waitz, Lena Silbermayr

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Ordering the right quantity of goods is a challenging task for any business, but especially for a grocer as fresh products have only a very limited selling period. Both over- and understocking are negatively influencing profits. In addition, customers often ask for a very high availability of products, which results in grocers tending to overstock and subsequently producing large amounts of leftovers. Recently, countries have started forcing retailers to limit their food waste by introducing regulations to achieve more sustainable behavior. We investigate an omni-channel system in grocery retail for perishable products that offers a physical store and an online channel with separate inventory. We optimize ordering decisions for multiple substitutable newsvendor products considering multiple objectives: (i) profit, (ii) fraction of leftovers and (iii) fill rate. In case of stock-outs for their preferred product in the preferred channel, customers react by substituting with another product, switching the distribution channel or not buying anything, depending on their individual preferences. The modelling of customer behavior (i.e., demand for different products in both channels and individual product- and channel substitution rates) are derived from a conjoint-analysis conducted in 2022 in Vienna, Austria. Using the empirically revealed demands and substitution rates, we derive the efficiency frontier of the aforementioned conflicting objectives. Results reveal possible strategies to manage inventories considering the trade-offs between profit, waste and service level.

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Implications of dynamically adjusting perishable replenishment policies

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A recent study from united nations environmental protection highlights that around 360 million tons of food are wasted annually before reaching households worldwide. Managerial and technical solutions characterize waste prevention interventions in a supply chain. Managerial solutions reduce the time from production to consumption, whereas technical solutions extend product shelf-life. This work focuses on managerial solutions levered by inventory replenishment policies. While accounting for service level expectations and external uncertainties, this work presents a classification model to facilitate the dynamic adjustment of replenishment policies. To fit with perishability characteristics, age-dependent replenishment methods are considered. Replenishment methods are evaluated and classified based on a digital twin. The latter captures various configurations of forecasting accuracy, lead time, review period, and batch size for empirically investigated product groups with different shelf life and demand variability. Write-offs from expiration and lost sales are the primary modeled performance measures. Furthermore, this work elaborates on the adjustment criteria, i.e., internalities that burden the change of the replenishment method. Product movement data is extracted from two wholesalers with 16 distribution centers in Austria. Demand patterns are considered non-stationary, i.e., no prior statistical distribution fitting occurs. To test the generalizability of the classification model, we evaluate it using various product groups. The contribution of this work is threefold: (i) it explores implications of dynamically adjusting perishable inventory policies, (ii) it presents an inventory decision support framework for grocery supply chains, and (iii) it derives managerial insights and implications to facilitate wasteless grocery operations in the future.

Dynamic pricing for multiple substitute perishable products

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Dynamic pricing is a widely used strategy to fine-tune the prices of goods and services subject to changing and selective consumer behavior. Notably, for grocery retailers, the reduction of prices of perishable foods over their shelf life creates a strong incentive for consumers to buy items close to their expiration date and thus prevent such products from spoiling. Despite the growing work undertaken to formulate such discount policies, there has been a consistent emphasis on building them on a product-by-product basis, meaning that cannibalization effects between the sales of similar products and the differentiation of discounts according to the characteristics of the different products have been overlooked. Aiming to create a holistic policy that maximizes the retailer's total profit and minimizes food waste at the store level, this paper addresses the design of an integrated methodology for dynamic multi-product pricing. Based on the sales history of a yogurt category of a European retailer, we first train a demand forecasting algorithm that predicts the consumption pattern of each product. Then, we incorporate it into a reinforcement learning algorithm (Proximal Policy Optimization algorithm) that simultaneously determines the magnitude and timing of the discounts for each product with different shelf life and prices. Finally, we compare the obtained policies using different reward functions to obtain a more robust approach. With this study, we strive to provide a generalizable procedure and reform current perishable product management systems.

Cumulative Quantile Loss for the Multi-Period Newsvendor

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The newsvendor problem seeks the ideal order quantity for a single period, such as a day in the case of newspapers or a season for fashion products. Classical solution approaches compute the optimal service level, or newsvendor quantile, by considering the costs of insufficient (underage) and excessive (overage) inventory and sampling the corresponding order quantity from a known demand distribution. Recent research on the data-driven newsvendor problem treats the demand distribution as uncertain, approximating it through historical data and covariate features for a single period. However, retailers face varying replenishment periods in periodic review order-up-to (T, S) policies for different products based on their perishability, leading to a multi-product, multi-period inventory problem. This contribution introduces a problem-specific cumulative quantile loss function to find data-driven optimal order quantities in such realistic problem settings using recurrent and transformer-based neural network architectures. Thereby, we propose an approach that circumvents the otherwise infeasible problem of aggregating non-normally distributed daily forecasts. We benchmark the resulting inventory decisions against conventional approaches in three real-world retail datasets using quantile loss and inventory metrics. We discuss practical implications and explore the potential for extending our method to accommodate datadriven continuous review inventory policies.

Leveraging Association Rule Mining and Multi-Metric Analysis for High-Performance SKU Identification in Retail Operations

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Due to increasing competition, retailers operating in the grocery and FMCG domains are faced with the challenging task of maintaining long-term profitability. One of the most crucial strategic decision-making aspects for these retailers is to maintain a high-performance assortment plan for each format. Consequently, it is essential for a retailer to identify the most favorable stock-keeping units (SKUs) that contribute to an optimal profitability scheme. The objective of this study is to develop an innovative and data-driven methodology that utilizes unsupervised machine-learning techniques to identify key SKUs that are vital for the success of retail operations. The proposed methodology initially employs the Association Rule Mining algorithm to analyze transaction data, facilitating the discovery of significant relationships between products. Subsequently, a multi-metric index is constructed, which represents a weighted average of various key performance indicators (KPIs) that retailers use to assess the sales volume trends of the SKUs. This index is used to rank distinct products based on the rules established in the previous section.To evaluate the effectiveness of the proposed methodology, a large-scale dataset from a national supermarket chain in Turkey is utilized. The product rankings obtained through this methodology are then employed to identify high-performance goods. This approach is characterized by its flexibility and adaptability, as it integrates association rule mining and multi-metric analysis. As a result, it provides a novel and robust strategy for the identification of SKUs, which can assist retail managers in optimizing their product portfolio.

The value of in-store services in omnichannel retailing

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This study examines the impact of in-store services, particularly buy-online-pickup-in-store (BOPS) and return-to-store services, on additional purchases, which can be due to new product exploration or exchange behavior. By considering various consumer decisions during the ordering and post-order stages, eight distinct groups of purchases are identified. A multiple-treatment methodology is employed to measure the net value of additional spending obtained by deducting returns from additional consumer spending. The findings reveal that offering in-store services, especially BOPS service, enhances customer exploration of a broader range of product categories. In-store purchases account for the majority of additional spending on new products, indicating the importance of physical stores in facilitating product exploration. Furthermore, while using return-to-store services, customers tend to spend more in-store on the same categories as their initial purchase, highlighting the role of physical stores in converting returns into exchanges and retaining customers.

Online Channel Planning for Omnichannel Grocery Retailing: From Customer Understanding to Operational Decisions

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While many traditional retailers have embraced e-commerce in line with the online sales growth tendency, profit margins of this channel are not keeping up. We study the strategic online channel planning of a retailer that runs an online operation with home delivery from a network of Brick-and-Mortar stores. Decisions regarding the online channel namely, which stores to use for online fulfillment, the delivery fee, and the online assortment, affect both retailers' costs and customers' demand. The main objective is to maximize profit across both online and offline channels, ensuring the profitability of the online channel does not come at the expense of the cannibalization of offline sales. Using transactional data, we estimate a logit model to model customers' choice between buying online or offline. The findings confirm that not only the channel's attributes, namely the distance to physical stores, the delivery fee, and the assortment, influence customers' decisions, but also the size of the basket. We use the parametrized choice model to derive the frequency of orders and customers' share of wallet, as a function of the online channel attributes. We resort to a continuous approximation for estimating delivery costs and model the profit maximization problem as a continuous nonlinear problem. In a series of numerical studies, we draw managerial insights for retailers seeking to improve their omnichannel profitability and market share.

Hybrid Segmentation of Customers in FMCG

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The relationship between firms and customers is not a one-way road for a while now. Once the passive recipients of the value, customers have become the commodity. Customer value management's importance increases with the competition. Studies show that retaining existing customers is more profitable than attracting new customers. In this study, we propose a customer behavior analysis model to predict the next segment of a customer. Movements between the segments can suggest the behavior of a customer, such as predicting churn. Using static and dynamic features, we model the customer behavior. First, we cluster customers with static features to establish segments. Then we analyze customer behavior with dynamic features such as purchase amount, and the last purchase date. A dynamic model is then trained for the customer's life cycle to predict the next segment. Each period the model returns a list of customers flagged with upward or downward movement. We use this list as input for a resource allocation model to allocate promotional resources to customers. As a result we aim to maximize the retention of valuable customers while minimizing the cost of promotion to customers determined to churn.

Individualized substitution suggestions in online grocery retailing

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Problem definition: Presenting online retail customers with relevant individualized substitution suggestions when an item is forecasted to be out-of-stock (OOS) is a challenging problem, as illustrated by anecdotal evidence published in The Wall Street Journal (Bartholomew, 2022) or publicly reported by Walmart (Venkatesan, 2021). We investigate how to provide improved individualized substitution suggestions by employing state-of-the-art choice models and propose a novel approach to improve model learning and deal with the no-purchase prediction. Academic/practical relevance: Online retailers can obtain both top-line and bottom-line benefits from presenting customers with individualized substitution alternatives when an ordered item is forecasted to be OOS at the time the order must be prepared to be delivered. First, when a customer chooses a replacement, the online retailer ensures a sale occurs if the first-choice item is OOS but the second-choice item is in-stock. Second, it avoids the loss of customer goodwill and the costs associated with complaints and reimbursements due to a poor substitution performed without customer input. Finally, it can also obtain efficiency gains during order picking by avoiding the need for the picker to call the customer to identify a proper substitution. In collaboration with a partner online retail platform in Europe, we demonstrate the value of our refined model to improve their operations. Methodology: Our model extends the DAG-based partial order choice model proposed by Jagabathula, & Vulcano (2018) and later extended by Jagabathula, Mitrofanov & Vulcano (2022) to improve how it incorporates and predicts the no-purchase option, which — differently from what occurs in their setting — we observe when a customer decides not to pick a substitute. In addition, our proposed methodology incorporates suggestions to improve how the model learns from additional, fresh data, as customers make new purchases, are offered substitution alternatives, and decide on picking a replacement item or none. Results: Numerical experiments based on our partner's data show our refined model can accurately

predict the customers' choice from those offered by the partner firm in 53.1% of the cases. These results substantiate a field experiment that will be conducted during April 2023 to assess the benefits of the model and compare its performance to both the partner's incumbent machine learning model and the second-best model from the numerical experiments results, as benchmarks. Managerial implications: We expect our field experiment results will show evidence of the benefits of our proposed refined model and its impact on customers' substitution selection rate and purchase frequency, on the retailer's revenue, and on operational benefits associated with the reduction in the number of calls made by pickers.

When is the Next Order? Nowcasting Channel Inventories with Point-of-Sales Data to Predict the Timing of Retail Orders

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Slow-moving goods are common in many retail settings and occupy a vast part of retail shelves. Since stores sell these products irregularly and in small quantities, the replenishing distribution center may only place batched orders with manufacturers every few weeks. While order quantities are often fixed, the challenge for manufacturers facing such intermittent demand is to forecast the order timing. In this paper, we explore the value of Point-of-Sales (PoS) data to improve a food manufacturer's order timing forecast for slow-moving goods. We propose an inventory modeling approach that uses the last order, PoS data from retail stores, and the expected lead time demand to estimate the retailer's channel inventory. With this dynamic estimate, we can 'nowcast' the retailer's inventory and predict his next order. To illustrate our methodology, we first conduct an experimental simulation and compare our results to Croston's exponential smoothing and a moving average model. Next, we validate our approach with empirical data from a small German food manufacturer that serves a grocery retailer with a central distribution center and 53 hypermarkets. We find that our approach can improve the accuracy of order-timing predictions by up to 35 %. We overcome a shrinkage-induced bias by incorporating an inventory correction factor. Our approach describes a new way of utilizing PoS data in multi-layered distribution networks and can complement established forecasting methods such as Croston. Particular applications arise when the order history is short (e.g., product launch) or not representative of future demand (e.g., during COVID-19).