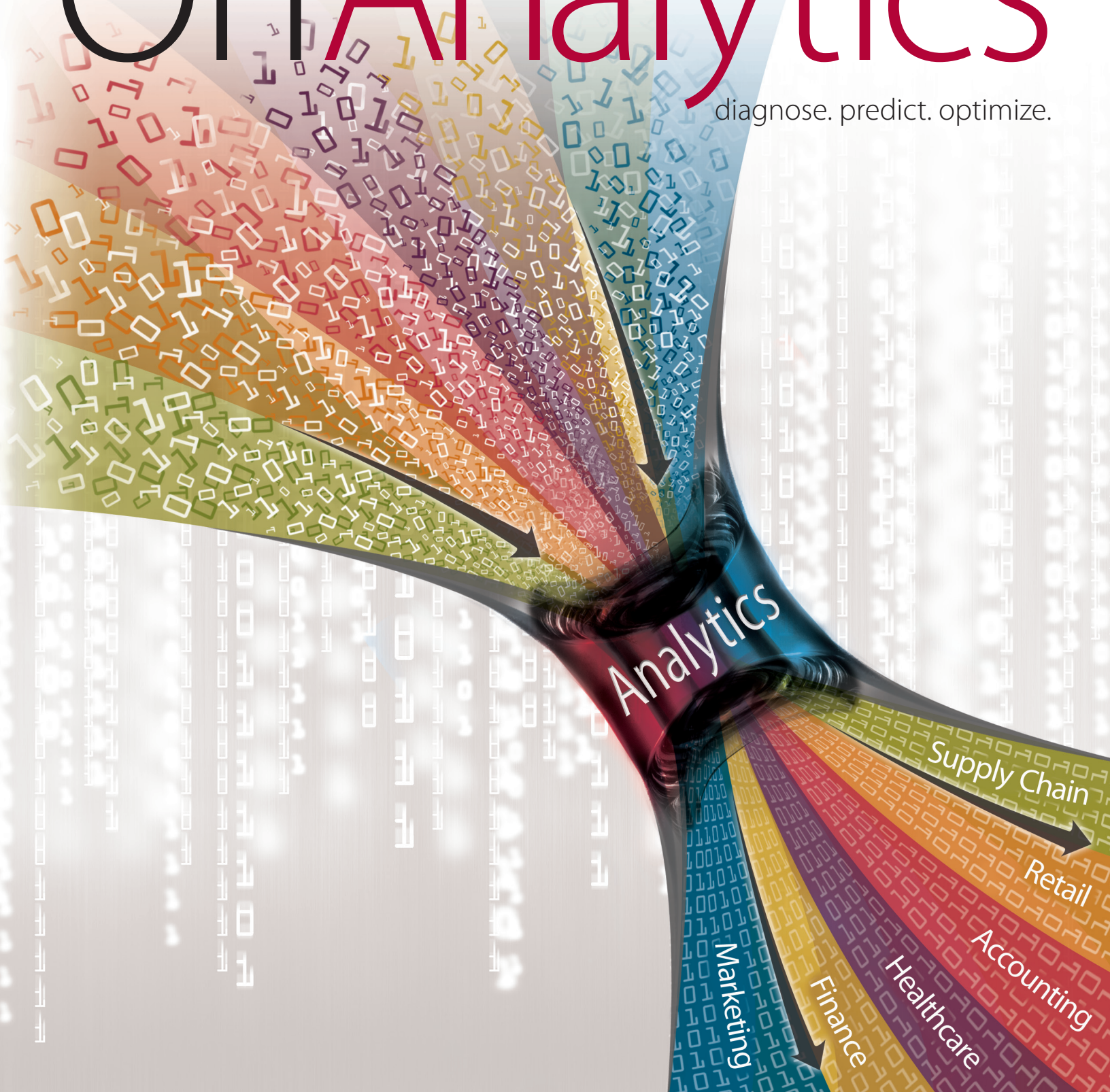**KELLEY SCHOOL OF BUSINESS**

Spring 2012

OnAnalytics

diagnose. predict. optimize.

Analytics

Supply Chain

Retail

Accounting

Healthcare

Finance

Marketing

Welcome from the Dean

Why Now, Why at Kelley?

Global competition and the quest to accomplish more with less make it imperative for businesses to continually innovate. The digital revolution has enabled companies to achieve high levels of productivity and control over the past several decades and the use of information systems, the internet, and other digital tools has enabled higher efficiency in processes and better, more accurate reporting of performance. The emergence of low cost storage and retrieval capabilities has created valuable information resources with a plethora of data about customers, inventories, business operations, product performance, prices, sales, advertising campaigns, employees, supply chains – indeed, virtually every aspect of the business. Given this, businesses around the world are looking at ways to leverage these data to create business value and they are looking at analytics to help them do this.

The area of analytical decision making using models has been in existence since the late 1940s with the development of operations research as a discipline. The evolution of large-scale databases and data warehouses provided corporations with core analytics capabilities that can support the development of performance management and reporting, dashboards, balanced scorecards, etc. The combination of these two areas with traditional statistical tools enables the development of predictive models and intelligent decision making and is broadly defined as business analytics. It's no longer about what people did, it's about what people are going to do. It's how numbers are used to shape business plans, converting data to business value using predictive modeling and forecasting.

Business Analytics is emerging as a key area for organizations to leverage data for competitive advantage. Companies around the world are, as a result, embarking on a plan to develop the full potential of business analytics. This, in turn, has created demand for professionals who have an understanding of analytical methods that can be combined with technical and business talent to implement business change. It has also created interest in the research our faculty, across nearly every business discipline and industry, already conducts at the Kelley School.

The Kelley Institute for Business Analytics at Indiana University was established to serve the interests of our students, faculty, and external corporate partners by providing thought leadership, research opportunities, teaching materials and programs, and linkages to ideas and information in this important and exciting emerging field. I invite you to learn more about our institute and investigate how our faculty research is impacting virtually all areas of business organizations - from marketing to human resources, from supply chain to finance and risk management.

Sincerely,

Daniel C. Smith

Daniel C. Smith
Dean of the Kelley School of Business
Professor of Marketing
Clare W. Barker Chair

From the Editors

Welcome to the first issue of *OnAnalytics*, a new publication by the Kelley Institute for Business Analytics (IBA) which features applied research by the faculty at the Kelley School. While analytical based decision making has always been an element of successful management, in recent years advances in computing and information technology have made it possible for modern businesses and other organizations to deal with a complex and rapidly changing environment in ways that were only imagined just a few years ago. Business analytics enables managers to explore historical relationships in data more deeply and to detect and visualize trends of what happened in the past. More importantly, business analytics is now being used to explore multiple possibilities with simulations, to predict what is most likely to occur, and to guide managers toward optimal decisions.

Kelley School faculty employ analytics in a wide variety of contexts and *OnAnalytics* is designed to communicate this research to a broad audience of business leaders, students, consultants and other academics interested in analytics. Each article selected for this inaugural issue illustrates how analytics was used to better understand and improve decision capabilities in a variety of contexts:

- Deciding on the location of a major new manufacturing operation;
- Using analytics to manage retail category assortment;
- Detecting earnings manipulation in publicly traded corporations;
- Optimizing the scheduling of nursing professionals in a hospital setting;
- Examining the effects of defined-benefits pension plans on the capital structure of corporations; and,
- Assessing the relationships between market share and brand loyalty for consumer package goods.

These articles were selected to provide examples of how analytics can be used to reduce costs in hospital, retail, and manufacturing settings, enhance profits through improved brand management, and manage organizational risk associated with accounting manipulations.

The research briefs included focus on the key capabilities associated with business analytics[1]:

Decision capabilities. Business analytics can support cost reduction, profit enhancement, and risk management initiatives that are associated with all types of organizational assets: human, financial, physical, brand, intellectual property and information technology.

Information capabilities. Business analytics is based first and foremost on the collection of raw data in the form of text, numbers, images, and audio recordings from sources both external and internal to the organization.

Analytic capabilities. Business analytics employs a wide range of techniques, methods, and models from information systems, statistics, and operations research to transform information into insights.

We hope you enjoy *OnAnalytics*!

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1 "Gartner's Business Analytics Framework," Neil Chandler, Bill Hostmann, Nigel Rayner, and Gareth Herschel, 2011.

Q & A
with
Tom
Preston

Tom Preston leads the Booz Allen Technology Team ERP Advisory Services capabilities. He provides executive level financial management consulting for clients seeking to improve their financial management and systems capabilities and those planning for and implementing commercial off-the-shelf (COTS) financial and resource management systems. He regularly consults with and briefs senior executives across the government. Mr. Preston is the executive sponsor of the Booz Allen/ Kelley School ERP and Business Analytics certificate programs.

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1. How is business analytics being employed in the federal government?

In the federal government business analytics is being tied to financial data, financial operations, and supply chain operations. With the new spending limits and potentially automatic spending cuts, doing more with less is taking on a new reality and leveraging business analytics will be the key to make this successful. Business analytics is being applied at many different levels in the government. For example, the Vice Chief of Naval Operations needs business analytics to assess the overall fleet readiness while the base commander of SPAWAR (Space and Naval Warfare Systems Command) at San Diego needs a different type of analytics to manage his multibillion-dollar operational budget. As the business analytics capabilities grow, people are beginning to tie different data sources together to answer new questions. For example, you can now tie financial data with procurement and supply chain data with social media information and then map it geospatially. Organizations are beginning to think about new questions they can ask and then determine what data needs to be brought together.

2. What are the biggest challenges associated with applications of analytics in the federal government?

We need to get the business analytics tools as part of the mainstream: scope a problem, gather data, perform analysis, and develop compelling and meaningful recommendations. This will drive the adoption of analytics across the federal government. As data is the fuel for analytics, it is also the weakest link. Across the federal government, there are significant issues with data governance, data integration, and overall ownership of systems, data, and processes. While you can't boil the ocean, steps must be taken both within the organization and across multiple organizations to address this issue. If the data is suspect, any analysis related to the data will also be suspect.

3. What analytics trends do you see in the near future?

Lately, the federal government is increasingly seeking more visual-based analysis and wants to employ more readily available data to feed their analysis. Widespread adoption is based on understanding the tools and believing in the data. Sophisticated techniques will be effective if people do not see them as a black box process but rather understand at a high level the concepts and application of the processes.

4. For professionals that want to become more involved with analytics applications, what advice do you have regarding skills and experiences that would be most helpful?

There is plethora of applications and tools that professionals can focus on. You need to get excited about the data and understand what it's telling you, regardless of the tool. I would suggest that one take advantage of all the free information and training on the web around analytics applications. We are seeing huge growth in analytics-related opportunities and tools. Develop hands on expertise with at least one established toolset and experiment with some of the toolsets highlighted in the IBA wiki. Developing new ways to communicate, model and solve client challenges is the ultimate outcome.

OnAnalytics

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'Spackling' as an Alternative to Offshore Production

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"This study came about after I went to a conference on mass customization and met the head of operations for Timbuk2, a messenger bag company. He was thinking of moving some of his production from San Francisco to the Far East. We designed the study to help him quantify that decision and determine whether it was the best way to save money."

The past decade has witnessed a significant shift in manufacturing from the U.S. (and other western nations) to the Far East, in search of less-expensive, efficient manufacturing. For U.S. manufacturers that produce both make-to-order (MTO) and make-to-stock (MTS) items, a typical strategy might involve a (more expensive) flexible domestic factory creating the custom products and a (less expensive) overseas facility to make the standard variants. While this setup might intuitively appear to save money by minimizing the cost of the standard items, a more profitable approach for some companies might be to maximize use of the flexible domestic factory to also produce the standard items. By creating an analytical model and applying it to a real-world test case, the researchers show how some manufacturers can actually save money by foregoing offshore production in favor of an approach they refer to as "spackling," wherein the flexible factory's unused production capacity is filled in with production of standard-issue items. They also analyze a third strategy – "layered spackling" – that incorporates offshore production but also makes use of the flexible factory's downtime between custom orders.

Statement of the Problem

For many companies that offer MTO products, customers' expected turnaround time makes domestic production necessary, as shipping costs mitigate any labor savings achieved by sourcing products overseas. With MTS versions of these products, however,

products are made in advance of purchase, allowing slower, low-cost shipping to preserve the cost savings of overseas labor. Thus the traditional approach for this type of company has been to maintain two facilities, each with a different focus: a flexible, domestic plant to produce MTO items and an efficient, overseas plant to produce standard items.

This "focus" strategy, however, has its own inefficiencies. One is the unused capacity of the flexible plant, which sits idle after orders are filled. Another is the cost of setting up two separate plants to manufacture the same products. A third risk associated with the efficient plant is of that of inventory (over- or underproduction), whereas the flexible plant could produce stock to order.

With this study, motivated by a scenario at a messenger-bag company, Timbuk2, the researchers set out to create an assessment tool that would help the company determine whether a second plant was needed and whether greater cost savings could be achieved by spackling production either with or without the use of offshore production. They applied the model to assess whether the San Francisco-based company would benefit from moving its MTS production overseas.

Data Sources Used

The data for the empirical analysis of the model came from Timbuk2's financial records, which the company shared with the researchers.

Analytic Techniques

The researchers constructed a stylized, single-period model of costs based on a fixed expense for plant capacity, variable production expenses, costs associated with underage and overage (where appropriate), costs of opening a second plant, and a "lost-focus premium" for operating a multipurpose plant in the case of spackling.

The optimal solution for the focus case appears as a closed-form (newsvendor) explicit function, while the optimal solutions for the spackling cases are implicit functions that are easily solved numerically. The resultant equations can be used to determine optimal capacities for standard and custom products for the focus, pure spackling, or layered spackling strategies and the corresponding expected costs. The expected costs for each strategy can then allow a comparison that reveals the lowest-cost strategy.

Using the data provided by Timbuk2, the researchers performed sensitivity analyses of the relative merits of each strategy by graphing the expected costs for each strategy versus each of the following: unit production cost, the effect of cost efficiencies from focus, the effect of the mix of custom and standard demand, and the effect of opening costs for the efficient facility. These plots allowed the researchers to determine the thresholds at which the different strategies would emerge as the most cost effective. They followed up with a sensitivity analysis of the identified custom-standard mix threshold to test whether the threshold was robust to unit costs, horizon lengths, and demand distributions.

Results

The results of the Timbuk2 analysis revealed that with the then-current mix of custom and standard orders, layered spackling was the most cost-effective strategy so long as unit variable costs did not increase from their current level of $14 to more than $18.[1] Considering the fixed labor costs of production using flexible capacity, the focus strategy would be preferable to the layered spackling strategy only if the labor costs per unit was $3.50 or less, while the current rate was $6. Interestingly, the researchers found that an increase in custom demand, which Timbuk2 anticipated, could significantly shift the balance toward pure spackling. Layered spackling was optimal under the current mix of demand of 20% custom; however, a mix of 50% custom demand would make pure spackling most cost effective.

The sensitivity analysis revealed that the demand mix threshold was robust to the unit cost of efficient production and to the horizon length considered. The researchers note that the greater the fluctuation in custom demand, the more cost effective the pure spackling strategy becomes. Variability in standard demand, however, causes only a slight increase in the threshold at which pure spackling surpasses layered spackling in cost effectiveness.

Business Implications

The Timbuk2 data indicates that if the company anticipates reaching 50% custom orders, cost savings may be best achieved by maintaining a pure spackling strategy rather than opening an efficient facility overseas. Even if custom demand does not reach these thresholds, at the current level of unit costs a layered-spackling strategy is preferable to a focus strategy that fails to take advantage of the "free flexible capacity" provided by the flexible factory's downtime.

This analysis has important implications for companies that produce both MTO and MTS products. The Timbuk2 case demonstrates that the traditional focus strategy of using a flexible domestic factory for custom products and an efficient overseas factory for standard products does not always result in cost savings. While the benefits of employing efficient (overseas) production are often visible and easy to calculate, a more in-depth analysis highlights some of the more subtle benefits arising from better coordination of use of efficient capacity in conjunction with flexible capacity. In other words, if unaware of the benefits of spackling, senior management could be falsely attracted by a phantom savings of lower unit costs under efficient production, and unwisely choose a focus strategy with suboptimal results.

This study serves as an example of the benefits of using analytics to model projected expenses and guide sound business decisions. By systematically addressing a number of factors involved in operating a second facility, this model overturns some commonly held assumptions about the cost savings of moving production of standard items overseas.

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1 Material costs were considered variable, while labor costs—which were in the short term less linked to production levels—were considered to be fixed.

Kyle D. Cattani, Ely Dahan, Glen M. Schmidt, "Lowest Cost May Not Lower Total Cost: Using 'Spackling' to Smooth Mass-Customized Production," *Production and Operations Management*, 19(5), pages 531–545, 2010.

A Recipe for Retail Assortment

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As the variety of products on the market continues to expand, retailers are faced with difficult decisions about their stock assortments. The fear of failing to stock customers' preferred brands can cause retailers to fill their shelves with an overwhelming assortment of products, a potentially costly strategy that doesn't always yield returns. Taking into account the heterogeneity of customer preferences, customer's willingness to substitute a second or third choice if their first choice is unavailable, and the dissatisfaction customers experience when they cannot purchase their preferred brands, the researchers propose and test a model for retail category assortment that allows managers to balance customer satisfaction with short-term profit.

Statement of the Problem

Retailers face assortment decisions for each category of goods, balancing the attempt to stock as many preferred brands as possible with the constraints of limited shelf space and the administrative and warehouse costs of carrying each item. In order to make informed assortment decisions, managers need a means of quantifying the relative merit of customer satisfaction and cost savings. The researchers propose a systematic assessment tool that takes into account both the possibility of substitution and the "disutility" incurred when customers cannot purchase their preferred items.

Data Sources Used

In order to test the optimization model, the researchers used household scanner panel data available from the AC Nielsen Company, collected from supermarkets in a specified city. The researchers selected the category of canned tuna for the case study. Purchasing data was provided for 1097 households and the eight largest canned-tuna brands, which collectively represented 90% of purchases in the category. In addition to purchasing information, the data provided information on prices, in-store displays, and feature advertising.

Analytic Techniques

The assortment question is framed as an integer programming problem. The researchers used a multinomial probit model to serve as a discrete choice framework for modeling demand. To capture customer heterogeneity, they place a distributional assumption on the utility function parameters. They employ a diagonal covariance structure to simplify the calculation of choice probabilities.

Although the customer demand model contains both a deterministic and a stochastic component of utility, the researchers focus exclusively on the deterministic component when applying the model to avoid confounding the impact of heterogeneity and probabilistic choice on the assortment decision.

The researchers begin with a basic formulation for assortments and stocking that incorporates profits and disutility. They create a measurement of disutility equal to the reduction in price necessary to make the customer indifferent between the preferred and less-preferred items. The model also addresses the likelihood that certain products serve as "traffic generators" that have a high impact on store choice. Because scanner data does not capture no-purchase decisions, the researchers offer a formulation to reflect this disutility.

The problem has an embedded uncapacitated plant location model, which has been shown to be NP-hard. For the small problem sizes of interest to this study, the solution is easily obtained, but larger-scale models will call for heuristics.

The assortment decision will be affected by the depth of no-purchase (d, number of substitutions the customer is willing to make before choosing not to purchase) and the weight the retailer places on profit and customer disutility.

For the computational study, the researchers used the scanner data to obtain Bayesian posterior estimates of the model parameters and calculate coefficients of price, display, and feature. They created a cross-classification table of first and second preference brands for the sample, and computed optimal assortments at both $d = 2$ (substituting only if second choice was available) and $d = 3$ (substituting if second or third choice was available).

The linear programming package LINDO was used to solve the models. The program, written in C, allows the decision maker to vary the depth of no-purchase and weight placed on consumer disutility and profit. The researchers solved 80 instances of the problem at varying weights of disutility vs. profit (from 0.0 to 0.99).

An additional three-product, three-customer data set was also evaluated to provide a counterexample of the computational study's results.

Results

The researchers first solved the model with the canned tuna data with $d = 2$ (one substitution) and fixed costs set at $1 per brand per re-stocking period. (Retail contribution margins were assumed to be 30% of purchase price.) The results vary according to the relative weight assigned to customer utility and profit: a "myopic retailer" concerned only with immediate profit will benefit most from carrying only four items – brands numbered 1, 3, 5, and 7 – while those who weight disutility at 0.3 or above would carry brands 1, 3, 4, 5, 7, and 8. Brands 2 and 6 were dropped because they did not appear among the preferences revealed by the scanner data.

Interestingly, as the weight on disutility increases, the optimal assortment first grows to include brand 4 and then shrinks again – dropping 1, 4, and 5 but adding 8 – before adding back in first 4, then 5, and eventually 1 into the assortment. Also noteworthy are the significant drops in disutility accompanied by comparatively minimal drops in profit: changing the assortment from 1,3,4,5,7 to 3,7,8 causes a drop from 34.17 to 32.64 in profit but yields a decrease in disutility from 69.62 to 20.38.

Predictably, higher fixed costs result in smaller assortments when disutility is given less weight in relation to profit. With the fixed costs set at $5 per item per stocking period, a myopic retailer need carry only two items – 3 and 7 – and the weight placed on disutility would need to reach 0.7 in order to merit the full assortment of the six items identified among customer preferences. In this case, the number of items in the assortment only increases with increas-

ing weight on disutility. Like the first case, however, a steep drop in utility can be achieved with a minimal loss in terms of profit: adding item 8 to the assortment of 3 and 7 yields a drop from 95.92 to 20.38 in disutility, while the profit decrease is only from 22.72 to 20.64.

Analysis of the $d = 3$ case (substituting second or third preference) yielded similar results. Both profits and disutility were at least as large as for $d = 2$, and the optimal assortment changed non-monotonically (increasing then decreasing in size) with fixed costs set at $1 and monotonically (increasing) with fixed costs set at $5.

The three-product, three-customer instance revealed that the patterns observed in the computational study did not hold, indicating the difficulty of predicting the structure of optimal assortment.

Business Implications

This model can be used to assist retailers in determining optimal assortments within a product category, allowing retailers to weight their inputs to reflect the relative importance they place on customer satisfaction in relation to immediate profits.

Retailers should take note that, surprisingly, an incremental increase in the weight placed on customer satisfaction does not always yield a larger optimal assortment. Taking into account customers' willingness to (reluctantly) substitute for a less-preferred brand creates a more subtle and complex picture of optimal selection.

Additionally, the computational study reveals that a relatively small decrease in profits can yield a large drop in disutility, suggesting that a long-term strategy of customer retention may require only a small loss in immediate profits.

This study serves as an example of how analytics can be used not only to model profit maximization, but also to develop a means of addressing retailers' interest in satisfying customers. Such analyses help to guide sound businesses decisions over both the short and long-term horizons.

Ravi Anupindi, Sachin Gupta and M.A. Venkataramanan, "Managing Variety on the Retail Shelf: Using Household Scanner Panel Data to Rationalize Assortments," Retail Supply Chain Management, N. Agarwal and S.A. Smith (ed.), pages 155–182, 2009.

Fraud by the Numbers

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In this study the researcher created and tested a model to detect earnings manipulation using publicly available accounting data. Now known as the Beneish Model, the formula is widely employed by investors, lenders, and auditors to profile potential manipulators, assess companies' financial health, and determine the likelihood of fraud.

Statement of the Problem

When earnings manipulation is discovered, manipulating companies typically lose 40 percent of their market value. Developing a means of assessing the likelihood of financial statement fraud can help protect investors from the dramatic losses associated with earnings manipulation detection by the SEC.

Data Sources Used

Beneish used accounting data available from the financial statement service COMPUSTAT. A single annual report (Form 10-K) from each company provided two consecutive years of accounting data from the period between 1982 and 1992, allowing Beneish to compare data in the year manipulation began to data from the year prior. He identified manipulators through SEC records and media mentions, verifying that these companies were indeed required to restate earnings to comply with Generally Accepted Accounting Principles. This gave him a sample of 74 companies, which he matched to 2,332 controls from the same industries and years.

Analytic Techniques

Beneish examined eight variables, comparing the year of manipulation to the year prior to form a set of indices:

1. *Day's sales in receivables index (DRSI).* An increased ratio of receivables to sales could indicate revenue inflation.
2. *Gross margin index (GMI).* Deteriorating gross margins could be a sign of poor financial health, which could predispose firms to manipulate earnings.
3. *Asset quality index (AQI).* An increased tendency to capitalize expenses could indicate distorted costs records.
4. *Sales growth index (SGI).* Companies experiencing rapid growth may be predisposed to manipulate earnings in order to avoid the perception that growth has slowed.
5. *Depreciation index (DEPI).* Declining rates of depreciation could indicate a fraudulent assessment of assets' value.
6. *Sales, general, and administrative expenses index (SGAI).* An increase in the cost of operations could predispose companies to manipulate earnings.
7. *Leverage index (LEVI).* An increase in debt relative to assets could predispose companies to manipulate earnings.
8. *Total accruals to total assets (TATA).* An increase in the difference between accrual-based reported earnings and actual cash earnings could reflect inflated profits.

Note that DRSI, AQI, DEPI, and TATA are red flags that capture possible distortions resulting from current fraud, whereas GMI, SGI, SGAI, and LEVI are indicators of financial difficulties that could predispose companies to manipulate earnings.

> "By the time companies are caught manipulating earnings, it's too late for investors to protect themselves. I wanted to find a means of profiling for potential fraud that investors could use to rank firms and invest in those with low probabilities of manipulation."

Using SAS business analytics software, Beneish estimated his model for detecting earnings manipulation by comparing the scores of manipulators to those of non-manipulators on each of the indices during the period from 1982-88. He then evaluated the model's predictive performance on a holdout sample from the 1989-92 period.

The classification followed a binary format – manipulator or non-manipulator – so Beneish used a probit regression to model the outcome. However, because his data oversampled manipulators with respect to their true proportion in the population, he also used a weighted exogenous sample maximum likelihood (WESML) probit in addition to the unweighted probit model to correct for the possibility of oversampling manipulators.

Results

Beneish found there were significant differences between manipulators and non-manipulators on five of the indices: DSRI, GMI, AQI, SGI, and TATA. The weighted and unweighted probit models yielded similar results, as did repeated analyses of randomly generated test and holdout samples. The probability of manipulation increased with unusual increases in receivables, deteriorating gross margins, decreasing asset quality, sales growth, and increasing accruals.

In order to assess the model's usefulness as a classification tool, Beneish examined two types of errors: Type I errors classifying manipulators as non-manipulators and Type II errors classifying non-manipulators as manipulators. Depending on the probability cutoffs set, the model correctly identified between 58 and 76 percent of manipulators, but as Type I errors were minimized, Type II errors increased from 7.6 to 17.5 percent. This misclassification of some non-manipulators as manipulators is a problem that requires the model be used only in combination with other investigative strategies. High rates of growth or changes in credit policy, for example, could result in the model returning high scores for

companies that have not engaged in any type of financial statement fraud.

Business Implications

Compared to a naïve strategy in which all companies are assumed to be non-manipulators, use of the model is highly cost effective in identifying companies with a heightened probability of earnings manipulation and avoiding these investments. The model requires only a single annual report and can be applied using a spreadsheet already embedded with the formula.

Beneish's analysis can help:

- **Investors** avoid companies that are likely to manipulate earnings
- **Lenders** assess financial risk
- **Auditors** flag potential reporting problems and decide on the required scope of the audit
- **Managers** monitor emerging financial issues
- **D&O Insurers** set or adjust their premiums
- **Regulators** identify candidates for closer scrutiny

The Beneish Model serves as a powerful example of how business analytics can guide sound financial decisions by revealing widespread and persistent patterns relevant to business investment, management, and regulation.

Messod D. Beneish, "The Detection of Earnings Manipulation," *Financial Analysts Journal,* 55(5), pages 24–36, 1999.

Smart Nurse Scheduling Policies:
Savings and Staff Satisfaction

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"As states and federal agencies have been considering laws mandating nurse-to-patient ratios, I started talking with nursing managers to see how hospitals are handling scheduling at a time when there is a shortage of nurses. I wanted to see what could be done to create schedules that nurses would like and that would also address staffing ratios and control costs for the hospital."

Concerns over patient-care quality have prompted both state and national legislators to consider mandating nurse-to-patient ratios in hospitals; California has had such a policy in place since 2004. At the same time, the country continues to face shortages in qualified nursing staff. These dual constraints place a burden on hospital administrators to develop nursing schedules that not only meet specified ratios while keeping costs in check, but are also attractive to nurses who are in high demand. The researchers address this problem by proposing a scheduling model that takes into account not only costs and nurse-to-patient ratios but also the desirability of the schedule from the nurse's perspective. Applying the model to a real-world hospital yields a number of insights, including the observation that costs increase in a non-linear manner as the patient load is reduced and that relatively small increases in labor costs can facilitate a significantly more desirable schedule.

Statement of the Problem

Nursing labor typically represents more than half of hospitals' total budgets. Even in the absence of legally mandated staffing ratios, patient care requirements often lead to forced overtime, which itself is in the process of being legally restricted. Such schedules contribute to dissatisfaction and high turnover among nurses, who have their pick of employers due to widespread nursing shortages. Hospital administrators are thus tasked with controlling costs while simultaneously ensuring ratio-specific coverage and creating desirable schedules that do not violate overtime restrictions.

Date Sources Used

In order to test the scheduling model, the researchers used data from a 526-bed, nongovernmental, not-for-profit hospital in Indiana. The data set contained information about facilities, staff mix, nursing wages, shift lengths, shift times, nurses' typical scheduling preferences, historical data on patient load, and applicable nurse-to-patient ratios. The researchers examined three units: Medical, Surgical, and Orthopedic-Neurosurgery (Ortho-Neuro); nurses numbered 54, 43, and 46, respectively.

Analytic Techniques

The planning and scheduling model is presented as a bicriteria nonlinear integer programming problem with the objectives of labor cost and schedule desirability. The full model contains both a workload model (planning model) and a tour assignments model (scheduling model). The workload model concerns the planning phase of staffing, such as the number of nurses to hire, assign to each unit, and schedule for each shift, specifically accommodating nurse-to-patient ratios. The tour assignment model builds on the workload model to assign heterogeneous employees to shifts over the scheduling horizon.

The full model contains two objective functions: one to minimize wages and a second to minimize undesirable shifts. Inputs reflect a heterogeneous group with varying titles (RN and NA), shift lengths, availability, and scheduling preferences. A large number of constraint sets are described to: ensure minimal service levels; limit undesirable shifts, overtime, and weekends; and prohibit double shifts and "backward rotation" (starting a shift less than 24 hours after the last shift began).

Calculation of service levels requires some additional analysis to avoid overstaffing: variation in patient load calls for computation of staffing ratios with reference to patients rather than beds. By allowing for a small probability of violation of the staffing ratios (for example, a critical level of 5%), the model offers a much more efficient schedule (staff can be added as needed with excess nurses from other units, on-call or floating nurses, etc.). These probabilities can be calculated at the single-period (shift) level and aggregate (planning horizon) level using the Erlang loss model queuing method.

In cases where the minimally accepted single-period service level is as strict as the aggregate service level requirements, the constraint related to the aggregate service level can be dropped, creating a relaxed (partial) version of the model. Because the problem is prohibitively difficult to solve, the researchers describe heuristic algorithms for both the full and partial models.

To conduct the computational experiment that applied the scheduling model using the Indiana hospital data, the researchers used CPLEX 7.1 optimization software.

Results

The researchers analyzed three problem sets using the data. Problem Set A, representing the full model, contains 42 problem sets for each of the three units, with patient ratios ranging from 1:4 to 1:10, single-period service levels from 1.5% to 15%, and aggregate service levels set to 1% for each 5% of the single-period level. A maximum of two or three weekends was assigned to each nurse over the 5-week planning horizon, and the maximum number of undesirable shifts was fixed at a low level. Problem Set B-1 is the same as Problem Set A except that it drops the aggregate service level (representing the partial model). Problem Set B-2 is similar to Problem Set B-1 but examines varying demand patterns, weekend policies, and undesirable shift policies.

For Problem Sets A and B-1, the researchers found that, as expected, costs decrease as the number of patients per nurse increases. However, the rate of decrease is nonlinear: moving from one ratio to an adjacent, tighter ratio does not always result in a proportionate change in cost. Importantly, in cases where the patient load is high (e.g., eight or more patients per nurse), it may be possible to increase the service level with little if any additional cost. In Problem Set B-1, the highest proportional increase in cost was between 6 and 5 patients per nurse for the Surgical and Medical units and between 5 and 4 patients per nurse for the Ortho-Neuro unit.

In Problem Set B-2, the researchers found that the application of the scheduling desirability objective could reduce the number of undesirable shifts by 40% without impacting costs. Further, a very small (1%) increase in costs could reduce undesirable shifts by another 21%. Investment beyond this point, however, resulted in diminishing marginal returns. Limiting weekend shifts to only two or three per 5-week period cost only 1.4% more than a policy allowing nurses to be scheduled for all five.

Business Implications

This model can be used to assist hospital managers in creating nursing schedules that address staffing ratios while minimizing costs and maximizing desirability from the nurses' perspective. The results of the test case suggest that with little to no increase in cost, managers can significantly reduce the number of undesirable shifts assigned to each nurse.

The nonlinearity of the increase in costs as patient loads are diminished can also be used to inform policy at both the hospital and legislative level. Managers and legislators should be aware of the costs incurred at different patient load levels. On the one hand, high patient loads may be able to be decreased without substantially affecting costs. On the other, the cost difference between 6 and 5 patients per nurse or 5 and 4 patients per nurse may be so high that hospitals are forced to close departments. This reality should be weighed against the impact of such ratio changes on the quality of patient care.

This study serves as an example of how analytics can be used not only to control costs within a set of constraints on labor practices, but also to address employees' heterogeneous shift preferences. Such analyses can help to guide sound policy and business decisions that take into account the wellbeing of all those affected – in this case, the patients, the employees, and the organization.

P. Daniel Wright, Kurt M. Bretthauer, Murray J. Côté, "Reexamining the Nurse Scheduling Problem: Staffing Ratios and Nursing Shortages," *Decision Sciences*, 37(1), pages 39–70,

Pension Plans and Invisible Leverage

"When analysts consider the capital structure of companies, everybody looks at the balance sheet and almost nobody looks at the off-balance-sheet items, which is where you find most of the pension information. Pensions have been overlooked because the accounting is a nightmare, so I wanted to try to reconcile some of these hidden numbers."

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This study examines the impact of defined-benefit corporate pension plans on capital structure decisions. The researchers demonstrate that such pension plans, though not reported on balance sheets, have a significant impact on corporate capital structure, adding approximately one third more to balance sheet leverage, while tax savings from pension plans account for an average of 1.5% of the value of the firm. The findings provide a potential explanation of why corporations appear underleveraged from a tax perspective: pension contributions that lead to significant tax shields and pension liabilities have been overlooked in capital-structure analyses that rely solely on balance-sheet reporting.

Statement of the Problem

Research on capital structure determinants has long been confronted with the seeming conservatism among corporations with respect to their capital structure decisions. It appears as though most firms fail to take full advantage of the tax shields provided by debt.

However, the estimated debt-to-asset ratios have failed to take into account corporate pension liabilities, which are not reported on balance sheets. Similarly, tax-deductible con-

tributions to defined-benefit corporate pension plans have been overlooked in the overall calculation of tax benefits. The researchers set out to determine how these pension plans impacted overall leverage ratios and whether marginal tax rates were significantly lowered by pension-related deductions.

Date Sources Used

The researchers relied on data available from COMPUSTAT, a data provider commonly used in financial research. All publicly traded firms from 1991 to 2003 were included, excluding utilities, financials, and other firms with insufficient information to calculate leverage. About one quarter of these firms sponsored defined-benefit pension plans during this time period. This yielded a sample of 17,015 firm-year observations for plan sponsors and 60,127 firm-year observations for firms without pension plans. A robustness check on the COMPUSTAT data was also conducted using Form 10-K and Form 5500 reports.

Analytic Techniques

In order to calculate the impact of pension plans on corporations' capital structures, the researchers built "consolidated" balance sheets that incorporated the off-balance-sheet pension items into the firm's total assets and liabilities. Marginal tax rates were calculated by simulating taxable income using the COMPUSTAT data. These computations yielded a more accurate picture of the leverage ratios and marginal tax rates of firms with pension plans.

Using both a treatment effects model and a firm fixed-effects framework, the researchers compared firms with pension plans to those without to determine whether pensions were used as a substitute for debt financing. A three-equation treatment effects econometric model enabled them first to model how firms self-select into becoming pension plan sponsors, then to estimate the amount of pension benefits. Finally, they used the predicted value of pension liabilities to estimate financial leverage. This methodology is similar to a two-stage least squares (2SLS) technique and corrects for the endogeneity between pension liabilities and balance sheet debt. As an alternative to the 2SLS framework, which has been shown to be sensitive to the choice of instrument variables, the researchers also employed an ordinary least squares (OLS) regression.

The researchers also conducted an analysis of covariance to deconstruct the variation in leverage attributable to different factors. Finally, because COMPUSTAT collapses certain leverage-related data into net amounts, the researchers also conducted a robustness check of the COMPUSTAT data by running the same tests on hand-collected pension information for year 2003 S&P 100 companies.

Results

Adding pension liabilities onto the balance sheet increases both book and market leverage by about one third: average book lever-

age rises from 25% to 34%, while market leverage increases from 20% to 27%. This calculation demonstrates that firms with pension plans are significantly more levered than balance sheet items would suggest.

Likewise, the tax benefits of this consolidated leverage are approximately 31% higher when tax shields from pensions are added to benefits from balance-sheet debt, with tax savings from pension contributions accounting for an average of 1.5% of the market value of the firm. This approximate one-third reduction also applies to measurements of debt conservatism: the gap between optimum leverage from a tax perspective and observed leverage shrinks by approximately one third when pensions are included in calculations.

The results of the treatment effects analysis show that a 1 percentage point increase in the pension liability to total assets ratio is associated with a 0.36 decrease in the total debt to assets ratio. This finding suggests that companies are partially substituting pensions for debt financing to achieve a more balanced capital structure.

Analyses of covariance suggest that companies employing pension plans are more likely to be large and in unionized industries, to have a low market-to-book ratio, and to have higher profitability, tangible assets, and earnings. Notably, these are the same factors understood to affect capital structure, reinforcing the idea that pensions play a role in capital structure planning.

Business Implications

This study has implications for number of business stakeholders:

- **Analysts** may observe that when pensions are considered, corporations are not as conservative with respect to leverage ratios as previously thought. Furthermore, this study demonstrates that off-balance-sheet items can have a significant impact on corporate capital structure, suggesting that a thorough financial analysis requires review beyond the balance sheet.
- **Investors** should be aware that off-balance-sheet pension liabilities significantly affect corporate leverage ratios and marginal tax rates.
- **Regulators** should consider that the current system of balance sheet reporting does not accurately reflect the full picture of corporate liabilities.

This study demonstrates how the meticulous application of analytic methods yields insights that are not immediately observable from public records. By revealing the significance of off-balance-sheet pension liabilities, it calls into question a number of assumptions about corporate capital structure decisions.

Anil Shivdasani and Irina Stefanescu, "How do pensions affect corporate capital structure decisions?" *Review of Financial Studies*, 23(3), pages 1287–1323, 2010.

Triple Jeopardy for Small Brands

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This study tests the emerging theory of "Triple Jeopardy" for small brands in the marketplace: brands with less market share not only have fewer customers but are also purchased less often (Double Jeopardy) and, as this study demonstrates, experience lower levels of loyalty than larger brands. Using a comprehensive sample that captures a large percentage of purchases at mass merchandisers, grocery stores, and drug stores in the United States, the researchers demonstrate the fallacy of the commonly held assumption that small brands survive through the repeat purchase of a small but fiercely loyal minority. They also examine the influence that traditional marketing efforts have on loyalty, finding that promotional efforts actually result in decreased brand loyalty.

Statement of the Problem

Marketers and retailers alike rely on branding to influence purchase patterns and improve profits. An understanding of brand loyalty is a vital component of these strategies, and the widely used Dirichlet model of Double Jeopardy has been effective in helping researchers and executives predict a brand's performance in terms of share of category requirements (SCR, defined as the brand's share of purchases, or wallet, in the category). Despite the generalizability of the Dirichlet model, persistent deviations from the model's predictions have been observed. Although a handful of small studies have attempted to explain these discrepancies, none relied on representative samples, thus limiting the generalizability of the findings. With the present study and sample, the researchers sought to provide a complete picture of consumer behavior, test the validity of the Dirichlet model, determine the existence of Triple Jeopardy, and describe the influence of the marketing mix on brand loyalty.

Date Sources Used

Scanners at checkout counters capture an enormous amount of information, which is collected and sold by marketing research companies. The data set utilized in this study comes from SymphonyIRI Group (formerly Information Resources, Inc.) and includes all mass merchandiser, grocery store, and drug store purchases in the United States in the year 2000.

Scanner data is typically categorized into departments (e.g. bakery, deli, health and beauty), categories (coffee, toothpaste), and, in some cases, sub-categories (ground coffee, coffee beans). Following standard industry practice, the researchers conducted their analysis at the sub-category level, excluding brands that had less than 1% market share and categories that had less than three eligible brands or for which the eligible brands represented less than 80% of market share. The resulting sampling framework captured approximately half of all branded goods sold – 422 categories, 5,126 brands, and multiple billions of purchases.

Analytic Techniques

Three nested sets of analyses were estimated:

- First, the researchers tested the Dirichlet model's ability to predict individual consumer level purchasing frequencies and brand choices. Based on the representative sample, the researchers computed each brand's SCR and purchase frequencies, and examined the relationship between theoretical and observed behaviors.

> " The concept of 'Double Jeopardy' is a well established empirical finding: Small brands lose not just once because of their smaller volume but again because they don't get the same trial – they don't get as much shelf space and are not purchased as often. We saw that there seemed to be a third factor – sales of small brands were even lower than Double Jeopardy would predict – so we examined whether consumer loyalty might be creating a situation of 'Triple Jeopardy.'"

- Second, using the theoretical and observed behaviors, the researchers computed "excess loyalty" (i.e., loyalty above what would be predicted by the Dirichlet model) and examined if brand size predicted "excess loyalty" (i.e., Triple Jeopardy). Researchers also controlled for alternative explanations such as sales volume and market share.
- Finally, the researchers investigated the relationship between various elements of the marketing mix and consumer loyalty. Using multiple regression analysis, the researchers computed the impact of the brand's volume per purchase occasion, average price, average price cut, and percentage of volume sold on any promotional deal on brand loyalty.

Findings

The Dirichlet model was found to be highly accurate in predicting a brand's SCR. However, this study also identified persistent deviations from the model's predictions, providing supporting evidence for the "excess loyalty" phenomenon. More relevant, these persistent deviations were found to be significant and normally distributed, suggesting that "excess loyalty" may be accounted for by some other metric. In investigating the nature of this metric, the researchers found a significant positive relationship between market share and excess loyalty in 86% of the categories, offering strong evidence of the existence of Triple Jeopardy.

Seeking to determine what might explain this Triple Jeopardy effect, the researchers examined several marketing variables. Their findings provide supporting evidence that higher levels of promotions (through price, price cuts, and deals) are negatively associated with excess loyalty, whereas sales volume and market share are positively associated with excess loyalty.

Business Implications

If customers display higher levels of loyalty to larger market share brands, then smaller brands are at a more significant disadvantage than previously thought. The idea of relying on a small but loyal following does not necessarily make good business sense in light of these findings. Smaller brands may need to find some other means of increasing sales that does not count on high levels of loyalty. The significance of this finding is further heightened by retailers' increased power in the market through efficient assortment policies and popular private labels. Smaller brands need to identify alternative strategies for success in the product marketplace or face very limited or non-existent exposure at the retail level.

For larger brands, the news is generally good, as this study not only confirms Dirichlet's generalization that high market share brands are more frequently purchased, but also shows that these popular brands are likely to have more loyal customers. However, the negative association between the marketing mix and excess loyalty suggests that traditional promotional techniques need to be deployed with caution, as they do not create more loyal customers and may effectively decrease sales over time.

This study demonstrates the importance of empirically testing commonly held marketing assumptions, such as small brand customers' imagined loyalty and the use of promotions to win loyal customers. By calculating the effects of Triple Jeopardy and the surprisingly negative impact of promotions, this research offers marketers and retailers a revealing new picture of consumer behavior.

Sang-Uk Jung, Thomas S. Gruca, and Lopo L. Rego, "Excess Loyalty in CPG Markets: A Comprehensive Examination," *Journal of Empirical Generalisations in Marketing Science*, 13(1), pages 1–13, 2010.

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