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**MEASURING THE LIFETIME VALUE OF A CUSTOMER IN THE
CONSUMER PACKAGED GOODS (CPG) INDUSTRY**

BY

SARANG SUNDER

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree

Of

Doctor of Philosophy

In the Robinson College of Business

Of

Georgia State University

GEORGIA STATE UNIVERSITY
ROBINSON COLLEGE OF BUSINESS

2015

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ACCEPTANCE

This dissertation was prepared under the direction of *SARANG SUNDER'S* Dissertation Committee. It has been approved and accepted by all members of that committee, and it has been accepted in partial fulfillment of the requirements for the degree of Doctoral of Philosophy in Business Administration in the J. Mack Robinson College of Business of Georgia State University.

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ABSTRACT

MEASURING THE LIFETIME VALUE OF A CUSTOMER IN THE CONSUMER PACKAGED GOODS (CPG) INDUSTRY

BY

SARANG SUNDER

JULY 8TH, 2015

Committee Chair: *DR. V. KUMAR*

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In this study, we propose a flexible framework to assess Customer Lifetime Value (CLV) in the Consumer Packaged Goods (CPG) context. We address the substantive and modeling challenges that arise in this setting, namely (a) multiple-discreteness, (b) brand-switching, and (c) budget constrained consumption. Using a Bayesian estimation, we are also able to infer the consumer's latent budgetary constraint using only transaction information, thus enabling managers to understand the customer's budgetary constraint without having to survey or depend on aggregate measures of budget constraints. Using the proposed framework, CPG manufacturers can assess CLV at the focal brand-level as well as at the category-level, a departure from CLV literature which has mostly been firm-centric. We implement the proposed model on panel data in the carbonated beverages category and showcase the benefits of the proposed model over simpler heuristics as well as conventional CLV approaches. Finally, we conduct two policy simulations describing the role of the budget constraint on CLV as well as the asymmetric effects of pricing in this setting and develop managerial insights in this context.

Keywords: Customer Relationship Management (CRM), Structural models, Bayesian estimation, Consumer Packaged Goods (CPG), Multiple discreteness, Customer Lifetime Value (CLV), Budget constraints

ACKNOWLEDGEMENTS

I would not be where I am without the unwavering support of my family, committee members, advisers, fellow PhD students and friends. I greatly appreciate their belief and confidence in me. I would like to express my deepest gratitude to my advisor, Dr. V. Kumar (VK) who has been instrumental in molding me as a researcher from the day I met him. I will be forever grateful to VK for taking me under his wing, mentoring and believing in me through my years as a PhD (and Masters) student. I will always look up to him for advice and a source for inspiration as I build my career in this discipline. I thank my dissertation committee of Dr. Yi Zhao, Dr. Robert Leone and Dr. Denish Shah who have advised and supported me over the years both professionally and personally. I am also extremely grateful to my friends and fellow PhD students at the Center for Excellence in Brand and Customer Management (CEBCM) many of whom have been my sounding board for research ideas and have in general made my work days more fun and enjoyable. Because of them and my professors, my doctoral experience at GSU has been one I will always deeply cherish.

I am extremely thankful to my family who have stuck with me through my highs and lows. I thank my parents, Sunder and Usha, for supporting me and remaining so confident in me no matter the path that I choose. I thank my brother Shyam and my grandparents Appappa, Bigamma and Samboo paati who, each in their own ways, have supported me and given me encouragement throughout. I also owe a debt of gratitude to Ranjini and Kedar who have advised me and have remained close confidants through the years. Finally, my journey as a PhD student would have never been completed without the love, support and patience of my wife, Anu. She has always been right beside me, proof reading my papers, being a soundboard for my ideas and supporting me throughout. Her reassuring voice and calming presence has kept me going through thick and thin. It is difficult to fail (no matter how challenging the task) when you have so many people who truly believe in you.

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INTRODUCTION

The customer-centricity paradigm has long been documented as being one of the most important tenets of effective marketing in today's dynamic environment. With the advent of technology and Customer Relationship Management (CRM), there is an explosion of disaggregate and granular customer data (transactional as well as survey) available to firms. Research has proposed several methods and metrics to evaluate the customer such as Recency-Frequency-Monetary value (RFM) (Cheng and Chen 2009), Share of Wallet, Past Customer Value (PCV), etc. In the past decade, Customer Lifetime Value (CLV) has emerged as an effective metric for CRM and a leading indicator of customer engagement with the firm (Kumar 2014). Customer Relationship Management (CRM) strategies developed from CLV modeling has led to positive financial gains in Business-to-Business (B2B) as well as Business-to-Consumer (B2C) settings (Kumar and Shah 2009; Villanueva and Hanssens 2007). Since the CLV metric is heavily dependent on customer relationships and transaction data, it has mostly been implemented in the relationship-marketing settings. However, the concepts of CLV and customer-centric marketing are applicable in traditionally product-centric industries such as consumer packaged goods (CPG) as well. In fact, the implementation of CLV in the consumer packaged setting is one of the explicitly stated objectives of the Marketing Accountability Standards Board (MASB)¹.

However, traditional marketing (especially in the CPG context) has focused on reaching out to consumers through mass marketing and delivering standardized products/services. While this has worked in the past, it may no longer be sustainable in a dynamic and digitally connected marketing environment. Although traditionally used aggregate metrics (such as market share,

¹ <http://www.themasb.org/projects/underway/>

sales volume, revenue etc.) which are commonly used in the CPG context to assess brand performance convey important information about the product/brand and can be readily calculated, they do not provide us with the complete picture. While aggregate metrics give managers an indication of the health of the brand and serve as an ‘aggregate’ proxy for performance, they do not provide any information regarding which customers grew and which ones did not.

Further, flow based metrics (such as market share, brand sales etc.) are very sensitive to extraneous shocks (Yoo, Hanssens, and Kim 2011) and ignore the heterogeneity present among households. CLV presents stability based on consumer behavior which is long-term focused and forward looking in nature. CPG firms are investing heavily in innovations in CRM that would move them closer to a CLV-based approach to decision making. While there are several case studies and white papers hinting at the need for customer centricity in CPG industry, to our knowledge, there is no academic study providing a robust methodology to assess CLV in the CPG industry. Through this research, we hope to provide the first step in applying customer valuation and customer centric marketing in the CPG industry.

In order to assess CLV in the CPG industry, we need to build a model that accurately captures consumer’s decision making in this setting. The implementation of a CLV-based marketing paradigm in CPG firms is faced with several challenges such as (a) multiple discreteness problem (where consumers make more than one brand in the same occasion), (b) heavy brand switching and (c) budget constrained nature of CPG purchases. First, CPG consumers² do not always purchase a single brand in a given month. Due to the relatively lower

² In this study, we use “consumer”, “customer” and “household” interchangeably. Our model is implemented at the household level, but we note that the model is flexible to be estimated at the consumer level if the data were available.

(relative to relationship driven CLV contexts) costs of switching in the CPG industry (Carpenter and Lehmann 1985), variety seeking consumers tend to try various brands within the same shopping period, thus leading to multiple discreteness in CPG consumption which has been documented in the literature (Allender et al. 2013; Dubé 2004; Richards, Gómez, and Pofahl 2012). This multi-brand purchase in the same given month leads to violations of typical discrete choice models which are commonly used in conventional CLV models. This presents the first challenge wherein, in order to accurately capture the consumption patterns, the CLV model needs to account for multiple discreteness.

Second, given the low cost of switching, we need to explicitly account for brand switching and competing brand effects in the CPG context. Previous research has highlighted the importance of accounting for brand switching in CPG markets, especially in situations of low product differentiation (van Oest 2005). A relatively small price promotion in one week could induce customers to switch brands and consume another product (Bell, Chiang, and Padmanabhan 1999; Sun, Neslin, and Srinivasan 2003). However, conventional CLV models which rely on internal company data often ignore the role of competition and brand switching. Extant CLV models that do account for brand switching rely heavily on survey data describing either the customer's actual switching (Rust, Lemon, and Zeithaml 2004) or Share of Wallet information. (Kumar and Shah 2009). The collection of survey data, while viable in business setting where relationships are clearly defined, becomes very challenging in the CPG context due to scale and cost issues associated with appending panel data with survey information.

Third, existing evidence in consumer behavior as well as economics shows that households keep track of category-specific budgets especially in the CPG setting (Antonides, Manon de Groot, and Fred van Raaij 2011; Heath and Soll 1996; Stilley, Inman, and Wakefield 2010) and

try to maintain category spending (focal product category + outside substitutes) within a target maximum level, so as to have control over consumption or spending (Gilboa, Postlewaite, and Schmeidler 2010). That is, consumers have unobserved limits on the amount of dollars that they are willing to allocate toward a specific category, which includes the product category as well as outside substitute goods. For example, a consumer could view water, juice and carbonated soda as substitutes and allocate dollars toward this ‘mental’ category (focal product category as well as substitutes outside the product category). The budget constraint would then be encompassing all the dollars allocated toward this overall spending category. In the economics literature, Hastings and Shapiro (2013) explore this phenomenon of mental category-specific budgets using panel data from a US retailer and show that a category level budgeting predicts customer behavior quite well. The idea of mental budgeting and mental accounting was first proposed by Thaler (1985) as a theoretical model of consumer behavior and later used in marketing literature (Cheema and Soman 2006; Heath and Soll 1996). Prelec and Loewenstein (1998) point out that when consumers make purchases they often experience a *pain of buying*, which acts as a counterbalance for the pleasure of consumption. Mental budgets act as a form of self-control to ensure that they stay within the spending limits at the category level (and thus, at the grocery trip level). However, inferring the consumer’s latent mental ceiling/budget has proven to be challenging. Much of past research in the area of mental budgeting has relied on some form of survey data (Du and Kamakura 2008; Stille, Inman, and Wakefield 2010). Since collecting and appending survey data in the CPG setting is very difficult, it becomes necessary to *infer* this information using readily available transaction data. This issue is further underscored when addressing CLV in the CPG setting since managers need to know not only what the CLV of the customer is, but also the maximum budget allocations that could be made within the category.

Knowledge of the limits of a customer's spend (budget constraints) helps managers avoid overspending on customers who have a low ceiling and underspending on customers who have a high ceiling. Our main research objectives are highlighted below,

1. *Getting a long-term customer centric view of the CPG customer:* How to model the consumer's CLV in a CPG setting?
2. *Explicitly account for multiple discreteness and heavy brand switching:* How to leverage scanner panel data in the CPG industry to explicitly consider brand switching and account for the multiple discreteness issue when modeling CLV?
3. *Understanding the budgetary constraint:* How to infer the customer's budget constraint at the individual level? This information would allow managers to assess the budgetary ceilings that households impose for specific categories.
4. *Policy Simulations in CLV modeling:* How can firms use a structural approach to assess CLV in the CPG setting and eventually conduct relevant counterfactuals without having to conduct expensive studies in the field?

We implement a structural model of multiple discrete purchases on scanner panel transaction data spanning across three years. We showcase the predictive power of our approach relative to conventional CLV modeling approaches and also highlight its advantages over simpler heuristics (such as usage, market share etc.). Additionally, we compute individual CLV and segment the customers into high, medium and low CLV segments. At the segment level, we provide insights into each CPG brand's share of CLV and discuss the implications for each brand. Finally, we conduct two policy simulations that are managerially relevant. First, we simulate the effect of changes to the budget constraint on CLV. We find that, on average, a reduction in the budget constraint leads to a greater effect in CLV than a gain in budget. We

show that this effect is heterogeneous, that is, the magnitude of the effect is different depending on CLV segment. Second, we study the own and cross effects of price on quantity consumed. We find that the effects are non-symmetric for increases and decreases in price, indicating nonlinear price elasticities. Further, as we highlight, this effect too is heterogeneous across CLV segments.

The remainder of this article is organized in the following manner. In the next section, we discuss the related marketing literature in the areas of CLV, and multiple discreteness modeling and outline our contributions. Next, we provide a brief description of the data used in the empirical application and present evidence of multiple discreteness in the data. Then, we develop the structural model of multiple discreteness, discuss the operationalization of the budget parameter, and derive the likelihood. Within this section, we also elaborate on the Bayesian estimation procedure used to recover the parameters. Next, we elaborate on the findings from the study and compare our model with conventional CLV models. In the subsequent section, we compute the CLV, and conduct managerially relevant counterfactuals (or) policy simulations that could aid CPG manufacturers in understanding CLV in the CPG setting. Finally, we highlight the key academic and managerial implications of the proposed approach and conclude with limitations and future research directions.

LITERATURE GAP

Customer Lifetime Value (CLV) modeling

CLV is an individual-level customer valuation metric that takes into account the total profit contribution of a customer over his/her lifetime. It can be formally defined as *the sum of the cumulated cash flows- discounted using the weighted average cost of capital (WACC)- of a customer over his/her entire lifetime* (Kumar 2014). As is evident from the above definition,

CLV measures the net worth of the customer. Since it is measured at the individual level, companies that have computed CLV can now assess the distribution of their customer base according to the potential value that they will achieve. The advantage of modeling the CLV from a firm's perspective is that the CLV metric gives the manager a view into the future profit potential of the customer. Thus, by knowing the future profit potential of the customer, managers can optimally allocate marketing dollars toward the right customers at the right time (Venkatesan and Kumar 2004). Researchers have proposed several strategies (customer acquisition, retention etc.) based on the CLV metric and have implemented these strategies in various industries such as airlines, telecommunications, banking etc. It is to be noted that the past implementations of CLV have been for industries with stronger customer relationships. Applying the CLV framework to the CPG industry presents several practical challenges, the most important being that the customer's switching costs and brand loyalty are relatively lower. Since our focus is on the CPG industry which is a B2C non-contractual setting, we will review the CLV literature that conforms to this setting. In Table 1, we outline the representative research in the CLV literature and elaborate on the contributions of this study toward CLV modeling. There are mainly three criteria that need to be addressed when reviewing the extant CLV literature, namely, (a) the level of aggregation, (b) whether competition is included, (c) modeling approach and application. We will discuss the following criteria in detail in the subsequent paragraphs.

(Insert Table 1 here)

Level of Aggregation: The level at which CLV/CE is computed depends on the kind of data that is available to the researcher. As prior literature has stressed, the more disaggregate the data, the more valuable the insights. Nevertheless, in certain situations, an aggregate view of CLV (either at the territorial level or firm level) has proven to be quite beneficial to the firm. For example,

Keane and Wang (1995) implement a lifetime value framework at the geographical level in a newspaper setting and develop insights for the same. Several researchers have also used publicly available data (such as company reports, third-party reports etc.) to evaluate the average CLV or CE at the firm level. For example, Gupta, Lehmann, and Stuart (2004) propose a method to estimate the average CLV of a customer for a firm using publicly available data while projecting the revenue stream to an infinite horizon. This methodology was further improved and substantiated by Wiesel, Skiera, and Villanueva (2008) by linking CE to shareholder value.

While firm-level estimation of CLV has immediate managerial advantages, it does not account for the heterogeneity among the customers. Conducting a customer base analysis at the aggregate level comes with its own risks. Specifically, ignoring heterogeneity in the CLV estimation can lead to a consistent downward bias in elasticities and therefore under report the impact of marketing on CLV (Fader and Hardie 2010). Given the richness of the data available to us and the ‘structural’ evaluation of the model, we develop our modeling framework at the individual customer level and therefore, explicitly account for heterogeneity in the customer base.

Competition in CLV modeling: Since consumers make choices relative to competing brands/firms/offerings in the marketplace, it is important to evaluate the importance of competition in CLV modeling especially in the CPG context. By failing to account for competitive effects, CLV models could overestimate the impact of the firm’s own marketing activities on CLV. Researchers have tried to mitigate this issue by including survey based measures of the customer’s Share of Wallet (SOW) to control for competitive effects. However, this approach has two shortfalls. First, it is difficult for the researcher to collect survey data for the entire customer base and maintain the database for the entire transaction history of the customer. Second, the SOW metric does not explicitly incorporate competition into the choice

framework of the customer since it is used more as a control variable. Rust, Lemon, and Zeithaml (2004) use a Markov switching matrix to account for the customer's brand switching tendencies. However, this method only considers the customer's switching behavior but not simultaneous purchasing behavior (purchasing from multiple brands at the same time). Further, their approach relies heavily on the data gathered from large scale surveys of customers. This may prove impractical in the CPG setting due to the cost structures associated with data collection and inherent reporting biases within the survey data. The lack of consumption and other marketing related data has proven to be very difficult to gather, especially in a CLV setting. However, the rise of cooperative databases wherein data across multiple firms is pooled by third party vendors has enabled researchers to have a clearer view of the customer. For example, Liu, Pancras, and Houtz (2014) develop a framework for firms to manage customer acquisitions using cooperative databases. Our approach to handling competition follows a similar perspective. Leveraging data from third party vendors such as Nielsen/IRI, we directly including competition within the consumer's utility and implementing a unified CLV model on transaction data from scanner panel data.

Choice, Quantity, & Timing Modeling: Previous research on CLV modeling has mostly relied on separate specifications of choice, quantity and timing decision models to describe customer decision making (Gupta et al. 2006; Kumar and Luo 2008). While these models have worked well in situations where customer relationships are well defined, they may not be well suited for the CPG context. A choice-then-quantity approach forces the researchers to make explicit assumptions regarding the temporal ordering of decisions. In a CPG setting, this assumption may not hold especially when consumers purchase more than one brand in the same purchase occasion and switching costs are relatively low. Specification of separate choice, quantity and

timing models could lead to parameter proliferation problems as well as the introduction of new random utility error terms (for each decision model) into consumer preference (Chintagunta and Nair 2011). Further, a reduced form approach of specifying joint models of multiple decisions could suffer from the Lucas critique. This is true with dynamic models such as vector auto regression models and other multivariate time series models which are commonly used in CLV modeling. Thus, we propose a unified structural model which incorporates all of the above consumer decisions within the same utility framework, thereby avoiding the parameter proliferation problem while still modeling CLV.

In the CPG context, Yoo, Hanssens, and Kim (2011) merge a VAR based framework with a stochastic model for customer behavior (BG/BB model from Fader, Hardie, and Shang (2010)) and provide valuable insights describing the evolution of customer equity in a CPG market. They show that CE is much more stable and a better metric to use in the CPG market. This approach, however, is applicable only for a one-brand-one-category setting and does not address the multiple discreteness issue that is common in CPG purchases. For grocery product categories, such as carbonated soft drinks, canned soup, pasta, cereals etc., households regularly purchase assortments of brands (Allender et al. 2013; Dubé 2004; Kim, Allenby, and Rossi 2007; Richards, Gómez, and Pofahl 2012). This multiple discreteness issue violates the single-unit purchase assumption of standard discrete choice models that past CLV models have been reliant on. As we elaborate in the data section, handling the multiple discreteness issue is critical as almost 40% of all transactions suffer from this problem in the carbonated soft drinks category. Though the multiple discreteness issue has been studied in marketing literature in the past, it has never been studied from a CLV perspective.

Models of multiple discreteness

In the CPG setting, consumers tend to purchase assortments of products/brands in a shopping trip, thus leading to the multiple discreteness problem. The multivariate Probit model (Manchanda, Ansari, and Gupta 1999), which essentially treats the consumer choice decision as a set of correlated binary choice models has been proposed to handle this issue without the use of a structural modeling approach. While popular in marketing literature, this approach is suboptimal when studying CLV since it does not make any conclusions regarding the quantity decision, which is critical for CLV computation. Direct utility structural models which derive demand from Karush-Kuhn-Tucker (KKT) conditions have been proposed as a viable alternative to model multiple discreteness while taking advantage of the continuous nature of consumer purchase. Variants of these models include those proposed by Kim, Allenby, and Rossi (2002), Bhat (2008) as well as Satomura, Kim, and Allenby (2011) which rely on satiation to explain multiple discreteness. An alternative approach in the economics literature was proposed by Hendel (1999) who treats multiple discreteness as temporary variety seeking behavior. This approach was later applied in marketing by Dubé (2004) to study demand in carbonated soft drinks.

In the current study, we adopt a direct utility approach to structurally model multiple discreteness while accounting for variety seeking behavior in the demand model. While falling within the broader streams of multiple discreteness modeling and CLV, our work differs from prior literature in the following ways. First, unlike previous literature (for e.g. Satomura, Kim, and Allenby 2011) who have mostly used data from a controlled conjoint study (survey data), we implement our model on a longitudinal transaction database in a CPG setting. Second, we allow the budget parameter to deterministically vary with time (as a function of demographics, and

seasonality effects) in our model so as to capture any time variations in the budget constraint within the data. Finally, and most importantly, our main objective in this research is to apply a multiple discrete modeling approach to predict the future profit stream of each customer (CLV) across multiple brand purchases. In the next section, we describe the data in which the empirical model was developed and implemented.

DATA

The empirical setting for the application of the proposed CLV model is the CPG industry. Specifically, we used scanner panel data for carbonated beverages obtained from Nielsen/IRI in our subsequent analyses. In the data, we observe monthly carbonated soft drink purchases at the UPC level made by 40,098 consumers who were part of the Nielsen panel between the periods of July 2007 and August 2010.

Next, we describe the criteria used in preparing the data in order to develop and estimate the proposed model. First, a common challenge in modeling scanner panel data is to devise an aggregation strategy such that a tractable set of choices/alternative are used for estimation (Gordon, Goldfarb, and Li 2013). That is, too many alternatives in the data makes it computationally cumbersome and also could lead to identification problems in the recovery of parameters. We aggregated Universal Product Code (UPC) level data within the category into manufacturer level brands. While it is possible to aggregate the data at the brand-size level instead, we note that this leads to significant complications in our model as it requires the estimation of several new parameters. Further, in our data there were a lot of customers who only purchased a single size throughout the timeline of the data. Moreover, based on our conversations with executives of one of the large CPG manufacturers in the dataset, we learned that CLV at the brand level also carries significant value in this setting. We do, however note

that our CLV model could accommodate more granular (brand-size) data provided there was enough variation in consumption patterns. This yielded a dataset considering customer purchases across four major brands (Coca Cola, Pepsi, Dr. Pepper and Private Labels) accounting for a cumulative 89% of market share in the overall sample.

A second issue faced when building models using only customer-level scanner panel data is that the researcher observes price only when the consumer makes a purchase of the focal brand. In order to infer the missing price data for the other brands, we follow the heuristic outlined by Gordon, Goldfarb, and Li (2013) and Erdem and Keane (1996). We imputed the price information using purchases by other consumers in the same store type in the same month. That is, when customer 'i' did not purchase brand 'b' at time 't', we search the database for any other customers 'k' (where $k \neq i$) who purchased brand 'b' at time 't' in a similar store type. We then compute the average of the price across the 'k' to arrive at an imputed price which we use in place of the missing information.

Model Free Analyses

In the data, we observe temporal variations in brand purchases as well as prices. To provide a deeper understanding of the data structure and patterns, we provide visual representations of key trends in the data. First, in Figure 1 (Panels A & B), we illustrate the time trend in market share as well as price for the four major brands in the data. We can see that there are two leaders in the market, Coca-Cola and Pepsi, who command an average of about 30% market share. Visual inspection suggests that these two brands seem to be close competitors and seem to steal market share from one another on a month to month basis. This is further supported when we study the time trend of price data. On the other hand, we can see that Dr. Pepper's market share is increasing over time as is its price. The above trends indicate that there is

significant competition between brands in this market and in addition to pricing, there are several factors that could be influencing this.

(Insert Figure 1 here)

While aggregate metrics give managers an indication of the health of the brand and serve as an ‘aggregate’ proxy for performance, they do not provide in-depth information regarding which customers grew and which ones did not. Further, they do not address the inherent heterogeneity among customer preferences to marketing. To illustrate this point, we compute household level market share (the percentage of purchases of the focal brand relative to total number of purchases). Figure 2 describes the distribution of household level market share across the four major brands being considered. There are two key points to be noted in Figure 2. First, there is a wide variation in customer purchases, suggesting that heterogeneity is indeed important and needs to be considered.

(Insert Figure 2 here)

Second, the distribution of purchases across brands is also differences. A key question is that when one brand decides to modify its price, how do the customers react? That is, given an increase in price of Coca-Cola, the customer could (a) increase his purchase of another brand *and* reduce his share of Coca-Cola purchases while still maintaining his overall consumption level, or (b) continue to purchase Coca-Cola, but reduce the quantity consumed to remain within the budget constraint. A model based approach (especially a structural model) is therefore, useful in describing consumer decision making and reactions to observed changes in marketing. Overall, the variations in the data help motivate the need to use a sophisticated modeling approach to accurately address the above issues. In the following subsection, we further motivate the need for

applying a multiple discreteness framework to the current context by providing evidence from the data and literature.

Multiple-discreteness check

In order to check the extent of multiple discreteness within the data (40,098 customers), we computed the number of interior and corner solutions amongst the consumers and present the results in Table 2.

(Insert Table 2 here)

From Table 2, we can see that about 45% of the transactions are in fact interior solutions, which lead to the multiple discreteness issue. The multiple discreteness issue exists at the weekly level as well. We found that, at the weekly level, almost 30% of the transactions are multiple discrete. We crosschecked the same for other categories for which we had data (Canned pasta, and Yogurt) and found results that were consistent with our findings in the carbonated beverages category. In fact, there has been research in the past describing the multiple discreteness issue in carbonated soft drinks (Dubé 2004), yogurt (Kim, Allenby, and Rossi 2002), fresh produce (Richards, Gómez, and Pofahl 2012), salty snacks (Kim, Allenby, and Rossi 2007) and ice creams (Allender et al. 2013). It is important to note that though we implement the proposed model for the carbonated beverages category, the proposed framework is easily adaptable to other CPG categories³ as well. The conventional methods of CLV modeling (which rely on classic choice, frequency/timing and quantity modeling) would end up combining a large percentage of the transactions into a single brand purchase which could in turn significantly bias the estimation and lead to inaccurate CLV calculations. The proposed model not only accounts

³ Even for categories that do not exhibit very high multiple discreteness, the proposed model will simplify to a discretized modeling framework, thus simplifying estimation.

for the above described multiple discreteness issue but also integrates the three main decisions (choice, frequency/timing and quantity) within the same model.

METHODOLOGY

Formally, CLV is defined as the sum of the cumulated cash flows- discounted using the weighted average cost of capital (WACC)- of a customer over his/her entire lifetime (Venkatesan, Kumar, and Bohling 2007). Following prior literature on CLV modeling, the lifetime value of the customer has two components; a) Predicted Contribution Margin and b) Predicted Marketing Cost.

$$\begin{aligned}
 CLV_i &= NPV \text{ of } GC_i - NPV \text{ of } MC_i \\
 &= \sum_{t=t_1}^T \sum_{j=1}^J \frac{\hat{q}_{ijt}(m_j P_{jt})}{(1+d)^{t-t_1}} - \frac{\overline{MC}_{jt}}{(1+d)^{t-t_1}}
 \end{aligned} \tag{1}$$

Where,

\hat{q}_{ijt} = predicted quantity of brand ‘j’ purchased by customer ‘i’ at time ‘t’ (in units)

m_j = profit margin of brand ‘j’ (as a percentage)

P_{jt} = price of brand ‘j’ at time ‘t’ (in dollars)

\overline{MC}_{jt} = average marketing cost per customer incurred by brand ‘j’ at time ‘t’

d = discount rate (12% annually)

j = brand indicator ranging from (1 to J)

The first term in the above equation depicts the profit stream of each customer in the database and discounts this value to the present value. The second term in the above equation describes the marketing expenses borne by the firm toward customer ‘i’. Specific to our case, CPG firms do not market individually to each customer. Instead, CPG customers are typically reached via mass marketing channels such as television commercials, newspaper inserts, in-store displays etc. Due to this, the marketing cost per customer in the CPG setting is likely to vary across brands but not much across customers. In the empirical application presented in the study, we assume a zero-base marketing spending similar to Yoo, Hanssens, and Kim (2011).

Appending and re-estimating the framework along with marketing cost data will only improve the CLV estimates, but not change our substantive conclusions. The model describing the customer's budget constrained utility maximization problem is presented below along with brief discussions of each component.

In order to model the stochastic component (\hat{q}_{ijt}), we provide a structural approach wherein the consumer maximizes his/her utility for each trip across a variety of brands. In order to account for the multiple discreteness issue, we specify a direct utility model where consumers are assumed to be utility maximizers subject to a budgetary constraint (or) monetary ceiling.

The Budget Constraint in the CPG context

In this subsection, we elaborate on the theoretical underpinnings of the budget constraint construct, its boundaries and definition. Extant literature on mental accounting (Cheema and Soman 2006; Thaler 1985) has shown that consumers impose restrictions on themselves to avoid over spending and consumption. These restrictions are usually in the form of mental dollars that consumers assign toward consumption and have been shown to exist in the grocery setting (Milkman and Beshears 2009). In this study, we follow the view of Stilley, Inman, and Wakefield (2010) who suggest that mental budgets for grocery trips are comprised of itemized portions (or allocations at the brand/product level).

However, it is important to comment on the manner in which categorization could occur within the consumer's mindset. A valid criticism of imposing budget constraints at the category level is that consumers do not always see substitutes within the category (as defined by the brand/industry). Research in categorization (Antonides, Manon de Groot, and Fred van Raaij 2011; Ratneshwar, Pechmann, and Shocker 1996) has shown that consumers represent products and substitutes differently. Thus, a model of consumer behavior (such as the one proposed in this

study) that imposes a budget constraint at pre-defined category-level could be mis-specified since it does not capture the substitution effects accurately. To overcome this difficulty, within the model presented in this study (below), we specify the budget constraint (or) monetary ceiling to be the maximum monies allocated by the consumer toward the focal category as well as substitutes that may be considered outside the focal category. For example, the budget constraint that we attempt to quantify in this study is the maximum dollars that the consumer allocates toward the carbonated soft drinks category plus substitute product categories (such as water, juice, etc.). We impose no restrictions on the manner in which these dollars are allocated across substitutes. In the following section, we develop the consumer's overall utility maximization problem and describe the salient features of the model.

Consumer's Utility Specification

The consumer's overall utility (U_{it}) can be expressed as a function of his/her utility from consumption and category-level savings. The savings utility which tracks the overall spending within the focal category as well as the budget constraint acts as a counterbalance to the consumption utility (Prelec and Loewenstein 1998). Utility from consumption is derived from purchase of specific brands from a subset of offerings. Typically, from a discrete modeling approach, this is the utility derived when a consumer purchases a brand. In this context, due to the multiple discreteness issue, the consumer is assumed to purchase a set of brands (as opposed to one brand). The consumption utility (U_{it}^{Cons}) is therefore a sum of utilities ($\sum_{j=1}^J U_{ijt}$) that the consumer gains from consuming/purchasing a set of brands. The second component of the consumer's overall utility is the utility from savings (U_{it}^{Sav}).

The consumer's category-level utility from savings is described as a function of his/her category-level monetary savings from a shopping trip. We can specify the monetary savings as

the difference between the consumer's budgetary ceiling or mental account (y_{it}) and the amount of dollars spent toward the category at time 't' ($\sum_{j=1}^J P_{jt}q_{ijt}$). The budget constraint (y_{it}) is the maximum allocation to goods in a mental category (focal product category + substitutes outside the product category) and helps ensure that the overall utility is concave with positive, but diminishing marginal returns.

$$\begin{aligned}
 U_{it} &= U_{it}^{Cons} + U_{it}^{Sav} \\
 &= \sum_{j=1}^J U_{ijt} + f\left(y_{it} - \sum_{j=1}^J P_{jt}q_{ijt}\right)
 \end{aligned} \tag{2}$$

Where,

U_{it} = overall utility from consumption by consumer 'i' at time 't'

U_{ijt} = brand-level utility for consumer 'i' at time 't' for brand 'j'

y_{it} = Unobserved budget allocation within category by consumer 'i' at time 't'

P_{jt} = Price of brand 'j' at time 't'

q_{ijt} = Quantity of brand 'j' consumed by consumer 'i' at time 't'

U_{ijt} from Equation 2 can be further decomposed into sub-utilities for each brand (Equation 3). The "+1" in $(1 + q_{ijt})$ allows for the possibility of corner solutions in the model, where q_{ijt} can take zero values. This specification is important since there could be situations wherein the consumer (who is extremely loyal to a specific brand) will never purchase any other brand, thus leading to quantity demanded for other brands to be zero. Further, this formulation works well for CLV modeling since it incorporates choice, quantity and frequency (or timing) decisions within the same utility specification. Due to this, the current modeling approach avoids problems of over specification and maintains model parsimony, while still addressing multiple discreteness and the budget constrained nature of consumer decision making. Further, the savings side of U_{it} can be described log-linearly where λ_i (Equation 3) is introduced to convert the monetary savings into utility. Similar to past work on multiple discreteness, we assume that

monetary savings have positive demand and no corner solutions (i.e. $y_{it} - \sum_{j=1}^J [P_{jt}q_{ijt}] > 0$ and $q_{ijt} \geq 0$). The overall consumer utility at ‘t’ is now given by,

$$U_{it} = \sum_{j=1}^J [\psi_{ijt} \ln(1 + q_{ijt})] + \lambda_i \ln \left(y_{it} - \sum_{j=1}^J [P_{jt}q_{ijt}] \right) \quad (3)$$

The baseline utility (ψ_{ijt}) in Equation 3 can now be written as a function of stochastic (ε_{ijt}) and deterministic (ψ_{ijt}^*) parts. In our subsequent implementation, we specify ψ_{ijt}^* to be a function of brand-level, customer-level and state dependence covariates which we elaborate in the estimation section.

$$\psi_{ijt} = \psi_{ijt}^* + \varepsilon_{ijt} \quad \text{and} \quad \varepsilon_{ijt} \sim N(0, \sigma^2) \quad (4)$$

The utility specification in Equation 3 leads to the Karush-Kuhn-Tucker conditions of constrained utility maximization wherein interior ($q_{ijt} > 0$) or corner solutions ($q_{ijt} = 0$) are possible. We can derive the overall likelihood by connecting the error (ε_{ijt}) to the observed demand (q_{ijt}) in each of these conditions. When the consumer ‘i’ purchases brand ‘j’ at time ‘t’ yielding observed demand (q_{ijt}) to be greater than zero (interior solution), the first order condition for Equation 3 leads to a normal density function.

$$\begin{aligned} \frac{\partial U_{it}}{\partial q_{ijt}} &= \frac{\psi_{ijt}}{1 + q_{ijt}} - \frac{\lambda_i P_{jt}}{y_{it} - \sum_{j=1}^J [P_{jt}q_{ijt}]} = 0; \text{ if } q_{ijt} > 0 \\ \Rightarrow \varepsilon_{ijt} &= \frac{\lambda_i P_{jt}(1 + q_{ijt})}{y_{it} - \sum_{j=1}^J [P_{jt}q_{ijt}]} - \psi_{ijt}^*; \text{ if } q_{ijt} > 0 \end{aligned} \quad (5a)$$

On the other hand, when the consumer does not purchase brand ‘j’ at time ‘t’, thus yielding observed demand (q_{ijt}) to be equal to zero. This leads to a probability mass function and denotes the corner solution.

$$\frac{\partial U_{it}}{\partial q_{ijt}} = \frac{\psi_{ijt}}{1 + q_{ijt}} - \frac{\lambda_i P_{jt}}{y_{it} - \sum_{j=1}^J [P_{jt} q_{ijt}]} < 0; \text{ if } q_{ijt} = 0$$

$$\Rightarrow \varepsilon_{ijt} < \frac{\lambda_i P_{ijt}(1 + q_{ijt})}{y_{it} - \sum_{j=1}^J [P_{jt} q_{ijt}]} - \psi_{ijt}^*; \text{ if } q_{ijt} = 0$$
(5b)

We now link the baseline utility to covariates by specifying the deterministic portion (ψ_{ijt}^*) to be a linear function of covariates that describe the customer's purchase behavior (Equation 6). In the current implementation, we include full heterogeneity in the intercept and the state dependence parameters while including brand specific parameters for the other variables. We do, however, note that the framework is flexible enough to incorporate heterogeneity in all the parameters (provided there is enough variation in the data).

$$\psi_{ijt}^* = \alpha_{ij} + \delta_i SD_{ijt} + \beta_j X_{it}$$
(6)

Where,

α_{ij} = brand (j) and customer (i) specific intercept term

δ_i = customer (i) specific state dependence parameter

SD_{ijt} =State dependence variable (measured currently as a dummy variable denoted as 1 if customer bought brand 'j' at time 't-1'; 0 otherwise)

β_j = brand (j) specific parameter

X_{it} = customer (i) specific variables at time 't'

We can further decompose the budget constraint parameter (y_{it}) to vary with time as a function of factors that are both intrinsic as well as extraneous to the environment. In the current operationalization (Equation 7), we decompose the budget constraint parameter to be a function of the demographics (age) and seasonality effects (summer months).

$$y_{it} = \zeta_{0i} + \zeta_1 Age_{it} + \zeta_2 Age_{it}^2 + \zeta_3 Seas_t$$
(7)

Where,

ζ_{0i} = baseline budget constraint parameter (estimated) for consumer 'i'

Age_{it} = Age of consumer 'i' at time 't'

$Seas_t$ = dummy variable denoting 1 if month= May-August (summer months) and 0 otherwise

We include the square term of Age in Equation 7 in order to test for any quadratic effects of Age on the budgetary constraint for each customer. We also expect that the consumer's budget does not stay the same throughout the year. Especially for frequently purchased goods, the consumer's budgetary allocation changes depending on seasonal effects. To account for this, we also include a seasonality dummy variable to capture the effects of summer on the consumer's budget allocation.

Heterogeneity

Consumers exhibit rich heterogeneity in the frequently purchased goods markets . We incorporate heterogeneity in the consumer's inherent brand preference parameter (α_{ij}), the state dependence coefficient (δ_i) as well as the baseline budget parameter (y_i). We assume that the above coefficients follow a normal distribution with location parameters specified below,

$$\alpha_{ij} \sim N(\bar{\alpha}_j, V_{\alpha_j}) ; \delta_i \sim N(\bar{\delta}, V_{\delta}) ; \zeta_{0i} \sim N(\bar{\zeta}_0, V_{\zeta_0}) \quad (8)$$

where $(\bar{\alpha}_j, V_{\alpha_j})$, $(\bar{\delta}, V_{\delta})$, and $(\bar{\zeta}_0, V_{\zeta_0})$ represent the population means and variances of the distribution of α_{ij} , δ_i , and ζ_{0i} respectively.

Likelihood

Using the assumption of normal errors, equations 5a and 5b can be combined to form the overall likelihood which is a combination of density (for interior solution) and mass (for corner solutions). We represent the parameter space as an array " θ_i " for expositional purposes such that $\theta_i = \{\alpha_{ij}, \delta_i, \beta, \zeta_{0i}, \zeta_{1-3}\}$ and write the likelihood for household 'i' as,

$$\begin{aligned}
L_i(\theta) &= \int_{-\infty}^{\infty} L_{0i}(\theta_i)^{I(q_{ijt}>0)} \cdot L_{1i}(\theta_i)^{(1-I(q_{ijt}>0))} f(\theta_i) d\theta_i \\
&= \int_{-\infty}^{\infty} \prod_{t=1}^T \prod_{j=0}^J \left(\phi(\varepsilon_{ijt}) \cdot |J|_{\varepsilon_{ijt} \rightarrow q_{ijt}} \right)^{I(q_{ijt}>0)} \\
&\quad \cdot \Phi(\varepsilon_{ijt})^{(1-I(q_{ijt}>0))} f(\theta_i) d\theta_i
\end{aligned} \tag{9}$$

Where,

$$I(q_{ijt} > 0) = \begin{cases} 1; & \text{when } q_{ijt} > 0 \\ 0; & \text{else} \end{cases}$$

$\phi(\cdot)$ = pdf of the normal distribution

$\Phi(\cdot)$ = truncated normal distribution

$|J|_{\varepsilon_{ijt} \rightarrow q_{ijt}}$ = Jacobian of the transformation from the random utility error (ε_{ijt}) to the likelihood of observed data (q_{ijt})

$f(\theta_i)$ = heterogeneity distribution of parameter space θ_i with location parameters $\bar{\theta}, V_{\theta}$

The Jacobian for our model is given by the first order derivative of the error term with respect to q_{ijt} as given below,

$$|J|_{\varepsilon_{ijt} \rightarrow q_{ijt}} = \frac{\partial \varepsilon_{ijt}}{\partial q_{ijt}} = \frac{\lambda_i P_{jt}}{y_{it} - \sum_{j=1}^J P_{jt} q_{ijt}} + \frac{\lambda_i P_{jt}^2 (1 + q_{ijt})}{\left(y_{it} - \sum_{j=1}^J P_{jt} q_{ijt} \right)^2} \tag{10}$$

Let N be a collection of all ‘i’ households in the data. Then the overall likelihood for the data can be given by,

$$L(\theta)_{overall} = \prod_{i=1}^N L_i(\theta) \tag{11}$$

Unlike prior work on multiple discreteness (Kim, Allenby, and Rossi 2002), we are interested in estimating the consumer’s budget constraint in order to assess the ceiling of their purchase within the category. Thus, we treat the budgetary constraint (y_{it}) as a parameter and infer it in the estimation. In the following section, we comment on the theoretical and empirical identification issues faced when estimating the proposed model.

Model Identification

Given the structure of our model, it is important to provide some intuition regarding the identification of the model parameters. The overall utility model (Equation 3) consists of two main components that need to be estimated in order to achieve our stated objectives, namely, (a) the baseline utility ψ_{ijt} through its associated hierarchical parameters (α_{ij} , δ_i , & β_j) and (b) the budget constraint y_{it} through its associated hierarchical parameters (ζ_{0i} , ζ_1 , ζ_2 , & ζ_3). Recall that according to Equation 7, y_{it} is allowed to vary deterministically as a function of a baseline budget constraint (ζ_{0i}) along with exogenous covariates. An identification problem arises when we attempt to simultaneously evaluate the intrinsic preference at the brand level α_{ij} , the baseline budget constraint ζ_{0i} , as well as the Lagrangian λ_i . That is, it is possible that one could generate the same observed data (P_{jt} , and q_{ijt}) using more than one unique combination of the parameters (α_{ij} , ζ_{0i} , and λ_i). Thus, given the data (which includes price and quantity information at the customer-brand level), it is not possible to empirically identify all three parameters listed above (Satomura, Kim, and Allenby 2011). Therefore, we need to fix at least one of these parameters in order to identify the others jointly. As stated before, our main parameters of interest are the baseline utilities as well as the budget constraint parameter. In order to uniquely identify α_{ij} and ζ_{0i} , we first fix $\lambda_i = 1$ and $\sigma^2 = 1$. The following approach to diagnose the identification problem in budget constrained utility models has also been used in prior work on multiple discreteness (see for e.g. Kim, Allenby, and Rossi 2002; Kim, Allenby, and Rossi 2007). We provide more details on the specific elements in the data that allow us to reliably recover the parameters as well as theoretical arguments on identification in **Appendix A**.

The budget constraint (y_{it}) is modeled in the exponential form in order to constrain it to positive values (since it is impossible to have negative budgets). Similar to Satomura, Kim, and

Allenby (2011), we also impose logical ceilings on the budget parameter such that the estimated value for customer ‘i’ does not exceed the observed maximum purchase value (in dollars) within the data such that, $y_{it} \geq \max(\sum_{j \in J} P_{jt} q_{ijt})$.

Estimation

The proposed model was estimated using a hybrid Bayesian Markov chain Monte Carlo (MCMC) algorithm. The use of Bayesian methods is needed since one of our objectives is to infer the budget constraint (y_{it}). The Bayesian approach allows us to create latent variables, use data augmentation methods and estimate the parameters sequentially. The assumption of normal errors allows us to break down the estimation process into more efficient Gibbs sampling (from full conditionals) and Metropolis-Hastings (M-H) sampling methods.

Our estimation process is outlined below (see Figure 3). We first begin by drawing ψ_{ijt} based on whether q_{ijt} is equal to or greater than zero. In the case when $q_{ijt} > 0$ (interior solution), we use the normal distribution to infer ψ_{ijt} and when $q_{ijt} = 0$ (corner solution), we use the truncated normal distribution to infer ψ_{ijt} . Given ψ_{ijt} , we now treat the underlying estimation of α_{ij} , δ_i , and β_j similar to a multivariate regression with heterogeneous parameters which can be estimated using Gibbs sampling. The remaining parameters (ζ_{0i} , and ζ_1 - ζ_4) are drawn using the M-H algorithm since we cannot derive the full conditional distributions for the same. We specify the prior distribution on the hyperparameters $(\bar{\alpha}_j, V_{\alpha_j})$, $(\bar{\delta}, V_{\delta})$, and $(\bar{\zeta}_0, V_{\zeta_0})$ to be non-informative and flat. The prior means were normally distributed and the prior variances were inverse Wishart distributed. Our overall estimation algorithm is described in more detail in the **Appendix B**.

(Insert Figure 3 here)

Variable Operationalization

As elucidated in Equation 6, we introduce brand and customer level covariates to explain variance in the baseline utility equation. We elaborate on the variables used in this study below.

State Dependence: Following prior literature on state dependence in consumer choice, we include a state dependence term (SD_{ijt}) to track the inertia in the consumer's purchase pattern. In the current implementation, we specify state dependence as a dummy variable similar to past research investigating state dependence in choice modeling (Dubé, Hitsch, and Rossi 2010; Seetharaman, Ainslie, and Chintagunta 1999). Specifically, if the consumer buys brand 'j' during the previous shopping occasion (t-1), then the state dependence term for that brand is equal to 1.

$$SD_{ijt} = I\{q_{ijt-1} > 0\} \quad (12)$$

The specification in Equation 12 induces a first-order Markov process on choices. Although this is the specification that is used commonly in empirical research (Dubé, Hitsch, and Rossi 2010), we note that the above specification is flexible enough to include higher order state dependence terms as well. It is also important to note that SD_{ijt} is brand specific and can take multiple non-zero values for each purchase occasion, due to the multiple discreteness issue (where the consumer could have purchased more than one brand at t-1). We refer to δ_i as the state dependence coefficient that captures the effect of the state dependence term (SD_{ijt}). If $\delta_i > 0$, the model implies that the purchase of a brand reinforces the household's latent utility for that brand. By accounting for brand and customer specific intercepts (α_{ij}), we capture the household's underlying preferences for brands and also explicitly separate them from the household's tendency to be state dependent ($\delta_i > 0$).

Past purchase behavior: In Equation 6, we also specify X_{it} as a matrix of customer level variables that could be the drivers of consumer purchase behavior. Table 3 shows the variables used in this study, their operationalization and expected effects.

(Insert Table 3 here)

In order to capture the consumer's consumption intensity within the category, we use total quantity purchased at the previous purchase occasion ($LASTQty_{it}$) and recency of last purchase ($Recency_{it}$). These variables are expected to explain the consumer's category level consumption patterns by accounting for the incidence of a past purchase as well as the depth of the previous purchase. Prior research has shown that there exists a negative effect of recency of purchase on CLV (Kumar and Shah 2009). Within the CPG context, recency will have a negative effect on quantity purchased. That is, the longer the time since the last purchase, the less likely the customer is to purchase within the category. For example, consumers who have not made a category purchase (high values of $Recency_{it}$) are likely to have churned and thus derive much lower utility from consuming the brand. In order to capture the effect of the depth of the previous purchase, we include the lagged values of quantity purchased as a covariate (Chintagunta and Haldar 1998; Jain and Vilcassim 1991). This variable will also account for observable differences in consumption among households (such as heavy vs. light users) as well as control for category consumption levels per household (Jain and Vilcassim 1991).

The general behavioral tendency of a customer to selectively purchase brands that are offered as 'deals' is defined in this study as $DEALintensity_{it}$. $DEALintensity_{it}$ indexes the consumer's deal usage intensity or the extent to which the consumer purchases brands that are on deals/features/displays within the store. The role of deals in the CPG setting is not only to provide monetary savings to the customer but also be able to signal quality . Past research has

shown that deal usage with regard to national brands (which command higher loyalty) is associated with higher perceived savings (Ailawadi, Neslin, and Gedenk 2001) and would result in higher derived utility. Thus, deal usage is expected to have a positive effect on the utility for national brands. However, the above latent savings are not perceived for store brands (since they do not command loyalty or high perceived quality). Thus, the high deal intensive consumers would, in fact derive a lower utility for private labels leading to lower purchase quantities.

Similar to the deal intensity variable, we operationalize *COUPintensity_{it}* in order to capture the coupon usage behavior of consumers. Consumers who are serial coupon users are likely to purchase only the value of the coupon being offered rather than indulge in cross-buying or up-buying within the category. Evidence of this behavior was shown in the retailing sector by Shah, Kumar, and Kim (2014) who study the above phenomenon in the context of promotional habit strength. Drawing parallels from this research, it is expected that consumers who consistently use coupons are likely to purchase lesser quantities.

Since the data is from consumers who made purchases from either food or non-food (such as drug stores) stores, we can study whether consumers who are especially loyal to a specific kind of store are more/less likely to purchase within the category. Especially important is the fact that high food store purchase intensity might lead to different effects for different brands (Ailawadi, Pauwels, and Steenkamp 2008). For example, consumers who are heavy drug store purchasers may not purchase private labels (possibly due to an availability issue). In this study, we use *STORE_intensity_{it}* to study whether store format loyalty influences the overall quantity purchased.

With ever increasing attention being cast on the health impact of foods (especially carbonated sodas), consumers are moving toward ‘diet’ sodas as an alternative due to their lower

sugar and calorie content. In fact, recent research by Ma, Ailawadi, and Grewal (2013) shows that consumers diagnosed with diabetes change their consumption patterns to accommodate a lower sugar and carbohydrate diet, which in our case translates to a shift from regular to diet soda. Diet products, thus, are likely to be perceived with a higher utility due to their ‘health’ related advantages. Therefore, higher diet soda consumption in the past (measured as $DIETSODA_intensity_{it}$) is likely to lead to a higher consumption in the future. The summary statistics of the data is provided in Table 4.

(Insert Table 4 here)

RESULTS

Simulation Study

In order to check the robustness of our model specification and estimation methodology, we first conducted a simulation study to calibrate the performance of our model. Data was generated according to the utility specified in Equation 4 assuming a three brand market. We generated consumption data for 500 consumers each having an observation length of 20 time periods. All the parameters were well recovered, having the true values within 95% credible intervals, thus confirming that our estimation method can recover the true parameters and can be implemented on real transaction data. Please refer to **Appendix D** for details on the simulation exercise.

Model Evaluation & Performance

We estimate the proposed model on a randomly selected sample of 500 customers (total number of transactions= 12,837) from the above described consumer scanner panel data for the

carbonated beverages category⁴. We used 20,000 iterations of the Markov chain to generate parameter estimates, with the first 10,000 discarded as burn-in. In order to assess the performance of the model, we use the Mean Absolute Deviation (MAD) and Mean Absolute Percentage Error (MAPE) to assess the predictive accuracy of our model. We rely on MAPE as a preferred metric to gauge model fit because it is unit-free and easier to interpret. We gauge model performance for in sample as well as out of sample fit.

In this section, we compare our modeling approach to a more conventional choice and quantity modeling approach that is typical for extant CLV models (Gupta et al. 2006). Specifically, we estimated a multivariate probit choice model using the simulated maximum likelihood approach to predict customer choice across various brands and subsequently used a regression model to predict quantity (see **Appendix E** for model and estimation details). To assess out of sample fit, we estimated the model using the first 30 months of data and used the remaining 6 months as hold out. In Table 5, we report in sample and out of sample fit statistics (MAD and MAPE) for each brand as well as overall category level quantity. As we can see, the proposed model predicts brand-level quantity purchased (\widehat{q}_{ijt}) quite well, yielding an average MAPE across brands of 20.74% (in-sample) and 23.09% (out of sample). When considering the total category quantity purchased, the model performance dips slightly to a MAPE of 27.75% (in sample) and 29.87% (out of sample). This result is markedly better than the benchmark model which has an average MAPE of 48.90% (in sample) and 50.64% (out of sample) when predicting brand level quantities. At the category level, the MAPE is 41.61% (in sample) and 43.89% (out of sample) which are both worse than the proposed model. The choice then quantity model

⁴ We repeated the analysis for 3 different samples of 500 customers and arrived at similar estimation results.

performs much worse in this case since it involves specifying multiple equations (each associated with a random utility error) with several parameters. The proposed model is superior to the conventional CLV modeling approaches as it exploits quantity information within the choice framework and prevents parameter proliferation (Chintagunta and Nair 2011).

(Insert Table 5 here)

Findings from Model Estimation⁵

Consumer's Budget constraint. One of the main modeling issues that we deal with in this study is the explicit estimation of the consumer's budget parameter using Bayesian methods. To our knowledge, this is the first study to estimate the consumer's budget using transaction data and use this to calculate CLV. In Table 5, we report the parameter estimates for Equation 10. We find that the average consumer baseline budget allocation for the carbonated beverages category is $\exp(3.371) = \$29.40$ for a month. Consistent with Du and Kamakura (2008), we find that there is significant heterogeneity in the budget parameter. This heterogeneity in the consumer's budget is important to consider especially in the CPG industry where each consumer/household can have different thresholds and priorities when allocating a budget toward a particular category. As we elaborate in the discussion section, CPG companies could potentially build customer profiles for high budget customers and try to achieve a larger portion of their share of wallet. Further, we find that the age of the head of the household has a positive effect on the budget. Specifically, as the consumer ages, the budget allocation toward carbonated beverages also increases. Since the squared term is not significant, we conclude that the effect is only linear and not quadratic. The non-significance of the quadratic term could be due to the range of age that we observe in the

⁵ To establish external validity, we presented our findings to executives from one of the largest firms in this industry who provided valuable qualitative insights corroborating the results.

data. Future research could further explore the long-term effect of age on the consumer's budget constraint.

(Insert Table 6 here)

Inertia effects: Consistent with Seetharaman, Ainslie, and Chintagunta (1999), we find that there exists inertia in the marketplace wherein consumers prefer to stick to their past experiences. This result is consistent with theoretical explanations of routinized response behavior (Assael 1974) especially in heavily advertised, convenience goods associated with limited informational search and stronger brand attitudes. Furthermore, we also find that the inertia effect is heterogeneous in that consumers vary in their levels of inertia (some consumers may be a little bit more variety seeking than others). By profiling customers who are more/less variety seeking, firms can identify consumer segments that may have a higher tendency to indulge in brand switching.

Brand-specific effects: Table 7 describes the brand specific parameter estimates for baseline utility (ψ_{ijt}). Looking at the heterogeneous intercept term (α_{ij}), we find that consumers are heterogeneous in their intrinsic preference level for brands in the carbonated beverage category. Looking at the means of the α_{ij} distributions ($\bar{\alpha}_{ij}$), we find that the highest preference level is for Coca-Cola and the least for Private labels. This ordering follows the market share order in the category where Coca-Cola has the largest market share and Private Labels have the least. As described previously, heterogeneity ($V_{\alpha_{ij}}$) is significantly large for this category, a result that was also demonstrated by Dubé (2004) in the same category. Notably, the heterogeneity term is large for Pepsi indicating a high variance in intrinsic preferences among Pepsi's customer base.

(Insert Table 7 here)

Turning to the effect of the covariates, we find that $LASTQty_{it}$ positively affects the consumer's purchase behavior across all brands. That is, consumers who purchased large

quantities in the past are likely to do the same in the current period. This result suggests that consumers do not necessarily take inventory into account when making frequent purchases in the carbonated beverages category. Further, specific to frequently purchased goods, heavy users could be developing habits behavior of purchasing that lead to creation of behavioral loyalty. This result is in line with Venkatesan, Kumar, and Bohling (2007) who also find a positive relationship between past and current quantity purchase. We also find that the effect of $Recency_{it}$ is significant and negative for Pepsi and Dr.Pepper while insignificant for the other brands (even though the sign of the coefficient is consistent). This indicates that consumers who have not made a purchase in the category in a long time (high recency) have likely churned. The model suggests that this variable is especially important for Pepsi and Dr.Pepper.

The results suggests that $DEALintensity_{it}$ is positively associated with Coca-Cola and Dr. Pepper, but negatively associated with Private Labels. This differential effect of deal usage and brand preference is supported in the literature. Specifically, Ailawadi, Neslin, and Gedenk (2001) show that consumers who do not focus on the ‘deal’ aspect of the purchase and therefore make fewer purchases on deals tend to gravitate toward store brands. Further, consumers who tend to be quality conscious and deal prone tend to avoid private label brands and gravitate toward national brands. Turning to the effect of coupon usage behavior, consumers that are serial coupon users are found to be selective in their purchases and hence, unlikely to exhibit high purchase behavior. This could be because these consumers only purchase the quantity/value indicated in the coupon. Similar coupon proneness behavior has been studied recently from a habitual perspective by Shah, Kumar, and Kim (2014) in a retail setting. Finally, we find that consumers who purchase frequently at food stores are likely to purchase Private Label brands.

This could be a factor of the distribution intensity of Private Labels in these stores, thus increasing product availability.

CLV IN THE CARBONATED BEVERAGES CATEGORY

CLV Measurement

The main objective of this research was to compute the CLV of a customer in the CPG setting. Using the proposed model, we can now predict the quantity purchased for each brand in the market (\widehat{q}_{ijt}) using the parameter estimates into the future and substitute the predicted values in Equation 1 to arrive at the CLV of a customer. First, we hold brand price (P_{jt}) at the mean and the brand-specific covariates (except $LASTQty_{it}$ and $Recency_{it}$) at the last recorded value for the CLV prediction, thus making the assumption that the consumer does not change his habits during the prediction window. Second, for each future period in the prediction window, we update the $LASTQty_{it}$, $Recency_{it}$ and SD_{ijt} variables based on the previous (predicted) values. Next, using the above generated covariates along with the parameter estimates we generate the overall utility function (Equation 3) and subsequently maximize this expression to obtain purchase quantities for each brand. Sufficient logical constraints ($\widehat{q}_{ijt} > 0$) are applied in the constrained maximization routine which can be achieved using subroutines in the R software (e.g. `constrOptim`, `nlminb` etc.). This process is repeated for the future time periods (36 months in our context). We choose a CLV prediction time window of 36 months for the following reasons. First, given the dynamic environment that CPG firms typically operate, a prediction window of three years offers a good trade-off between predictive accuracy and horizon when computing CLV. Second, the choice of a three year window also has roots in managerial decision making horizons. Prior to computing CLV, we interviewed several executives in one of the firms in the data to get an understanding of the decision horizons that were generally considered industry

standards. We learned that due to the dynamic environment in the marketplace, CPG managers cutoff the decision horizons at 3 years or less, after which marketing allocations are reconsidered. Finally, in general, the concept of discounting cash flows results in a majority of the customers' lifetime value being captured within the three years window (Gupta and Lehmann 2005; Kumar and Shah 2009). For the context of the study, based on the guidance provided by Nielsen, we use a constant margin value of 0.28 for all the brands. Further, following Yoo, Hanssens, and Kim (2011) we assume a marketing cost of zero without loss of generality (since marketing investments in this category are made at the aggregate level and rarely vary across customers). We do, however acknowledge that each brand would have its own margins and marketing cost values but due to lack of information, we are forced to make simplifications on the same.

The above analysis yields a mean CLV of a customer in this category to be \$148.69 with a standard deviation of \$101.57. In order to investigate this distribution further, we summarize the CLV scores of the customers in ten deciles where each decile represents the mean of 10% of the customers organized in descending order of CLV scores (Figure 4). Similar to prior CLV work, we find that the bulk of dollars (in the form CLV) are concentrated in the top few deciles. In fact, the first three deciles constitute almost 55% of the entire profits! This result, though familiar in a relationship marketing setting is new to the CPG industry and presents further evidence that CPG brands need to move toward customer centricity rather than relying on aggregate measures of brand performance (such as market growth, market share, etc.).

(Insert Figure 4 here)

We also compared our proposed CLV segmentation approach to simpler heuristics that are commonly used by managers. The proposed CLV approach is an improvement over simpler

naïve heuristics since it accounts for multiple discreteness, unobserved heterogeneity, competitive effect, variety seeking as well as the consumer's budget constraint. Although past literature (Venkatesan and Kumar 2004) has shown that CLV outperforms conventional metrics and simpler heuristics in various business settings, we assess how well the traditional metrics match up against the proposed CLV. We focus primarily purchase frequency, consumption level and monetary value which are commonly used in marketing practice due to their simple interpretation and implementation. Specifically, we segment the customers based on the above metrics and compute the mismatch or discordance between the deciles created using simpler heuristics and the proposed CLV approach. We find that across deciles, there is a significant mismatch between the metrics. The discordance between deciles was an average of 61.6% (79.6% for purchase frequency, 56% for total quantity consumed and 49.2% for total revenue) across metrics. This result further motivates the need for a model based and a predictive method to assess customer value rather than relying on naïve heuristics that might be easier to interpret and implement but may lead to suboptimal customer base evaluations.

Studying the Brand's share of total CLV

Our modeling approach allows us to study not only the customer's lifetime value for the entire category, but also the brand level CLV for the category (Equation 1). Using the distribution of the CLV scores (Figure 4) as basis, we designate customers in Deciles 1, 2 & 3 as High CLV, Deciles 4, 5, 6, & 7 as Medium CLV and Deciles 8, 9 & 10 as Low CLV. Based on this classification, we present the brand-level shares of CLV for High, Medium and Low CLV customers in the carbonated beverages category.

(Insert Figure 5 here)

Figure 5 presents some interesting results. Although Coca-Cola commands the largest market share in the carbonated beverages market, surprisingly, in the sample dataset Pepsi tends to attract a large percentage of the high CLV segment (approximately 41%). This is further supported through the parameter estimates where we noted that the heterogeneity for inherent preferences was higher for Pepsi than for Coca-Cola, even though the mean preference level for Coca-Cola was greater. Further, the majority of medium and low CLV customers are found to be Coca-Cola customers. We see that Coca-Cola seems to be attracting a majority of the Low CLV customers, purportedly in an attempt to capture the ‘long tail’. Though this strategy is commendable, it is still important to capture the high CLV customers since their spending power (share of wallet-budget) is higher and thus, represent high profit potential. Finally, as expected, we see that the Private Label brand customers tend to be few and predominantly lower CLV customers. These customers tend to be value conscious and have little or no brand loyalty (behavioral and attitudinal) as the quality perceptions for this brand are lesser than the national brands.

Figure 5 represents an important status quo report of the state of brands in the carbonated beverages market with respect to CLV. Using the results, managers of each brand will have a good understanding of the kind of customers that their respective brands have rather than just using aggregate measures to assess brand performance. In the following section, we conduct two managerially relevant policy simulations and discuss our findings.

POLICY SIMULATIONS

Simulation Exercise #1: Budget Constraints & CLV

In addition to segmenting the customers into deciles, we are also interested in studying the relationship between the estimated consumer budget and CLV. High CLV customers seem to

have high budgetary allocations toward the category and this trend is true for lower CLV deciles as well. The correlation between CLV and budget is also significant and positive ($\rho=0.78$; $p<0.001$). However, an interesting question is *how do consumers react to budget changes?* Further, *how does this impact CLV?* In fact, recent experimental research by Carlson et al. (2015) shows that consumers do, in fact change consumption pattern in the presence of shrinking budgets. Since the proposed modeling framework is structural in nature, we are able to empirically investigate the budget effects on consumers. That is, we conduct theoretically grounded policy experiments varying consumer budget constraints and assess the impact on CLV. Specifically, holding all other effects constant, we attempted to understand the effects of a 20% increase/decrease in budget constraint at the customer level on his/her CLV. Figure 6 describes the results of the policy simulation.

(Insert Figure 6 here)

In Panel 1, we can see that the percentage change in average CLV for an increase in the budget constraint is lesser than that of a decrease in the budget constraint. This non-linear effect (concave) of the budget constraint on CLV is important for managers to realize since it has implications for understanding consumers' mental accounts for certain categories. Further, from Panels 2-4, we can see that the effects are different depending on the type of customer. Specifically, we can see that high CLV customers' future profitability is least affected by changes in the budget constraint. However, low CLV customers tend to be more sensitive to budget constraint changes. Thus, brands that tend to attract low CLV customers need to be aware of the conditions or situations (such as recessionary trends) that could influence the consumer's mental accounting process and, eventually the budget constraint.

Simulation Exercise #2: Pricing & Consumption

One of the key firm action variables that managers use to improve brand performance in the CPG setting is price. Although we do not specifically estimate a price coefficient in the model, we can easily assess own and cross price effects through policy simulations. Further, in our model, the budget constraint parameter acts as a ceiling and helps us identify competition between brands. That is, customers with large budgets are likely to be more price inelastic since for price increases they are more likely to absorb the extra cost of consumption as long as their budget slack is high. However, this may not be the case for customers who have a lower budget constraint. In such a case, the limiting nature of the budget constraint forces customers to reevaluate and adjust their consumption across brands in reaction to a price increase. Given this, it is important for managers to assess *which* customers are more/less elastic and *where* the brand switching will occur. If Coca-Cola increases its price, which customers are more likely to purchase other brands and which brands are considered as close substitutes in this market? Finally, do price increases and decreases lead to symmetric responses among consumers? We attempt to answer these key questions through a policy simulation exercise where we simulate consumer responses for variations in price.

We generate two scenarios, wherein the focal brand's price increases by 10% and price decreases by 10% while maintaining all other covariates and other brand prices constant. Using the estimated parameters (θ) along with the new price information, we simulate the consumer's quantity purchases (\widehat{q}_{ijt}). In Table 8 and Table 9, we report the findings from this policy simulation.

(Insert Table 8 and Table 9 here)

In Table 8, we report the effects of a 10% increase (decrease) in focal brand's price on the percentage change in average quantity demanded. First, we can see that the direction of the price elasticity is negative for price increases and positive for decreases. However, the magnitude of the effect across brands is not symmetric. The absolute value of the effect of a 10% decrease in price is greater than the corresponding increase in price. This nonlinearity in price elasticity is consistent across brands. Second, looking at the magnitude of the own effects (diagonal elements in Table 8), we see that private labels exhibit the highest price elasticity with Coca-Cola, Pepsi and Dr. Pepper following. Using this result, managers can assess how CPG customers react to changes in price. Further, looking at the cross price effects, we find that changes to Coca-Cola prices influence Pepsi and vice versa. This indicates that Pepsi and Coca-Cola are closely competing with one another and price is a key differentiator. This result is further substantiated in model free analyses (Figure 1).

While the above analyses gives us an understanding of the average effects of price on brands, a key element of this study is the issue of heterogeneity. While aggregate data analysis techniques commonly used by CPG brands can assess price elasticity at the aggregate level, it is important to address heterogeneity in this construct. Specifically, do CLV segments react differently to price changes? To illustrate this, we conduct a policy simulation wherein we varied Coca-Cola's price by 10% and assessed its corresponding effect on customers in high, medium and low CLV segments (Table 9)⁶. We find that the high CLV segment (-7.28% for price increase and 8.93% for price decrease) and the low CLV segments (-10.14% for price increase and 12.39% for price decrease) are indeed very different in their responses to price changes. High CLV customers are less sensitive to price than low CLV customers. This is likely because

⁶ The policy simulations for Dr. Pepper, Pepsi and Private Labels are presented in **Appendix F**.

of the higher budget constraint for high CLV customers and the lower budget constraint for low CLV customers. This result is important for CPG managers when assessing pricing changes as they can now evaluate the heterogeneous effect of price on specific CLV segments.

DISCUSSION

CLV/CE gives the firm a long-term, forward looking, profitability oriented view of the customer base. However, academic work to date has been relatively silent in applying CLV in the CPG context. In this paper, we attempt to address this gap by proposing a structural approach to measuring the CLV of a CPG customer while accounting for the nuances and challenges of model building in the CPG context. We believe that this research addresses some important issues in its attempt to bridge the gap between customer base evaluation (CLV metrics) and the CPG context. One of the main objectives of the Marketing Accountability Standards Board (MASB) is to enhance the role of marketing in the board room. While several industries (with a large focus on relationship marketing) have adopted CLV and are able to enhance the role of marketing in the boardroom, CPG firms tend to lag behind. By relying on short term value metrics (such as market share, sales etc.), CPG managers find it difficult to establish a long-term profitability focus for marketing strategy. We attempt to resolve this issue in this study by proposing a structural approach to modeling the CLV of a CPG customer. We implement our modeling framework on transaction data in the carbonated beverages industry and develop insights for the same. Some findings and potential managerial implications of this research are discussed below.

One of the unique aspects of this study is that, in addition to measuring CLV, we also explicitly infer the consumer's budget allocations (through a Bayesian approach) toward his/her mental category and also draw associations between budgetary allocations and CLV. Given our

model specification, we are able to measure not only overall CLV for the category, but also CLV at the brand level. CPG managers can make use of this information to understand (a) where their firm stands with regard to future customer profitability and (b) how to move up the profitability ladder (to attract high CLV customers).

Specific to the carbonated beverages market, we outline customer behaviors that influence purchase patterns. We find that there exists a significant level of inertia (positive state dependence) among consumers of carbonated beverages. However, this effect is heterogeneous such that consumers have varying levels of inertia in their purchase patterns. We also find that, on the average, Coca-Cola is the most preferred brand while Private Labels are least preferred. This is congruent with the market shares within the market. While as expected, this preference is heterogeneous, we find that the heterogeneity parameter is largest for Pepsi. That is, even though the average preference for Pepsi is not very high, there are some consumers who are extremely loyal to the brand. This is evident in our CLV computation as well where we see that about 40% of the CLV share of the High CLV segment within our random sample belongs to Pepsi. Further, from our analysis, it is clear that Coca-Cola customers are not necessarily the most behaviorally loyal. We identify specific past behavior variables that affect the future purchase pattern of the customer and show that these effects are different for different brands. Specifically, we note that depending on the focal brand (Coca-Cola, Pepsi, Dr. Pepper, or Private Labels) the drivers of CLV are different. For example, customer deal usage intensity effect is positive for Coca-Cola and Dr. Pepper, but negative for the Private Label. Such outcomes are very useful for managers of CPG brands who can now allocate marketing spend accordingly. Additionally, we note that the proposed framework is flexible enough to be estimated at the sub-brand (e.g. Diet Coke,

Regular Coke etc.) and subcategory levels depending on the managerial need. This flexibility adds to the practical applicability of the proposed framework.

Finally, since our model is structural in nature we are able to conduct theoretically grounded policy simulations (what-if scenarios), a departure from reduced form modeling approaches that are common in CLV literature. We conduct managerially relevant policy simulations. Specifically, we show that the budget constraint and prices asymmetrically affect consumers. A 20% increase in the budget constraint leads to an average of 1.99% increase in CLV while the same percentage decrease in the budget constraint leads to a 2.89% decrease in CLV. We show that this effect too, is heterogeneous. High CLV customers are less volatile (with respect to changes to the budget constraint) in comparison to lower CLV customers. We see a similar asymmetric result for price changes suggesting nonlinear price elasticity. Further, we show that Coca-Cola and Pepsi (the market leaders) are in close competition with regard to price while Dr. Pepper seems to be least elastic.

This research also has implications for retailers (such as Kroger, Target, etc.) and market research companies (such as A.C. Nielsen) who collect longitudinal transaction data on customers. Using the proposed CLV modeling approach, retailers can make product assortment decisions based on long-term customer profitability as well as create leverage down the supply chain. Further, since this model is flexible to account for multiple categories, CLV can also be computed at the retailer level which has implications for marketing strategy at the retailer level as well.

IMPLEMENTING CLV IN THE CPG CONTEXT

It is no secret that firms have started to treat customers differentially. While the world of marketing is moving *fast* from a product centric to a customer centric paradigm, where the onus

is to gain a 360-degree view of the customer the moment he/she walks into the store. Especially with the growth of the Internet of Things⁷ concept, where appliances, products, brands and consumers are interconnected closely (Atzori, Iera, and Morabito 2010), the need to customize and individually market to consumers is paramount. In such a marketplace reality, Consumer Packaged Goods (CPG) industries are mostly being left behind due to several reasons. Being largely product centric in the past and mostly relying on flow based aggregate metrics of performance, CPG firms need to move to a customer centric CLV based paradigm. However it is important to comment on the key issues faced by CPG firms when attempting to assess CLV. Specifically, managers need to establish vital mechanisms that enable the collection and utilization of disaggregate data.

CPG manufacturers (such as Unilever, Proctor & Gamble, etc.) rarely have access to individual customer transaction data over a long period of time. This is because the actual data collection happens outside the control of the manufacturer. The data collection (at Point-Of-Sale (POS) systems) happens at the retailer's premises. Thus the ownership of the customer transaction data resides with the retailer. The retailer may or may not want to this disaggregate data since it also represents a competitive advantage to the retailer (due to store labels etc.). To overcome this problem, manufacturers have two broad options, (a) Collaborate closely with the retailer, or (b) purchase data from third party firms. The first option involves a deep collaboration and negotiation with the retailer and possibly, entering into a contractual relationship with the retailer. Some opportunities regarding this have been outlined in the supply chain management literature (for e.g. Sari 2008). The second option for CPG manufacturers is to

⁷ Wasik, Bill (2013), "In the programmable world, all our objects will act as one," [available at <http://www.wired.com/2013/05/internet-of-things-2/>].

purchase scanner/panel data from syndicated sources such as A.C. Nielsen or IRI. This method of purchasing secondary panel data is commonly used in marketing research as well as in marketing practice. Several research papers in marketing have leveraged this data to develop insights on the effect of marketing mix on customer behavior (for e.g. Guadagni and Little 1983; Kamakura and Russell 1993). In the absence of advanced forms of retailer-manufacturer collaboration (such as Vendor Managed Inventory (VMI) or Collaborative Planning, Forecasting and Replenishment (CPFR) systems), our recommendation to manufacturers is to address the data void using syndicated sources.

The adoption of CLV opens the door to proactive customer management and marketing decisions. In following paragraphs, we outline a few key strategic implications of implementing CLV in the CPG context.

Embracing the Customer-centricity Paradigm

CLV has been applied and its benefits have been showcased in several industries and business settings. Some examples of CLV implementations in various industries include insurance (Verhoef and Donkers 2001), catalog mailing (Petersen and Kumar 2015), B2B Hi-tech (Kumar et al. 2008), airlines (Rust, Lemon, and Zeithaml 2004), internet retail (Fader, Hardie, and Lee 2005), automobile (Yoo and Hanssens 2005), telecommunications (Kumar, Petersen, and Leone 2013), financial services (Shah et al. 2012). A common theme among the above implementations is that past implementations of CLV have been mostly on ‘relationship’ driven business settings. That is, the adoption of CLV and customer centric concepts have been restricted to industries which have been heavily focused toward building customer relationships. A glaring gap in the above is that the CPG industry is yet to adopt the customer centric concept. Even today, most CPG managers rely on flow-based and product centric metrics to evaluate

marketing effectiveness. While this has worked in the past, it is no longer sustainable. By relying on flow based aggregate measures (such as sales, revenue, market share, etc.) CPG managers are leaving the customer at the door! For example, when studying the effectiveness of a promotional campaign, managers would likely state that there is a sales bump during the promotional period thereby concluding that the promotional campaign has a positive effect on sales. *But where is the sales coming from? Which customers are really purchasing the product? Could it be that the promotion only attracted deal prone unprofitable customers? Further, did the promotional campaign help the firm cultivate behavioral loyalty (measured as CLV)?* Answers to these questions are not obvious using aggregate metrics.

Secondly, flow based metrics that are currently used in CPG industries are very sensitive to extraneous shocks (such as small changes in macroeconomics). The volatility that arises due to this makes marketing decision making error prone and inaccurate since managers are unable to assess *why* a certain phenomenon occurs. Business performance in CPG markets is *fast moving* and *volatile*, especially in the presence of heavy promotional spending, thereby leading to short run myopic marketing decisions which are based on *reaction* rather than with strategic focus (Hanssens and Dekimpe 2008; Yoo, Hanssens, and Kim 2011). In such environments, it is difficult to assess whether a brand is doing well or not. CLV (or its aggregated counterpart, Customer equity (CE)) presents stability based on consumer behavior which is long term focused and forward looking in nature.

In a digitally connected world, where consumers engage with each other as well as the brand in real time, the customer centric paradigm (especially in the CPG setting) is no longer a competitive advantage but a necessity. CPG firms are investing heavily in innovations in CRM that would move them closer to a CLV based approach to decision making (e.g. Kimberly-

Clark's Huggies brand⁸). By analyzing customer level transaction data (obtained through scanner panel studies), managers at Kimberly-Clark were able to not only quantify the dollar value of specific consumer segments, but also chart the lifecycle of the customer relationships. As a result, Kimberly-Clark was able to garner a clearer picture of its target market as well as the profitable opportunities (consumers) that exist in the marketplace.

Framework to Manage Customer Relationships

A CLV based marketing approach allows the firm to view the customer as an asset (Srivastava, Shervani, and Fahey 1998) and assess the impact of marketing spend on customer level assets. CLV adoption fits very closely within the customer centricity paradigm where the core philosophy is to 'serve the customer' and achieve 'customer profitability'. Couched within customer centricity are concepts central to marketing such as the need to increase focus on customer satisfaction (Oliver 1999), customer service (Zeithaml, Berry, and Parasuraman 1993), customer loyalty (Reinartz and Kumar 2002), quality perceptions (Rust, Moorman, and Dickson 2002) etc. CLV represents a path to achieving improvements in the above critical marketing metrics while maintaining high levels of profitability. In the recent years, CLV, its applications to various industries have received attention not only among researchers but in practitioner-focused books as well (for e.g. Bejou, Keiningham, and Aksoy 2012; Kumar 2014).

The CLV metric opens the door for managers to differentially allocate marketing dollars to specific *types* of customers (or) segments of customers based on their profitability. This capability has spurred a great deal of innovations in building marketing strategy to maximize

⁸ Nielsen (2011), "Nielsen Insights in Action: Determining Consumer Lifetime Value," (accessed April 24, 2015), [available at <http://www.nielsen.com/content/dam/corporate/us/en/public%20factsheets/Case%20Studies/CaseStudy-KimberlyClark-ROI.pdf>].

profitability through CLV. By adopting CLV based marketing strategies, marketers can now not only identify their most valuable customers, but also manage the entire customer relationship from acquisition to retention. Some examples of the strategic implementations of include managing acquisition and retention (Reinartz, Thomas, and Kumar 2005), customer churn/defection (Neslin et al. 2006), product return behavior (Petersen and Kumar 2015) to name a few. For a detailed review of the customer management strategies that could be implemented through CLV, please refer to the ‘Wheel of Fortune’ strategies by Kumar (2009). Further, CLV can be flexibly used for making resource allocation decisions in order to achieve financial performance. Upon implementing a CLV based paradigm, firms have the capability to vary marketing actions and spend in order to arrive at an optimal marketing mix. Venkatesan (2015) guides managers in this direction by providing a five step process to optimal resource allocation using CLV. Critically important to the success of the above is the adoption of CLV.

Linking Marketing to Firm Value

In today’s marketing world, it is not only important to show growth in marketing metrics (such as quality perceptions, satisfaction levels etc.), but also in financial metrics. In fact, Welch (2004) raises alarm that marketers are slowly losing ground in the boardroom since firms and shareholders are demanding that marketing be linked with firm financials. Taking this challenge head on, researchers have shown that CLV is one of the best paths to creating firm value. Adopting a CLV or Customer Equity (CE) based metric has been shown to have extremely high financial benefits (Bolton 2004; Gupta and Zeithaml 2006; Kumar and Shah 2009). In fact, Gupta and Zeithaml (2006), in their review article on the link between customer metrics and firm performance, make a generalization (based on several years of empirical research) that *“Marketing decisions based on observed customer metrics, such as CLV, improve a firm’s*

financial performance". Customer relationships need to be viewed as investment decisions and therefore, customers need to be viewed as assets who generate revenue. CLV based metrics not only improve shareholder value by increasing cash flow, but also by reducing retention and switching costs (Stahl, Matzler, and Hinterhuber 2003). Further, a well-managed CLV paradigm has the capability to accelerate cash flows (through cross selling etc.), reduce cash flow volatility & vulnerabilities (through the constancy of demand from loyal customers) and increase the residual value of the firm (through quality, trust, commitment and reputation). These advantages make customer centric firms attractive to investors who value the above characteristics. To this end, past research encourages firms to report CLV/CE based measures in their financial reports. Specifically, Wiesel, Skiera, and Villanueva (2008) recommend firms to report CLV to investors since such reports align customer management with corporate goals and investor perspectives. Customer Lifetime Value (CLV) signals the health of a firm and therefore, improves investor perceptions in Wall Street.

In conclusion, CLV is a metric that is gaining wide acceptance in the marketplace due to its enormous strategic, operational and financial benefits. Therefore, CPG firms would be heavily benefitted by involving Customer Lifetime Value (CLV) in their decision making to ensure future growth and sustainable competitive advantage.

LIMITATIONS AND OPPORTUNITIES FOR FUTURE RESEARCH

We believe that this research opens several interesting avenues for further research (such as multi-category CLV, uncovering factors that influence the consumer's budget etc.) and also help CPG firms move further down the path toward building strategies to maximize customer level profits. Our proposed empirical illustration is focused toward single category purchases while considering CLV at the manufacturer level. However, an interesting avenue to explore

could be to expand the analysis to consider a basket of goods such that we can study CLV from a retailer's perspective. Also interesting is the exploration of cross-category effects and the retailer's decision within the CLV framework. That is, as Shankar and Kannan (2014) elaborate, retailers need to know which category needs to be stocked more and when should bundling be marketed by the retailer. A retailer level CLV model accounting for cross-category dependencies could be a logical next step in expanding the CLV concept to grocery purchases and also help design profitable pricing strategies. In our analyses, due to lack of marketing data, we are unable to include marketing cost information within the CLV computation. Possibly, the use of cooperative databases that track marketing information (Liu, Pancras, and Houtz 2014) could mitigate this issue and provide more robust CLV estimates in this industry.

While the proposed model is estimated at the brand level, it is conceivable that one could implement the model on more disaggregated choice sets (such as brand-sizes) rather than just brands (Fader and Hardie 1996; Pancras 2011). Within our data, as we do not observe enough variation in the consumption patterns across brand-size alternatives, we are unable to estimate such a model without having to face increased complexities and identification issues in the model. We acknowledge that inclusion of the size information (especially within the choice sets) could increase the efficiency of the CLV model and leave the formal investigation of this issue to future research. An issue that could arise within the proposed framework is that there could be correlated unobservables (such as extraneous shocks) that might influence the covariates as well as the consumption patterns. In our model, we are unable to control for this because we allow for the budget parameter to vary across time only deterministically and not stochastically. Thus, we would not be able to assess (or observe) stochastic shocks to the system that might influence the consumption. However, a formal dynamic model with stochastically varying budgets (with

serially correlated errors) would significantly complicate the estimation process and lead to empirical identification issues due to the parameter proliferation problem. Future research could specify a dynamic model of consumer budgeting behavior and incorporate this within the CLV framework. As an extension, future research could also explicitly study the drivers of consumer budgeting behavior in the CPG setting. Further, an extension of this research could include complementarities across and within the category to increase efficiency of the estimation and gather insights.

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TABLES AND FIGURES

Table 1- Prior literature on CLV

Representative research	Level of Aggregation	Structural Model	Estimation of consumer's budget	Customer-level data	Choice, Timing & Quantity models	Competition	Industry Application
Wiesel, Skiera, and Villanueva (2008)	Firm	No	No	No	-	No	Multiple
Venkatesan, Kumar, and Bohling (2007)	Individual	No	No	Yes	Different models; Joint estimation	No	Hi-tech B2B
Rust, Lemon, and Zeithaml (2004)	Individual	No	No	Yes	Different models; Independent estimation	Yes; Markov switching	Multiple
Keane and Wang (1995)	Geographic Zone	No	No	No	-	No	Newspaper
Kumar et al. (2008)	Individual	No	No	Yes	Different models; Joint estimation	Yes; through imputation	Hi-tech B2B
Singh, Borle, and Jain (2009)	Individual	No	No	Yes	Different models; Estimation using data augmentation	No	Direct Marketing
Venkatesan and Kumar (2004)	Individual	No	No	Yes	Different models; Independent estimation	No	Hi-tech B2B
Borle, Singh, and Jain (2008)	Individual	No	No	Yes	Different models; Joint estimation	No	Direct Marketing
Fader, Hardie, and Lee (2005)	Individual	No	No	Yes	Different models; Independent estimation	No	Internet Retailer
This study	Individual	Yes	Yes	Yes	Single model and unified estimation	Yes; within consumer utility	Consumer Packaged Goods (CPG)

Table 2- Incidence of Multiple discreteness in data

Number of brands purchased	Number of transactions	% of total transactions
1	426,096	54.61
2	251,249	31.20
3	88,741	11.37
4	14,229	1.82

Table 3- Variable Operationalization

Variable	Operationalization
State Dependence (SD_{ijt})	Indicator function: $SD_{ijt} = \begin{cases} 1; & \text{if } q_{ijt-1} > 0 \\ 0; & \text{else} \end{cases}$ [Adapted from Dubé, Hitsch, and Rossi (2010)]
Category Consumption Intensity ($LASTQty_{it}$ & $Recency_{it}$)	$LASTQty_{it}$ is measured as the total quantity purchased by consumer ‘i’ at time ‘t-1’. [Adapted from Chintagunta and Haldar (1998)] $Recency_{it}$ is measured as the time (in months) since the last purchase for consumer ‘i’. [Adapted from Kumar and Shah (2009)]
Deal usage intensity ($DEALintensity_{it}$)	$DEALintensity_{it}$ is measured as the cumulative number of times that the consumer ‘i’ has purchased the brand when it was on a deal (expressed as a percentage of total number of purchases made). It must be noted that the measure is updated as ‘t’ increases and is also normalized by the denominator restricting values between 0 and 1. [Adapted from Shah, Kumar, and Kim (2014)] $DEALintensity_{it} = \frac{\sum_{s=0}^{t-1} \text{No of Deal purchases}_{is}}{\text{Cumulative total purchase freq}_{it-1}}$
Coupon Usage intensity ($COUPintensity_{it}$)	$COUPintensity_{it}$ is measured as the cumulative number of times that the consumer ‘i’ has purchased the brand when using a coupon (expressed as a percentage of total number of purchases made). It must be noted that the measure is updated as ‘t’ increases and is also normalized by the denominator restricting values between 0 and 1. [Adapted from (Shah, Kumar, and Kim 2014)] $COUPintensity_{it} = \frac{\sum_{s=0}^{t-1} \text{No of Coupon purchases}_{is}}{\text{Cumulative total purchase freq}_{it-1}}$
Store Usage intensity ($STORE_intensity_{it}$)	$STORE_intensity_{it}$ is measured as the cumulative number of purchases made in a specific store format (food stores in this study) as a percentage of total number of purchases made. Similar to other intensity measures (Shah, Kumar, and Kim 2014), this measure is updated as ‘t’ increases. $STOREintensity_{it} = \frac{\sum_{s=0}^{t-1} \text{No of food store purchases}_{is}}{\text{Cumulative total purchase freq}_{it-1}}$
Diet Soda purchase intensity ($DIETSODA_intensity_{it}$)	$DIETSODA_intensity_{it}$ is measured as the cumulative number of diet soda purchases as a percentage of total purchases made by the consumer. [Adapted from Shah, Kumar, and Kim (2014)] $DIETSODA_intensity_{it} = \frac{\sum_{s=0}^{t-1} \text{No of diet soda purchases}_{is}}{\text{Cumulative total purchase freq}_{it-1}}$

Table 4- Summary Statistics of Relevant Variables

Variable	M	SD	Correlation matrix										
<i>Price^{Coca-Cola}</i>	2.9	0.16	1										
<i>Price^{Dr.Pepper}</i>	2.37	0.12	0.732***	1									
<i>Price^{Pepsi}</i>	2.83	0.14	0.836***	0.735***	1								
<i>Price^{Private Label}</i>	1.26	0.04	0.725***	0.243***	0.558***	1							
<i>LASTQty_{it}</i>	6.92	6.21	-0.008	0.010	-0.009***	-0.017**	1						
<i>Recency_{it}</i>	1.3	0.86	0.053***	0.022**	0.035***	0.049***	-0.104***	1					
<i>DEALintensity_{it}</i>	0.25	0.25	-0.013	-0.010	-0.016*	-0.012	-0.110***	0.011	1				
<i>COUPintensity_{it}</i>	0.04	0.09	-0.003	-0.002	-0.001	0.001	0.035***	0.001	0.287***	1			
<i>STORE_intensity_{it}</i>	0.43	0.27	-0.020**	-0.011	-0.021**	-0.022**	-0.207***	0.023***	0.400***	0.006	1		
<i>DIETSODA_intensity_{it}</i>	0.31	0.28	0.007	0.006	0.006	0.005	-0.084***	-0.022**	0.156***	0.033***	0.130***	1	

*p<0.1|**p<0.05|***p<0.01

Table 5- Model Performance

		MAD		MAPE	
		In sample	Out of sample	In sample	Out of sample
<u>Proposed Model</u>					
<i>Brand-level Quantity (q_{ijt})</i>	Coca-Cola	0.54	0.61	21.01	22.94
	Dr. Pepper	0.54	0.65	23.51	26.70
	Pepsi	0.53	0.55	19.57	21.12
	Private Label	0.44	0.53	18.88	21.60
<i>Category-level Quantity ($\sum_{j \in J} q_{ijt}$)</i>		1.39	1.56	27.75	29.87
<u>Benchmark Model</u>					
<i>Brand-level Quantity (q_{ijt})</i>	Coca-Cola	1.09	1.21	50.91	51.64
	Dr. Pepper	0.78	0.86	44.85	46.93
	Pepsi	1.24	1.27	51.02	52.96
	Private Label	0.74	0.95	48.84	51.01
<i>Category-level Quantity ($\sum_{j \in J} q_{ijt}$)</i>		3.54	3.81	41.61	43.89

Table 6- Budget and State Dependence Parameter Estimates

Effect	Parameter	M	SD	
	<i>Intercept</i>			
	Mean	$\bar{\zeta}_{0t}$	3.371***	.026
	Heterogeneity	V_{ζ_0}	.280***	.019
Budget Constraint (y_{it})	<i>Extraneous factors</i>			
	Age_{it}	ζ_1	.017**	.009
	Age_{it}^2	ζ_2	.001	.006
	$Seas_t$	ζ_3	.013**	.006
	Mean	$\bar{\delta}_t$.148***	.017
State Dependence (SD_{ijt})	Heterogeneity	V_{δ_i}	.030***	.005

^alog form

***p<0.001 **p<0.05 *p<0.1

Table 7- Brand-Specific Parameter Estimates for Baseline Utility

Variable	Coca-Cola		Dr. Pepper		Pepsi		Private Label	
	M	SD	M	SD	M	SD	M	SD
<i>Intercept (α_{ij})</i>								
Mean	-.501***	.049	-.662***	.060	-.607***	.069	-1.219***	.059
Heterogeneity	.399***	.034	.420***	.034	.830***	.070	.709***	.066
<i>Covariates (β_j)</i>								
<i>LASTQty_{it}</i>	.005**	.002	.005**	.002	.006**	.002	.007***	.003
<i>Recency_{it}</i>	-.001	.013	-.021**	.010	-.048***	.016	-.013	.016
<i>DEALintensity_{it}</i>	.175**	.086	.339**	.114	-.009	.144	-.309**	.149
<i>COUPintensity_{it}</i>	-.036	.255	-.831**	.262	.355	.288	-.664**	.336
<i>STORE_intensity_{it}</i>	-.107	.086	-.001	.101	-.106	.122	.248**	.115
<i>DIETSODA_intensity_{it}</i>	.196**	.090	-.001	.094	.011	.117	-.061	.114

***p<0.001 **p<0.05 *p<0.1

Table 8- Own- and Cross-effects of Price

Focal Brand ($P_j^{+10\%}, P_j^{-10\%}$)	Price Elasticity: 10% increase (decrease) in Price ^{ab}			
	Coca-Cola	Dr. Pepper	Pepsi	Private Label
<i>Coca-Cola</i>	-9.11 (10.02)	0.68 (-0.70)	1.54 (-1.67)	0.96 (-0.98)
<i>Dr. Pepper</i>	0.67 (-0.76)	-8.67 (9.42)	0.78 (-0.85)	1.74 (-1.78)
<i>Pepsi</i>	1.84 (-2.05)	0.83 (-0.88)	-9.00 (9.70)	1.02 (-1.40)
<i>Private Label</i>	0.74 (-0.78)	0.89 (-0.96)	0.70 (-0.71)	-12.45 (12.86)

^aall reported values are in percentages

^bpercentage changes in quantity for *decreases* in price are in parentheses.

Table 9- Price effects across CLV segments (Coca-Cola)

CLV segments	% change in quantity demanded	
	10% increase in Coca-Cola price	10% decrease in Coca-Cola price
<i>High</i>	-7.28	8.93
<i>Medium</i>	-9.45	10.49
<i>Low</i>	-10.14	12.39

Figure 1- Time Trends in Key Variables

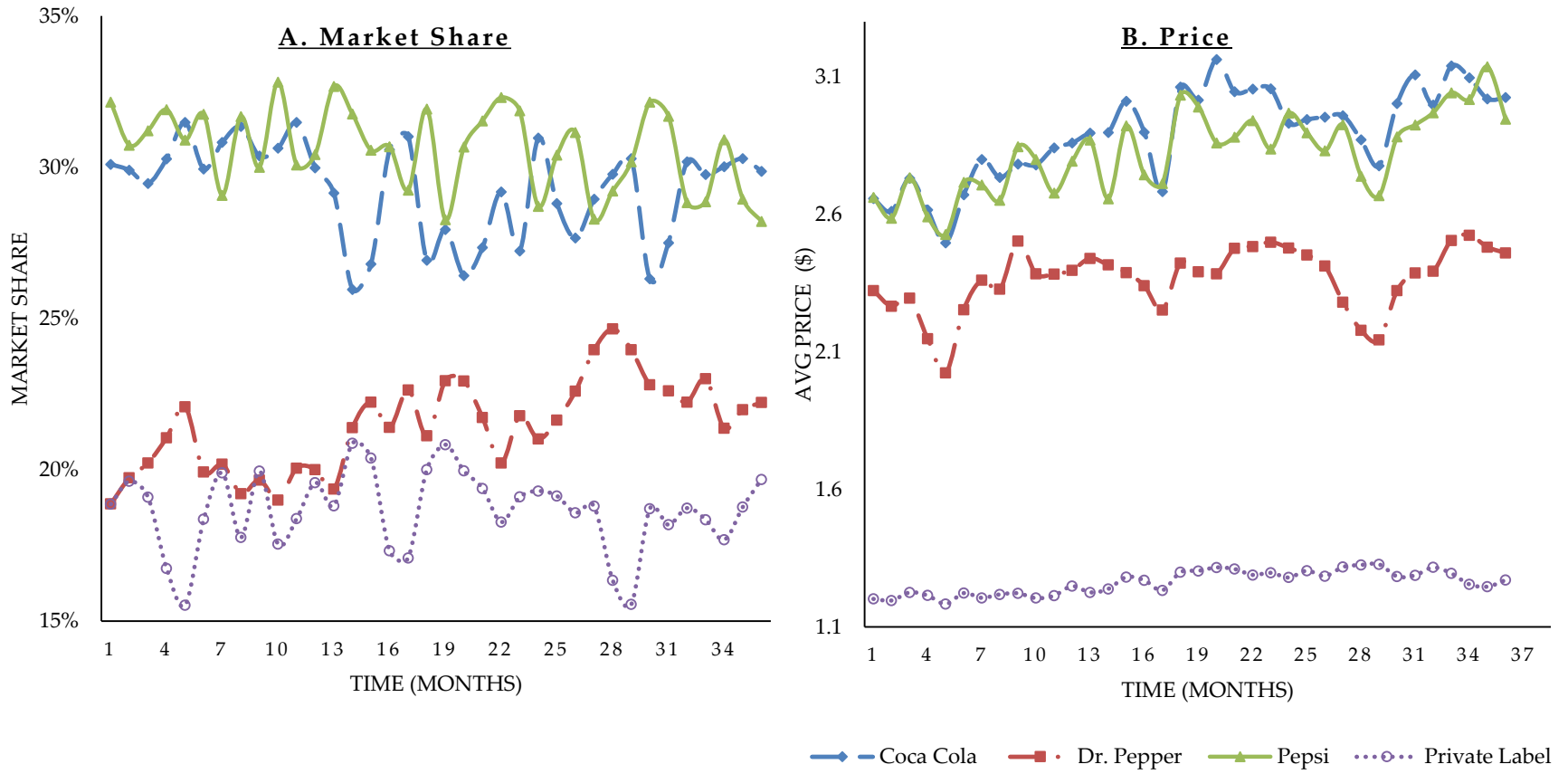


Figure 2- Histogram describing Customer-level Purchase Distribution

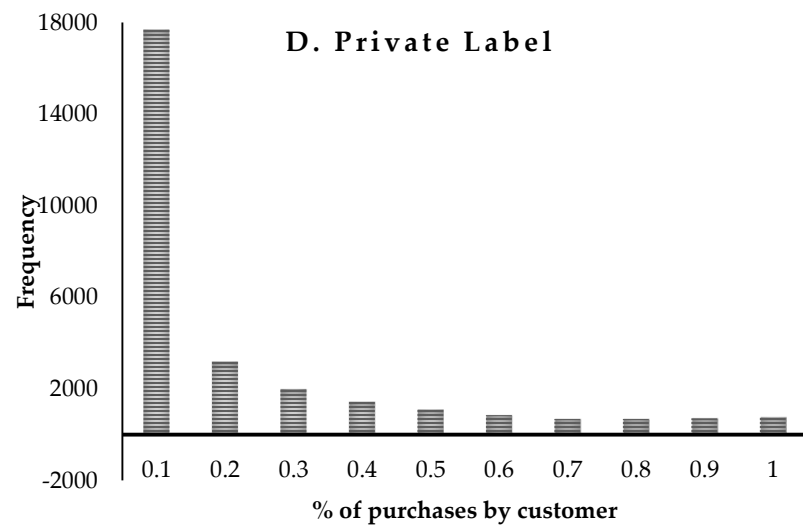
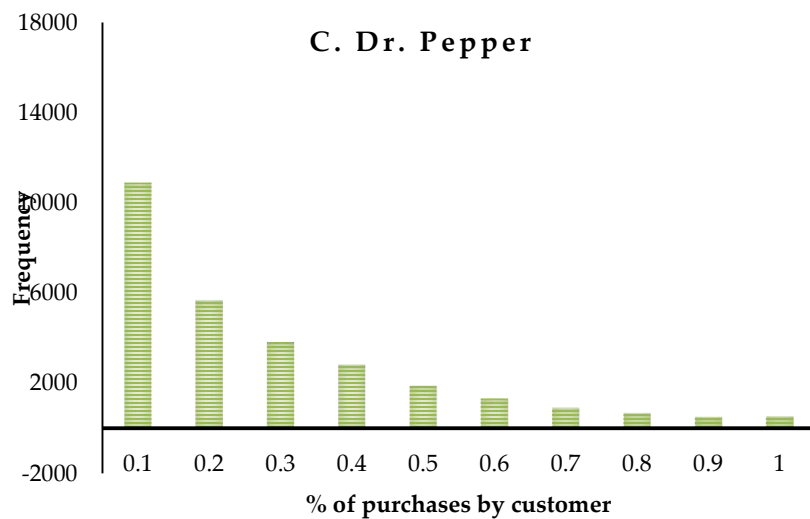
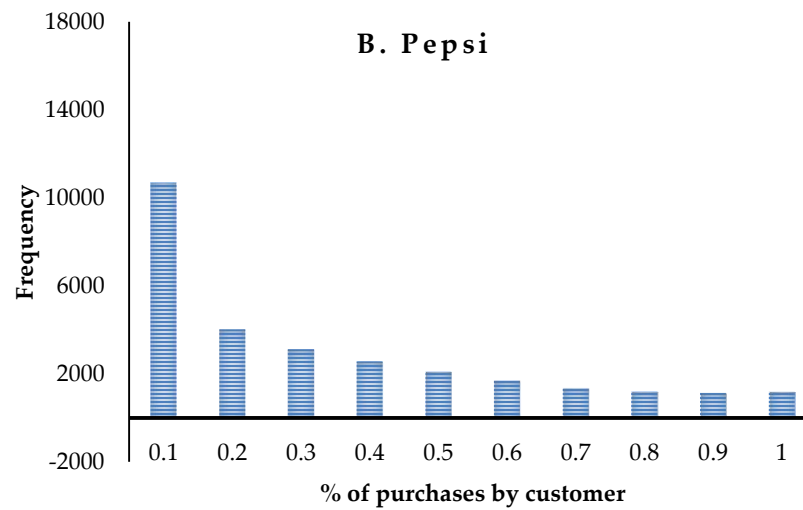
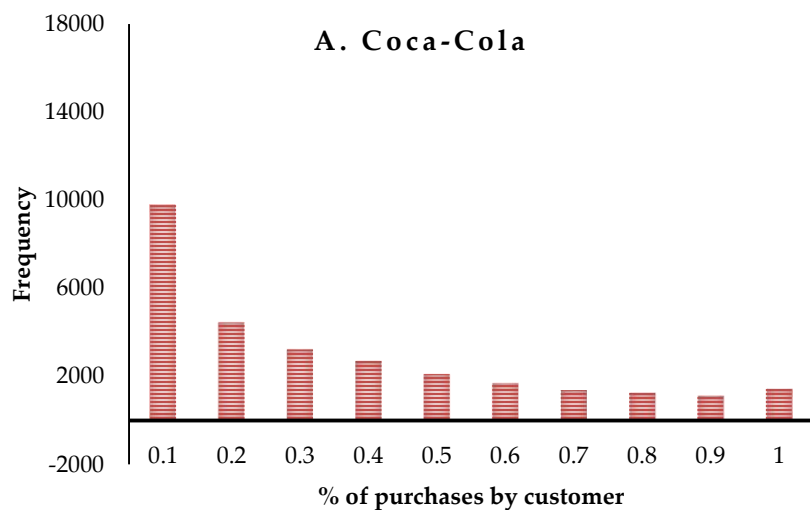


Figure 3- Bayesian Estimation Strategy

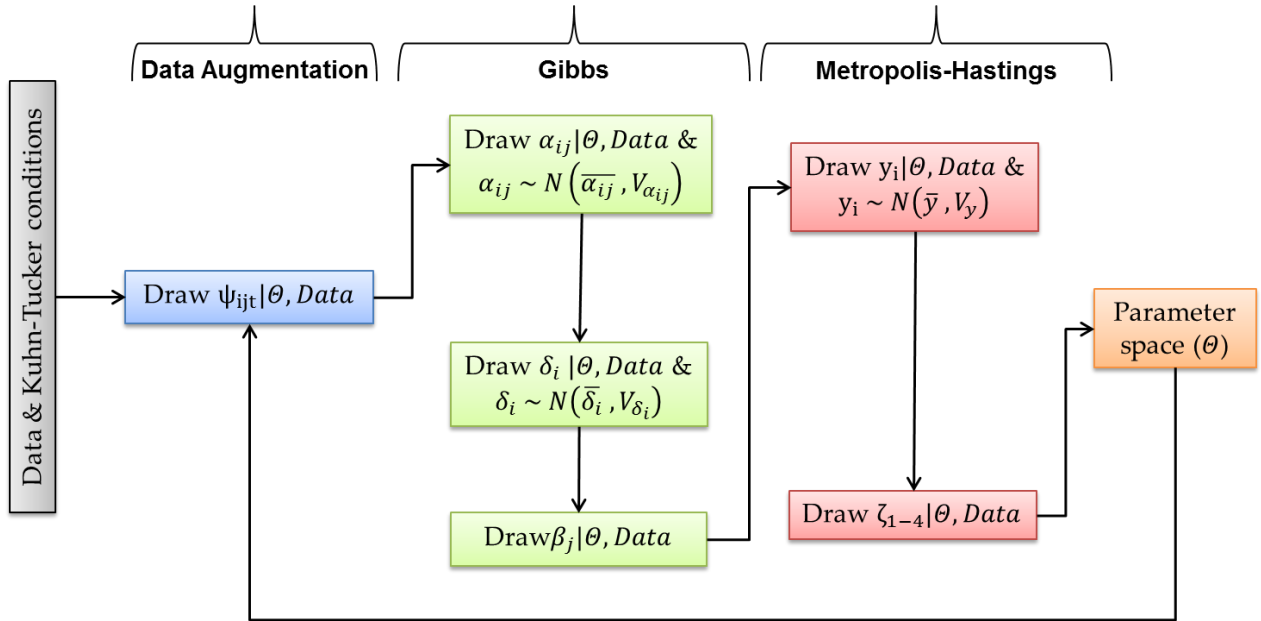


Figure 4- Distribution of Category-level CLV

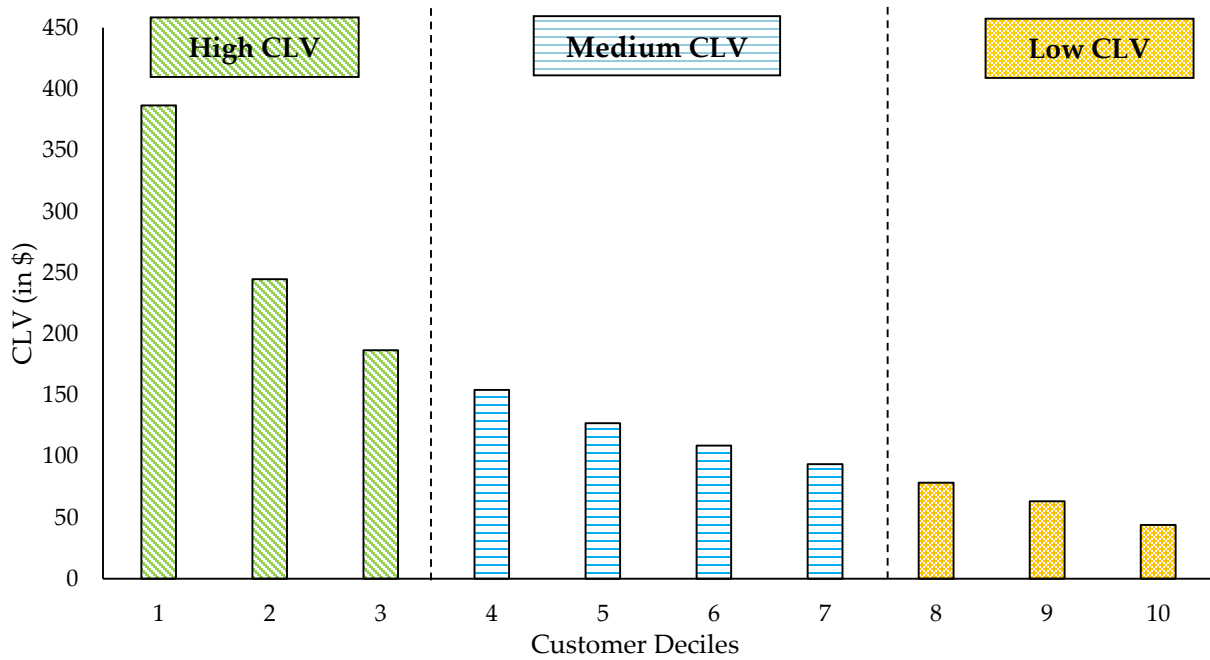


Figure 5- Brand share of Category-level CLV

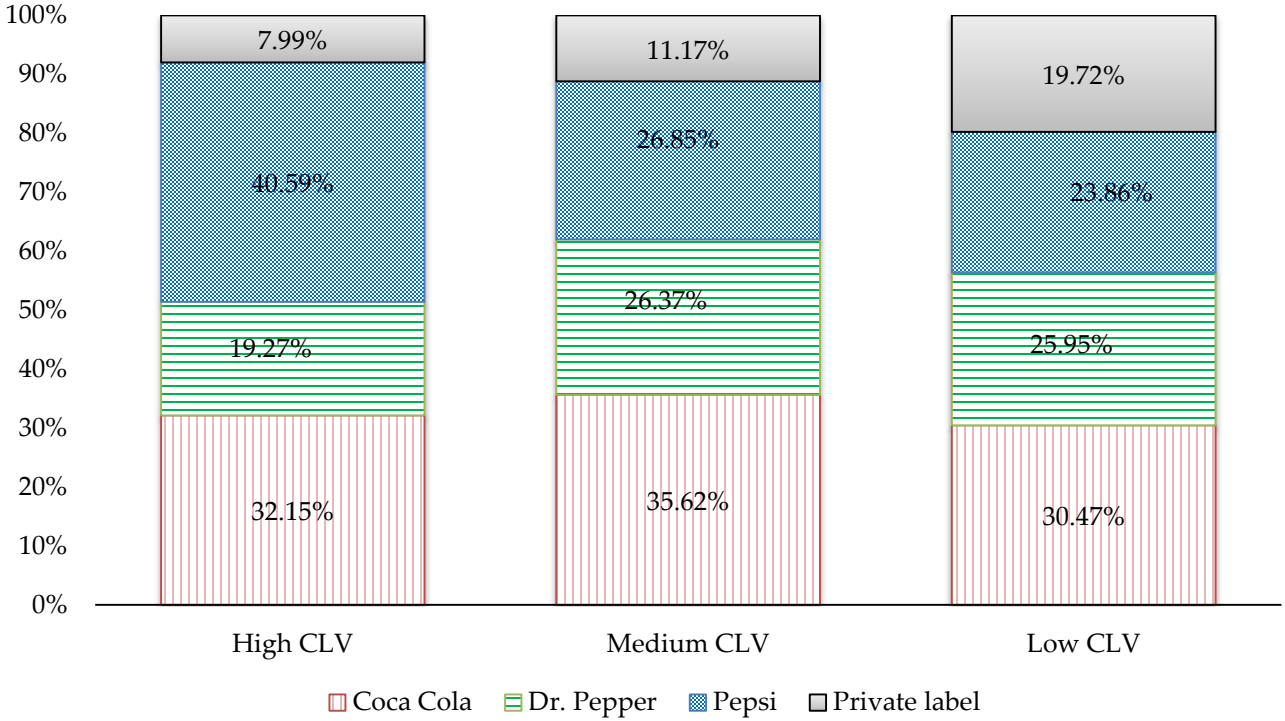
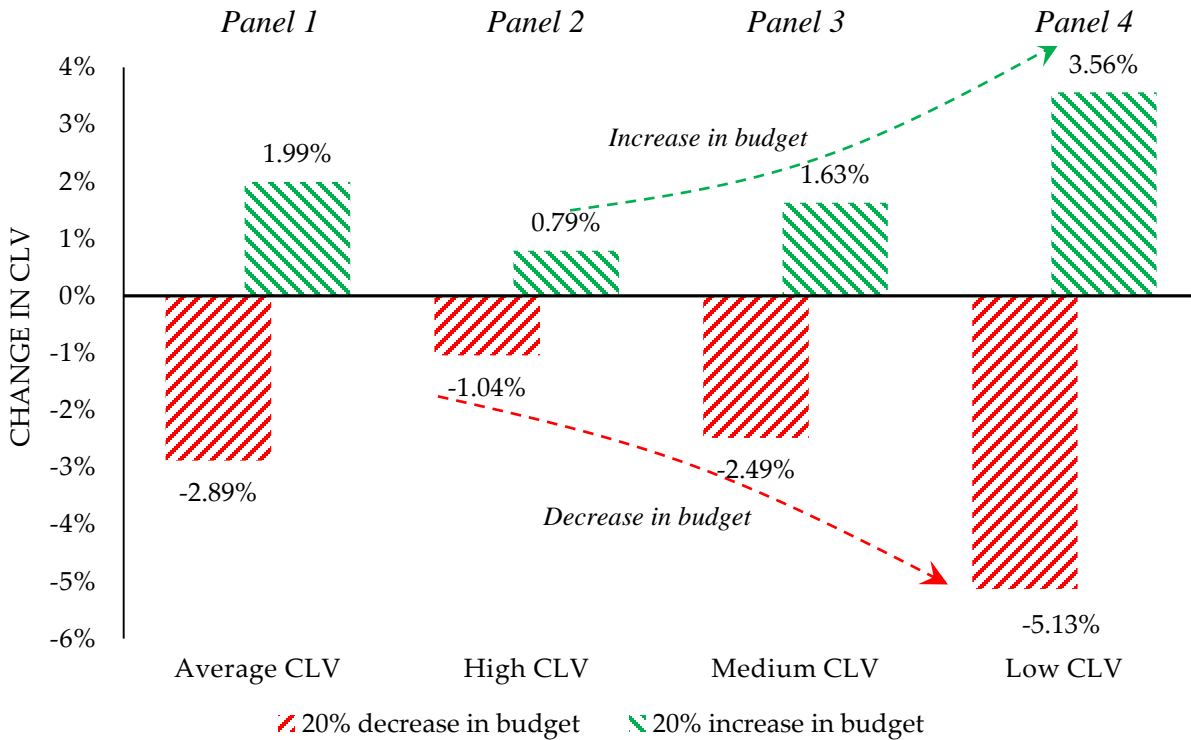


Figure 6- Counterfactual #1: Impact of the Budget Constraint on CLV



APPENDIX A- MODEL IDENTIFICATION

Unlike classical discrete choice models, budget constrained utility models like the one presented here, face an identification problem when trying to recover the intrinsic preference parameter (α_{ij}) in the brand utilities (ψ_{ijt}) along with the baseline budget constraint parameter (ζ_{0i}) which is couched within the overall budget parameter (y_{it}) as well as the Lagrangian (λ_i). To resolve this identification problem, we need to constrain at least one of the parameters in order to reliably recover the others. Following prior work (Bhat 2005; Kim, Allenby, and Rossi 2002; Kim, Allenby, and Rossi 2007), we fix $\lambda_i = 1$ and $\sigma^2 = 1$ in our estimation. This allows us to leverage our observed data to reliably identify the remaining parameters (α_{ij} and ζ_{0i}).

We now comment on the specific elements in the data that allow us to uniquely recover values of α_{ij} and ζ_{0i} . The identification of intrinsic preference α_{ij} in our model is very similar to a discrete choice model. Just like in a discrete choice setting, in order to identify intercepts (provided the scale and level of the utility are irrelevant) we need to observe enough variation in the consumer choices across brands (Train 2009). In our data, we observe a significant amount of brand switching, and variety seeking (across consumer variance in choices) as well as significant temporal variation in consumer tastes (within consumer variance in choices). This data, in combination with price variation across time and brands allows us to identify α_{ij} . We now turn to the data required to identify the baseline budget constraint (ζ_{0i}). Unlike classical discrete choice models which use only variation in choice (or market share) information, in our proposed model, we are able to leverage quantity information as well to help identify ζ_{0i} . As we describe in Equation 3, the budget constraint parameter is related to the dollar value that a customer spends toward the focal category. Thus, variation (across and within households) in quantity purchased at the brand level (q_{ijt}) along with temporal variation in prices at the brand level (P_{jt})

create a significant amount of variation in total dollars spent ($\sum_{j \in J} P_{jt} q_{ijt}$), thus allowing us to identify the baseline budget parameter ζ_{0i} reliably.

In addition, we justify the reliability of our estimation procedure by constructing theoretical scenarios where potential identification issues might exist and argue how the data allows us to uniquely identify the parameters α_{ij} and ζ_{0i} (holding all other covariates constant). Consider a consumer ‘i’ in two brand market at a time period ‘t’ where each brand is operating at price points P_A and P_B . Suppressing the ‘i’ and ‘t’ subscripts, we define the marginal utilities as a vector of the baseline brand level utilities $\{\psi_A, \psi_B\}$. Similarly, we define y as the overall category level budget constraint for the consumer. Given the available information, if the consumer decides to purchase quantities of q_A and q_B . The identification problem could potentially arise when unique combinations of the overall utility (described by α_{ij}) and y (described by ζ_{0i}) could generate the same data. Specifically, there are two conditions, where the overall utility vector $\{\psi_A, \psi_B\}$ and y that could generate the same values of the observed data (described by the vector $D = \{P_A, P_B, q_A, q_B\}$). The vector D can be generated through situations where consumer’s utility is high and budget constraint is low {Scenario 1: $\psi_A^{high}, \psi_B^{high}, y^{low}$ } or consumer’s utility is low and budget constraint is high {Scenario 2: $\psi_A^{low}, \psi_B^{low}, y^{high}$ }.

While in a static view these cases would generate the same observed data, we now show how variations in price elicit consumer responses that would allow us to uniquely identify $\{\psi_A, \psi_B\}$ and y . When P_A increases, the consumer in scenario 1 will decrease consumption of brand A (q_A) and increase consumption of brand B (q_B). This is because while the consumer derives high utility from consumption ($\psi_A^{high}, \psi_B^{high}$), she faces a heavy and restrictive budget constraint (y^{low}) that forces her to increase q_B . Thus, in scenario 1, there exists significant dependencies between P_A and q_B . When P_A increases in scenario 2, the consumer will decrease

consumption of brand A (q_A) but is unlikely to change her consumption of brand B (q_B). This is because the consumer has a low overall utility for consumption ($\psi_A^{low}, \psi_B^{low}$) to begin with and also has a very high threshold for the budget constraint (y^{high}), thus yielding a lower cross price elasticity. Thus, in scenario 2, the dependency between P_A and q_B is very low if not insignificant. Thus, using variation in pricing as well as quantity demanded at the brand level, we are able to construct unique estimates for utility and the budget constraint.

In conclusion, the level of the budget constraint parameter can be viewed as an indicator of competition. That is, when it is low, the consumer is more likely to switch across brands easily and when it is high, switching behavior is lesser. In addition to the above theoretical arguments, we also conducted a simulation study on synthetic data to make sure that we are able to recover the true parameters for various combinations of Y and y (true values) which would generate different values of D . Our estimation procedure was able to recover the true values for all the parameters within a confidence interval of 95%. Thus we can conclude that the identification of the parameters is reliable from a theoretical as well as an empirical standpoint.

APPENDIX B- ESTIMATION ALGORITHM

The estimation of the proposed model is done efficiently using a hybrid MCMC algorithm where (a) the parameters $(\alpha_{ij}, \beta_j, \delta_i)$ and their respective hyperparameters are drawn using Gibbs sampling since we can write the full conditionals, and (b) the parameters $(\zeta_{0i}, \text{ and } \zeta_1 - \zeta_4)$ and the respective hyperparameters are drawn using the Metropolis-Hastings (M-H) algorithm. Within the hybrid algorithm, we cycle through Gibbs and M-H sampling until convergence is achieved. As per the model specification, we have the following parameters that need to be estimated.

$$\alpha_{ij} \sim N(\bar{\alpha}_j, V_{\alpha_j}); \delta_i \sim N(\bar{\delta}, V_{\delta}); \zeta_{0i} \sim N(\bar{\zeta}_0, V_{\zeta_0}); \beta_j; \zeta_1 - \zeta_4 \quad (\text{B1})$$

We design the MCMC algorithm as follows,

Step 1: Data Augmentation & Gibbs sampling

Generate $\psi_{ijt} | \alpha_{ij}, \delta_i, y_i, \beta_j$: Our draws of ψ_{ijt} and the subsequent hyperparameters is analogous to the approach adopted in the Bayesian estimation of a multinomial Probit model (Albert and Chib 1993; Allenby and Rossi 1998) or a Tobit censored regression model (Chib 1992) with a few modifications. There are two conditions that would govern the data augmentation of ψ_{ijt} . In case of an interior solution ($q_{ijt} > 0$), the draw of ψ_{ijt} is done through a probability density function (see Equation 5a) such that,

$$\psi_{ijt} | \alpha_{ij}, \delta_i, y_i, \beta_j \sim N\left(\frac{\lambda_i P_{jt}(1 + q_{ijt})}{y_{it} - \sum_{j=1}^J [P_{jt} q_{ijt}]} - \psi_{ijt}^*, \sigma^2\right) \quad (\text{B2a})$$

Where $\psi_{ijt}^* = \alpha_{ij} + \delta_i SD_{ijt} + \beta_j X_{it}$ as described in Equation 6.

In the case of a corner solution ($q_{ijt} = 0$), then the draw of ψ_{ijt} is done through a truncated normal distribution (see Equation 5b) such that,

$$\psi_{ijt}|\alpha_{ij}, \delta_i, y_i, \beta_j \sim TN\left(\frac{\lambda_i P_{jt}(1 + q_{ijt})}{y_{it} - \sum_{j=1}^J [P_{jt} q_{ijt}]} - \psi_{ijt}^*, \sigma^2\right) \quad (\text{B2b})$$

Generate $\{\alpha_{ij}\}, \bar{\alpha}_j, V_{\alpha_j}, \{\delta_i\}, \bar{\delta}, V_{\delta}, \{\beta_j\}|\psi_{ijt}$: The above draw converts the Equation 6 into a standard multivariate regression model with heterogeneity. We can estimate the parameters listed in Equation A1 using Gibbs sampling since the full conditionals can be derived. Specifically, we draw the following densities,

$$\alpha_{ij}|\bar{\alpha}_j, V_{\alpha_j}, \psi_{ijt}, \delta_i, \beta_j \quad (\text{B3})$$

$$\delta_i|\bar{\delta}, V_{\delta}, \psi_{ijt}, \alpha_{ij}, \beta_j \quad (\text{B4})$$

$$\beta_j|\psi_{ijt}, \alpha_{ij}, \delta_i \quad (\text{B5})$$

$$\bar{\alpha}_j|\alpha_{ij}, V_{\alpha_j} \quad (\text{B6})$$

$$V_{\alpha_j}|\alpha_{ij}, \bar{\alpha}_j \quad (\text{B7})$$

$$\bar{\delta}|\delta_i, V_{\delta} \quad (\text{B8})$$

$$V_{\delta}|\delta_i, \bar{\delta} \quad (\text{B9})$$

The priors and the posterior densities for the above MCMC draws are detailed in

Appendix C.

Step 2: M-H Algorithm

Since we do not have closed-form expression for the posterior probability distributions of y_i , & $\zeta_1 - \zeta_4$, we need to use the Metropolis-Hastings algorithm with random walk for estimation. From Equation 9,

$$L_i(\theta) = \int_{-\infty}^{\infty} \prod_{t=1}^T \prod_{j=0}^J \left(\phi(\varepsilon_{ijt}) \cdot |J|_{\varepsilon_{ijt} \rightarrow q_{ijt}} \right)^{I(q_{ijt} > 0)} \cdot \Phi(\varepsilon_{ijt})^{(1 - I(q_{ijt} > 0))} f(\theta_i) d\theta_i \quad (\text{B10})$$

Let $\zeta_{0i}^{(m)}$ denote the m^{th} draw for ζ_{0i} . The next draw ($m+1$) is given by

$$\zeta_{0i}^{(m+1)} = \zeta_{0i}^{(m)} + \xi_{\zeta_0} \quad (\text{B11})$$

Where ξ_y is a draw from the candidate generating density (normal distribution).

The probability of accepting the new draw ($\zeta_{0i}^{(m+1)}$) is given by

$$\min \left[\frac{\exp \left(-\frac{1}{2} \left(\zeta_{0i}^{(m+1)} - \bar{\zeta}_0 \right)' V_y^{-1} \left(\zeta_{0i}^{(m+1)} - \bar{\zeta}_0 \right) \right) \cdot L(\theta_i)^{(m+1)}}{\exp \left(-\frac{1}{2} \left(\zeta_{0i}^{(m)} - \bar{\zeta}_0 \right)' V_y^{-1} \left(\zeta_{0i}^{(m)} - \bar{\zeta}_0 \right) \right) \cdot L(\theta_i)^{(m)}} , 1 \right] \quad (\text{B12})$$

If the new draw is rejected, then $\zeta_{0i}^{(m+1)} = \zeta_{0i}^{(m)}$. Using the drawn ζ_{0i} values, we can easily draw $\bar{\zeta}_0$ and V_{ζ_0} using Gibbs sampling similar to the procedure described in Step 1. This procedure of generating the parameter using M-H algorithm is repeated for the $\zeta_1 - \zeta_4$ parameters as well. Once this step is over, we iterate again over the densities drawn in Step 1 and then repeat this process until convergence is met.

APPENDIX C- THE GIBBS SAMPLER

The Gibbs sampler to make generate draws of $\{\alpha_{ij}\}$, $\{\delta_i\}$, and $\{\beta_j\}$ as well their corresponding hyperparameters is based on the estimation procedure of a multinomial probit model (Allenby and Rossi 1998; McCulloch and Rossi 1994; Rossi and Allenby 1993; Rossi, McCulloch, and Allenby 1995). The advantage of using the Gibbs sampler is that we avoid direct simulation or approximation of choice probabilities and exploit the full latent variable structure of the model through the augmentation of ψ_{ijt} . The basic Gibbs sampler strategy is to draw from a joint distribution of a collection of random variables by drawing successively from various conditional distributions. That is, we can ‘break’ the joint distribution estimation into k groups and cycle through these k conditional distributions without loss of generality.

Priors

There three sets priors that are used in the Gibbs sampler, (1) the priors on $\bar{\alpha}_j$ and V_{α_j} - the brand specific heterogeneous intercepts, (2) the priors on $\bar{\delta}$ and V_{δ} - the heterogeneous state dependence parameter, and (3) the priors on β_j - brand specific covariates.

1) Priors on $\bar{\alpha}_j$ and V_{α_j} :

a) $\bar{\alpha}_j \sim N\left(a_{0j}, \left(V_{\alpha_j} \otimes A_{0j}\right)\right)$; This is the natural conjugate prior for multivariate regression

where a_{0j} and A_{0j} are diffuse.

b) $V_{\alpha_j} \sim IW\left(v_{0\alpha_j}, V_{0\alpha_j}\right)$

2) Priors on $\bar{\delta}$ and V_{δ} :

a) $\bar{\delta} \sim N\left(c_0, \left(V_{\delta} \otimes C_0\right)\right)$; This is the natural conjugate prior for multivariate regression where

c_0 and C_0 are diffuse.

b) $V_{\delta} \sim IW\left(v_{0\delta}, V_{0\delta}\right)$

3) Priors on β_j :

$$\beta_j \sim N(d_{0j}, \sigma^2 D_{0j}^{-1}); \text{ where } d_{0j} \text{ and } D_{0j}^{-1} \text{ are defined to be diffuse.}$$

Conditional Posteriors

The Gibbs sampler cycles through posterior densities wherein we first use data augmentation to generate ψ_{ijt} and then use this value as *known* (see Step 1 in **Appendix B**).

Then we generate draws of the remaining parameters as described below.

1) $\alpha_{ij} | \bar{\alpha}_j, V_{\alpha_j}, \psi_{ijt}, \delta_i, \beta_j$

We first treat $\bar{\alpha}_j, V_{\alpha_j}, \psi_{ijt}, \delta_i$, and β_j as known and compute the following.

$$W_{ijt}^* = \psi_{ijt} - (\delta_i S D_{ijt} + \beta_j X_{it}) \quad (\text{C1})$$

which reduces the regression equation to

$$W_{ijt}^* = \alpha_{ij} + \varepsilon_{ijt} \quad (\text{C2})$$

Now the posterior can be written as,

$$\alpha_{ij} \sim N\left(\bar{\alpha}_j, \left(I_{ijt}' I_{ijt} + V_{\alpha_j}^{-1}\right)\right) \quad (\text{C3})$$

where

I_{ijt} is a vector of ones,

$$\bar{\alpha}_j = \left(I_{ijt}' I_{ijt} + V_{\alpha_j}^{-1}\right)^{-1} \left[I_{ijt}' I_{ijt} \widehat{\alpha}_{ij} + V_{\alpha_j}^{-1} \bar{\alpha}_j\right],$$

$$\widehat{\alpha}_{ij} = \left(I_{ijt}' I_{ijt}\right)^{-1} I_{ijt}' W_{ijt}^*$$

2) $\bar{\alpha}_j | \alpha_{ij}, V_{\alpha_j} \text{ \& } V_{\alpha_j} | \alpha_{ij}, \bar{\alpha}_j$

We can now hierarchically treat the hyperparameters in the regression equation as

$$\alpha_{ij} = \bar{\alpha}_j + \xi_{ij}^{(\alpha)}; \xi_{ij}^{(\alpha)} \sim N(0, V_{\alpha_j}) \quad (\text{C4})$$

Using standard conjugate theory, we can write the posteriors as follows,

$$\bar{\alpha}_j \sim N\left(\tilde{d}_j^{(\alpha)}, \left(V_{\alpha_j}^{-1} \otimes A_{0j}\right)\right); \quad (\text{C5})$$

$$V_{\alpha_j} \sim IW \left((v_{0\delta} + N), \left(V_{0\delta} + \sum_N (\alpha_{ij} - \bar{\alpha}_j)(\alpha_{ij} - \bar{\alpha}_j)' \right) \right)$$

Where,

$$\tilde{d}_j^{(\alpha)} = \text{vec} \left(\tilde{D}_j^{(\alpha)} \right); \tilde{D}_j^{(\alpha)} = (I_{ij}' I_{ij} + A_{0j})^{-1} (I_{ij}' \alpha_{ij} + A_{0j} \bar{d}^{(\delta)})$$

3) $\delta_i | \bar{\delta}, V_\delta, \psi_{ijt}, \alpha_{ij}, \beta_j$

We now treat $\bar{\delta}, V_\delta, \psi_{ijt}, \alpha_{ij}$, and β_j as known and compute the following.

$$Z_{ijt}^* = \psi_{ijt} - (\alpha_{ij} + \beta_j X_{it}) \quad (\text{C6})$$

which reduces the regression equation to

$$Z_{ijt}^* = \delta_i SD_{ijt} + \varepsilon_{ijt} \quad (\text{C7})$$

Now the posterior can be written as (stacking the 'j' observations one under another),

$$\delta_i \sim N \left(\bar{c}_0, (SD_{ijt}' SD_{ijt} + V_\delta^{-1}) \right) \quad (\text{C8})$$

where

$$\begin{aligned} \bar{c}_0 &= (SD_{ijt}' SD_{ijt} + V_\delta^{-1})^{-1} [SD_{ijt}' SD_{ijt} \hat{\delta}_i + V_\delta^{-1} \bar{\delta}], \\ \hat{\delta}_i &= (SD_{ijt}' SD_{ijt})^{-1} SD_{ijt}' Z_{ijt}^* \end{aligned}$$

4) $\bar{\delta} | \delta_i, V_\delta$

As before, we can hierarchically treat the hyperparameters in the regression equation as

$$\delta_i = \bar{\delta} + \xi_{ij}^{(\delta)}; \xi_{ij}^{(\delta)} \sim N(0, V_\delta) \quad (\text{C9})$$

Using standard conjugate theory, we can write the posteriors as follows,

$$\begin{aligned} \bar{\delta} &\sim N \left(\tilde{d}_j^{(\delta)}, (V_\delta^{-1} \otimes C_0) \right); \\ V_\delta &\sim IW \left((v_{0\delta} + N * T), \left(V_{0\delta} + \sum_{N*T} (\delta_i - \bar{\delta})(\delta_i - \bar{\delta})' \right) \right) \end{aligned} \quad (\text{C10})$$

Where,

$$\tilde{d}_j^{(\delta)} = \text{vec} \left(\tilde{D}_j^{(\delta)} \right); \tilde{D}_j^{(\delta)} = (SD_{ij} + C_0)^{-1} (SD_{ij}' \delta_i + C_0 \bar{d}^{(\delta)})$$

5) $\beta_j | \psi_{ijt}, \alpha_{ij}, \delta_i$

As before, the regression equation is rewritten as,

$$H_{ijt}^* = \psi_{ijt} - (\alpha_{ij} + \delta_i S D_{ijt}) \quad (\text{C11})$$

which reduces the regression equation to

$$H_{ijt}^* = \beta_j X_{it} + \varepsilon_{ijt} \quad (\text{C12})$$

Thus, the posterior is given by,

$$\beta_j \sim N(\tilde{\beta}_j, \sigma^2 (X'_{it} X_{it} + D_{oj}^{-1})^{-1}) \quad (\text{C13})$$

Where,

$$\tilde{\beta}_j = (X'_{it} X_{it} + D_{oj}^{-1})^{-1} (X'_{it} H_{ijt}^* + D_{oj}^{-1} \bar{\beta}_j)$$

APPENDIX D- SIMULATION STUDY

To make sure we don't have an identification problem as well as ensure that we recover the all the parameters in the proposed model, we conducted a simulation study wherein we created synthetic data and attempted to estimate the parameters specified in the model. Specifically, we simulated a market with 500 customers with 20 time periods each and individual specific budget constraints with a *true* population mean and variance. The market consisted of 3 brands operating at different prices⁹. Further, we generated fully heterogeneous and brand-specific parameters to capture the effect of 2 covariates. Using this data, we simulated consumer quantity purchases for each time period which we use in the model. Now, using the hybrid MCMC estimation algorithm explained earlier, we attempt to recover the *true* parameters. In all cases, we were able to recover the parameters within a 95% confidence interval confirming empirically that the estimation algorithm is able to recover the true parameters to a satisfactory degree. We report the true and recovered parameters in Table 10. Given this result, we now move to model estimation on the scanner panel data.

Table 10- Simulation Study Results

Parameter		Estimated values		True values		
		Mean	SD			
<i>Heterogeneous Budget Constraint:</i>		μ_y	2.999	0.004	3.000	
$y_i \sim N(\mu_y, V_y)$		V_y	1.037	0.004	1.000	
<i>Brand-specific covariates (b1, b2, & b3)</i>	<i>For brand 1:</i>		$\mu_{\beta 1}^{b1}$	-0.202	0.011	-0.200
			$V_{\beta 1}^{b1}$	1.518	0.099	1.500
	$\beta_{1i}^{b1} \sim N(\mu_{\beta 1}^{b1}, V_{\beta 1}^{b1});$		$\mu_{\beta 2}^{b1}$	-2.474	0.453	-2.000
	$\beta_{2i}^{b1} \sim N(\mu_{\beta 2}^{b1}, V_{\beta 2}^{b1})$		$V_{\beta 2}^{b1}$	0.097	0.004	0.089
	<i>For brand 2:</i>		$\mu_{\beta 1}^{b2}$	0.142	0.027	0.100
	$\beta_{1i}^{b2} \sim N(\mu_{\beta 1}^{b2}, V_{\beta 1}^{b2});$		$V_{\beta 1}^{b2}$	1.092	0.029	1.050

⁹ We iterated various combinations of choice sets and true parameters. Specifically, we tried recovering the true values using scenarios wherein the number of brands in the market varies from 2 to 4. Further, we also used various true values as well as starting values in the estimation algorithm.

$\beta_{2i}^{b2} \sim N(\mu_{\beta 2}^{b2}, V_{\beta 2}^{b2})$	$\mu_{\beta 2}^{b2}$	2.948	0.178	3.000
	$V_{\beta 2}^{b2}$	0.262	0.023	0.177
<hr/>				
<i>For brand 3:</i>	$\mu_{\beta 1}^{b3}$	0.465	0.073	0.500
$\beta_{1i}^{b3} \sim N(\mu_{\beta 1}^{b3}, V_{\beta 1}^{b3});$	$V_{\beta 1}^{b3}$	0.937	0.098	1.036
$\beta_{2i}^{b3} \sim N(\mu_{\beta 2}^{b3}, V_{\beta 2}^{b3})$	$\mu_{\beta 2}^{b3}$	1.987	0.074	2.000
	$V_{\beta 2}^{b3}$	0.032	0.008	0.038
<hr/>				

APPENDIX E- BENCHMARK MODEL SPECIFICATION

Conventional CLV models have mostly relied on a multi-equation choice and quantity models to evaluate the customer's purchase behavior (Gupta et al. 2006; Kumar et al. 2008). In order to take advantage of the correlations between brand choices, we specify a multivariate Probit choice model as follows. We begin with a J-equation multivariate Probit model described in terms of a correlated Gaussian distribution for underlying latent variables which translate to discrete choices through a threshold specification. The parameter space is denoted as $\Delta^{(1)}$ and we use the same variables used in the proposed model (denoted by Z). The consumer's choice of brand 'j' at time 't' is denoted by D_{ijt} .

$$D_{ijt}^* = \Delta^{(1)}Z_{ijt} + \xi_{ijt} \text{ and } \xi_{ijt} \sim MVN(0, \mathbf{V})$$

$$D_{ijt} = \begin{cases} 1; & \text{if } D_{ijt}^* > 0 \\ 0 & \text{else} \end{cases} \quad (\text{D13})$$

The joint probabilities of the observed choices ($D_{ijt} | \Delta^{(1)}, Z$) is given by the J-variate normal probabilities and can be estimated using simulation based integration methods. We follow the procedure detailed by Cappellari and Jenkins (2003) based on the GHK simulated likelihood method to estimate the above model. Next, conditional on the customer 'i' choosing brand 'j' at time 't', we estimated a log regression model to predict quantity purchased (Verhoef and Donkers 2001). For each brand 'j',

$$\log(q_{it}) = \Delta^{(2)}Z_{it} + \eta_{it} \text{ and } \eta_{it} \sim N(0, V_{\eta}) \quad (\text{D14})$$

The regression model is estimated using ordinary least squares and the predicted values \widehat{q}_{ijt} are used for the MAD and MAPE calculations.

APPENDIX F- RESULTS OF SIMULATION EXERCISE #2

Table 11- Impact of 10% change in Dr. Pepper Price

CLV segments	% change in quantity demanded	
	10% increase in Dr. Pepper price	10% decrease in Dr. Pepper price
<i>High</i>	-8.67	9.42
<i>Medium</i>	-7.99	10.13
<i>Low</i>	-9.37	11.32

Table 12- Impact of 10% change in Pepsi Price

CLV segments	% change in quantity demanded	
	10% increase in Pepsi price	10% decrease in Pepsi price
<i>High</i>	-9.00	9.70
<i>Medium</i>	-8.43	9.28
<i>Low</i>	-10.08	10.15

Table 13- Impact of 10% change in Private Label Price

CLV segments	% change in quantity demanded	
	10% increase in Private Label price	10% decrease in Private Label price
<i>High</i>	-12.45	12.86
<i>Medium</i>	-8.83	9.08
<i>Low</i>	-14.88	15.66