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Contents lists available at ScienceDirect

Australasian Marketing Journal

journal homepage: www.elsevier.com/locate/amj

Making sense of common Dirichlet deviations

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ARTICLE INFO

Article history:

Received 30 July 2017

Revised 7 October 2017

Accepted 31 October 2017

Available online 26 November 2017

Keywords:

NBD-Dirichlet

Brand choice behaviour

Non-stationarity

Niche brand

Duplication of Purchase

ABSTRACT

This paper reviews the regularly recurring deviations between buyer behaviour patterns and predictions from the NBD-Dirichlet model. Previous studies have tended to look at one or two Dirichlet Deviations in isolation; the aim here is to learn more about their managerial significance by categorising them according to their behavioural indicators, summarising their incidence and extent and relating them to the implied breaches of assumptions of the model. We replicate prior research results in a single, extensive database of 62 FMCG categories and find that the Dirichlet Deviations take three forms; slight systematic variances in expected metrics across all brands in every fitting, suggesting some failure in stationarity; certain types of persistent deviation for individual brands or groups of brands that indicate partitioning; and those that capture dynamic performance. Analysis shows that consumer purchase propensities are never quite fixed or entirely independent, yet brand performance remains close to Dirichlet prediction. Managers who use this model need to be aware of the strategic options that the deviations imply, and we discuss these. Findings also contribute to the idea that deviations might be reduced by model adaptations although the managerial simplicity of the NBD-Dirichlet sets a major challenge to this.

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CHINESE ABSTRACT

本文回顾了消费者行为模式与NBD-Dirichlet模型预测之间的常规性重复出现的偏差。以前的研究倾向于孤立地研究一个或两个Dirichlet偏差；本文目的是根据行为指标对偏差进行分类，总结其发生率和程度，暗示其可能违背了模型假设，进一步了解偏差的管理重要性。我们将以前的研究成果复制到单独的一个含有62个CPG类别的扩展数据库中，发现Dirichlet偏差有三种形式：每次拟合中所有品牌的期望度量都存在的微小系统方差，表明稳定性有一些缺陷；某个品牌或某组品牌特有的持续偏差，说明需要分类；以及捕捉动态表现的偏差。分析显示，消费者购买倾向从未完全固定或完全独立，但品牌表现仍然接近Dirichlet模型的预测。使用该模型的管理者需要意识到偏差所暗示的战略选择，我们对此加以讨论。研究结果也引出了通过模型改造来减少偏差的想法，尽管NBD-Dirichlet模型的管理简单性对此构成了重大挑战。

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1. Introduction

Managers concerned with setting strategic objectives in consumer packaged goods (CPG) categories must first consider how consumer choice behaviour defines competitive market structure. Is a brand growing because it has reached more buyers, or because its customer base is becoming more loyal? Which competing brands pose more (or less) of a threat? Since market share is most frequently a zero sum measure it is important for managers to understand brand performance in its competitive context (Franses et al., 2001) because the underlying metrics of buyer behaviour

(purchase frequency, penetration, switching, distribution of heavy and light buyers by brand) can only be improved at the expense of competitors.

One model that has been extensively adopted in industry (Kennedy and McColl, 2012; Sharp, 2010) is the NBD-Dirichlet (Goodhardt et al., 1984), because (a) it closely describes how consumers buy and brands compete (Ehrenberg et al., 2004), and (b) because it is parsimonious, depending on just a handful of theoretical assumptions concerning the distribution of brand purchase probabilities (Ehrenberg and Sharp, 2000), and (c) because its output then incorporates many well-established empirical generalisations in repeat-buying across competing brands. These norms include the laws of Double Jeopardy, Natural Monopoly and Duplication of Purchase, and the invariant patterns of consumer heterogeneity (Ehrenberg et al., 2000).

Dirichlet modelling is descriptive, not prescriptive. It seeks to uncover the main effects in observed data, rather than to obtain a

Declaration of Interest: This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

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<https://doi.org/10.1016/j.ausmj.2017.10.007>

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best fit. Its main use is to benchmark observed outcomes against what would be expected to happen in theory, in order to evaluate past performance, set realistic brand performance objectives, and develop insights in behavioural loyalty. Since most brand performance measures are about normal most of the time, when a deviation is observed it is not a call to reject the fitting, but rather to investigate *why* such a variance occurred. Indeed one of the main benefits of any Dirichlet fitting is the framework it provides from which to develop useful managerial insight.

Over time, and as a result of the model's wide generalisation, a number of regular deviations have been repeatedly documented between expected and observed performance metrics. Some, such as an excess loyalty described for many high share brands (e.g. [Fader and Schmittlein, 1993](#); [Pare and Dawes, 2012](#)) have attracted much attention; others such as the Erosion of Repeat Purchase Loyalty ([East and Hammond, 1996](#)) are rather less well-known. This paper reviews the incidence, extent and nature of these consistently recurring deviations, using evidence from a single, extensive database, and so although the deviations reported here are not new findings in themselves, the value in summarising them in this way is threefold.

First, as [Ehrenberg et al. \(2004\)](#) suggested, users of a Dirichlet model need to know about the range of deviations that they may routinely encounter, in order to correctly interpret unusual but not unknown aspects of market structure. We therefore provide a summary of the most common deviations, demonstrate how they can contribute to a better understanding of buyer choice behaviour in the context of the general model, and discuss the implications for strategic brand management. Second, many prior studies have tended to concentrate on one or two deviations in isolation, but because these may arise from the same breach of the theoretical assumptions, or produce complementary effects on two or more metrics, or share managerial significance, it is now valuable to discuss the main deviations together in order to understand any relationships between them. Third, the existence of a set of systematic deviations, some of which have taken on the characteristics of empirical generalisations in the literature, prompts a discussion of Dirichlet theory and the case for model adaptation.

The paper proceeds as follows. First, the NBD-Dirichlet is described and the deviations literature summarised to define the questions addressed. We next present the dataset and define the standard metrics used in the analysis along with an overview of the fitting procedure. The deviations are then empirically presented and discussed in detail, and the paper concludes with the summary and a discussion of the implications for managers, for marketing strategy and for theory development.

2. Background

2.1. The NBD-Dirichlet model

The NBD-Dirichlet model, usually just called the Dirichlet ([Goodhardt et al., 1984](#)) describes the patterns of choice by buyers – how many buy at all, how often they buy and what else they buy in a fixed time period. The model broadly assumes that consumers choose from a small portfolio of the available options (split loyalty), with (1) on-going fixed propensities to choose any one item (e.g. brand X six times out of ten). Consumers differ in the rate at which they buy the category, and (2) propensities differ greatly from consumer to consumer and (3) are independent of incidence of brand choice. The NBD-Dirichlet is specified for (4) non-partitioned and (5) stationary markets, i.e. there are no sub-groups in the population with different overall preferences and market size and brand shares are not changing. The model combines these five assumptions in two probability density functions, the Negative Binomial Distribution (NBD) for purchase incidence and the Dirichlet Multinomial Distribution (Dirichlet) for brand choice, to model

simultaneously the number of purchases for each competing brand in a category in a fixed time.

The Dirichlet output reproduces many of the discipline's most important empirical generalisations in consumer behaviour, such as the fundamental pattern of Double Jeopardy ([Ehrenberg et al., 1990](#)), from a single model fitting. It has been consistently observed that in split-loyal markets small brands suffer twice (hence Double Jeopardy); fewer people buy them than the more popular alternatives, and those that do, like them less and buy them a little less often. In these markets, the relationship between buyer numbers (penetration) and behavioural loyalty (e.g. purchase frequency) for all rival brands is mathematically predictable, but more surprisingly, the biggest difference between big and small brands is in the number of buyers they attract, and not the loyalty they earn, which varies little. The Law of Double Jeopardy thus defines “normal” buying in the category for a brand of any size. The pre-eminent effect of penetration on brand performance also underpins most other established behavioural regularities, including the Duplication of Purchase Law ([Dawes, 2016](#); [Ehrenberg and Goodhardt, 1970](#)). This states that the customer base of any brand buys other brands in the category predictably, in line with each rival's penetration, rather than with any perceived brand differentiation ([Romaniuk et al., 2007](#)).

On the face of it, these behavioural norms and the Dirichlet assumptions could be quickly rejected by practitioners as unrealistic and restrictive; and yet the model and the laws continue to predict the aggregate patterns of observed choice behaviour closely for frequently bought categories in grocery and other “repertoire” markets ([Scriven and Goodhardt, 2012](#)), as well as for less frequently bought product in subscription markets ([Sharp et al., 2002](#)). Dirichlet assumptions would be breached for example by any brand differentiation strategy that led to an effective segmentation of the market. Yet it has been repeatedly shown that not only do user profiles hardly differ between competing brands ([Kennedy and Ehrenberg, 2001](#); [Uncles et al., 2012](#)) but that those profiles also remain broadly stable even over consecutive years of continuous marketing spend ([Anesbury et al., 2017](#)).

The Dirichlet is probably therefore one of the most highly generalised models in marketing; the validity of its outputs has been continuously and systematically tested through replications in many sets of data, by different researchers, under varied conditions, using multiple methods over almost thirty-five years. In that time although the range of marketing tactics available to practitioners on both client and agency side has changed almost beyond recognition, and market opportunities expanded in line, yet the fundamentals of consumer behaviour have remained the same, so that the model continues to find uses in benchmarking and describing choice behaviour in new, unfamiliar and uncertain situations.

2.2. Building theory with Dirichlet deviations

For marketing scientists, recurring deviations from Dirichlet norms in many sets of data lead to new empirical generalisations, to build underlying theory. Marketers are concerned with disrupting equilibrium, and although the Dirichlet is not a dynamic model – it does not forecast change – in the steady state it can usefully predict period-to-period repeat purchase rates, how metrics differ from brand to brand as they evolve in longer (or shorter) time periods, and how those metrics would be expected to change in cases of growth or decline. Recently for example, [Dawes \(2016\)](#), [McCabe et al. \(2012\)](#) and [Riebe et al. \(2014\)](#) have successfully fitted model output to the observed buying metrics of dynamic brands, benchmarking those changes against the expected Double Jeopardy relationship, and confirming how increases in brand share (persistent and temporary) are explained by far greater movements in penetration than in purchase frequency.

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