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Purposeful empiricism: How stochastic modeling informs industrial marketing research

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ABSTRACT

It is increasingly recognized that progress can be made in the development of integrated theory for understanding, explaining and better predicting key aspects of buyer–seller relationships and industrial networks by drawing upon non-traditional research perspectives and domains. One such non-traditional research perspective is stochastic modeling which has shown that large scale regularities emerge from the individual interactions between idiosyncratic actors. When these macroscopic patterns repeat across a wide range of firms, industries and business types this commonality suggests directions for further research which we pursue through a differentiated replication of the Dirichlet stochastic model. We demonstrate predictable behavioral patterns of purchase and loyalty in two distinct industrial markets for components used in critical surgical procedures. This differentiated replication supports the argument for the use of stochastic modeling techniques in industrial marketing management, not only as a management tool but also as a lens to inform and focus research towards integrated theories of the evolution of market structure and network relationships.

1. Introduction

When asked why he robbed banks, Willie Sutton, a notorious bank robber, is reputed to have replied by saying "that's where the money is". The saying still resonates as an injunction to heed the most likely explanation. Indeed, physicians are taught "Sutton's Law" as a warning to seek the most likely diagnosis first[1] (Chang, 2009).

What lessons does "Sutton's Law" have for developing and integrating theory in industrial marketing management research? The search for a valuable contribution should start in the areas where that contribution is most likely to be found — to look for the banks. General theories seek to integrate middle level theories in order to explain a wide range of behavioral phenomena, independent of context (Hunt, 1983). This paper argues that well-established empirical regularities provide a starting point for integrating theory and form a solid foundation for higher level explanation — that is, they show us where the banks are. The observation of empirical patterns is an opportunity for guiding further research in order to uncover causal mechanisms and to "delve into the underlying processes so as to understand the systematic reasons for a particular occurrence or non-occurrence" (Sutton & Staw, 1995, p. 378). When those same patterns are repeated in different contexts, industries, firms and relationships, then we have the basis for integrating the causal mechanisms over these different situations.

While it is entirely possible that similar empirical patterns may arise from completely different causal mechanisms in different contexts, we argue that the most likely solution starts from the assumption that similar phenomena have similar generative mechanisms and that integrated general theory is most likely to emerge from a research program guided by a common understanding of the 'explananda' and the nature of the theories that provide the explanations.

The early Industrial Marketing and Purchasing (IMP) research is an excellent example of "Sutton's Law" in action. The original IMP researchers first located their bank — the emerging body of empirical evidence indicating the existence of stable long term relationships between individually significant buyers and sellers (Håkansson & Wootz, 1979). The empirical evidence arising from a study of almost 900 buyer–seller relationships across five European countries (Cunningham, 1980) provided the starting point for the research which resulted in the interaction approach (Håkansson, 1982) which in turn became the "most likely solution" at the heart of the IMP research program. As more researchers adopted the IMP approach, the theory became broader and deeper but at its heart it retains the principles of the interaction approach and the associated assumptions about the nature of buyers and suppliers and their network relationships (Ford & Håkansson, 2006).

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[1] We are indebted to an anonymous reviewer for helping us select the correct eponymous law — Occam's Razor refers to the simplest outcome, with Sutton's Law invoking the most likely outcome. While there may be overlap, there is no requirement for the most likely outcome to be the simplest.

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In a similar manner, stochastic theories of consumer choice have emerged to describe, model and explain regular patterns of buyer behavior. Such patterns have been observed across a wide range of consumer markets, from packaged goods to durables (Uncles, Ehrenberg, & Hammond, 1995). Applied to organizational markets, established consumer modeling techniques can provide insights into the dynamic nature of the portfolio of relationships between buyers and suppliers. Analysis of the exchange behavior in multiple buyer–seller relationship dyads detects patterns of structural change and provides a market "norm" against which to benchmark individual relationships (Gadde & Mattsson, 1987). However, previous studies have focused on multiple category suppliers to a single focal firm (Dubois, Gadde, & Mattsson, 2003; Kamp, 2005). In contrast, the analysis in this paper presents a study of multiple buyers and suppliers operating in a single category, demonstrating the power of analysis of the macroscopic patterns of behavior to identify and interpret structural changes and the impact of these changes on individual buyer–supplier relationships.

This paper argues that in addition to describing emergent aggregate behaviors in an organizational purchasing context, the use of such models can direct further research and development of theory to explain behavioral phenomena that repeat across firms, industries and business types. We present two empirical examples that use a stochastic model to analyze behavior in public healthcare procurement. Our approach is to compare the patterns predicted by the chosen stochastic model with actual purchasing behavior. Different forms of market structure are characterized by different observed purchasing patterns, informing and guiding further research to help to uncover the structures and generative mechanisms that help explain the observed phenomena. The deviations between the model predictions and the observed behaviors can also be interpreted in terms of the assumptions underlying the stochastic model; this in turn provides insights into the nature of interactions in industrial markets. Our approach helps to address the problem of limited progress in attaining theoretical unity in the understanding of buyer–seller relationships and industrial networks through the use of a stochastic model as an integrating mechanism for theory development.

The paper is structured as follows. Following this Introduction, we provide an explanation of how purposeful empiricism helps integrate theory and hence "contributes to general theory development in industrial marketing research" (Peters, Pressey, Vanharanta, & Johnston, 2013).

In Section 2.1 we present a brief overview of the NDB-Dirichlet stochastic model (subsequently referred to as the Dirichlet) before examining in Section 2.2 how its core assumptions can be interpreted within a context of extended networks of long term interorganizational relationships in business-to-business markets (subsequently referred to as the markets-as-networks approach). Within this section we indicate how the Dirichlet provides a theoretical lens through which to view any market, focusing attention on large scale regularities that repeat across different contexts and so contributing to the goal of "attaining theoretical unity" in our understanding of buyer–seller relationships (Peters et al., 2013).

Two empirical examples are presented in Section 3 illustrating how the large scale patterns predicted by the Dirichlet provide a mechanism to describe market structures that can be discussed in terms of relationship interdependence and connectedness. The empirical data are taken from a three year longitudinal study of purchasing surgical consumables in a public sector collaborative procurement organization. The study identifies two management interventions designed to influence purchasing behaviors, one initiated by a supplier and the other by the purchasing organization. The analysis of the purchasing patterns before, during and after these interventions provides valuable insights into market making and the extent to which purchasing patterns can be changed within the constraints of an established network of relationships.

Section 4 discusses how the observation of regular patterns of purchasing behavior, and just as importantly, deviations from these regular patterns can direct further exploratory and explanatory research to uncover the underlying portfolio of relationships, structures and generative mechanisms that give rise to the regular patterns, representing the purposeful empiricism in the paper's title. In contrast to blind empiricism and the development of theory in isolation, this purposeful empiricism directs the development of theory towards explaining empirical regularities that are replicated across different firm, business and industry contexts, with an increased likelihood of developing more unified theoretical understanding.

The paper proposes using the large scale regularities described by the Dirichlet as a guiding structure to direct and integrate further research. If phenomena repeat across different business contexts, the most likely explanation is that the phenomena have similar underlying mechanisms, thereby providing a basis for more general theory. The paper makes three contributions to the industrial marketing research literature. First, we present a highly differentiated replication of the Dirichlet in an organizational market where the patterns of buyer–supplier interaction are dynamic. Our second contribution is to show how the theoretical benchmarks predicted by the Dirichlet can deliver insights into changing market structures and thereby identify changes in the network of relationships. Our third contribution uses the empirical examples to demonstrate how the Dirichlet model provides a theoretical lens to focus analysis on specific situations. In particular, deviations from the Dirichlet benchmarks point to violations of the Dirichlet assumptions which in turn can direct analysis towards the underlying reasons for why the assumptions may not hold in specific circumstances.

2. With purpose — towards integrated theory

Theory provides explanation, demonstrates interconnectedness and posits causal mechanisms for observed behaviors and structures (Stewart & Zinkhan, 2006; Sutton & Staw, 1995). By extension, integrated or general theory explains a wider range of observed behaviors and structures, in particular by unifying data and empirical findings across different situations (for example, industry sector or business type) (Stewart & Zinkhan, 2006). Replicating empirical research in different contexts establishes boundary conditions for the findings and thus the range of conditions over which the theory is expected to hold, where the role of replication in the development of knowledge is succinctly described by Hubbard and Lindsay (in press).

However, the idiosyncratic nature of business organizations and their network relationships can make it difficult to select cases with common characteristics. To overcome this limitation we propose that the large scale patterns that emerge from the self-organizing behaviors of individual actors are used as the basis for selection of relevant research studies. If these patterns emerge in different situations, then it is this commonality that suggests the relevance of the patterns for directing further research (Downward, Finch, & Ramsay, 2002). Epstein (2008) calls these large scale regularities "*macroscopic explananda*" and describes how models that represent such patterns can capture "qualitative behaviors of overarching interest", thus informing the conceptual foundations of their respective fields.

The approach used in this paper uses a stochastic model of the observed regularities as a theoretical lens to focus the analysis on individual actors and their relationships. As the regularities can be characterized by a well understood theoretical model, the exceptions to the expected patterns can be interpreted in terms of the explicit assumptions of that model (Epstein, 2008).

With its emphasis on the utilization of actual purchase behaviors, stochastic modeling has an inherently empiricist epistemology unlike the predominantly realist and interpretivist epistemologies that inform much industrial marketing research (Easton, 1995). It should be noted that stochastic models provide mathematical representations of observed phenomena rather than seeking causal relationships. As a mechanism for describing the "what" – the observed event, the stochastic

model does not preclude a layered ontology, whereby the "why" – the underlying generative forces behind the observed event, may exist independently of the observation (Mingers, 2003).

Stochastic models that characterize regularities in buyer behavior are well established in consumer marketing research, although they are less widely adopted in industrial marketing. This may be due in part to difficulties in data collection as industrial marketers rarely have the wealth of panel or scanner data available to researchers of consumer buying behavior (Easton, 1980; Pickford & Goodhardt, 2000). The following section provides an introduction to the Dirichlet which is one of the best known and most well-established models in the marketing literature (Uncles et al., 1995).

2.1. The Dirichlet

The Dirichlet is a theoretical statistical model of purchase incidence and customer choice (Dacko, 2008), which was originally derived from empirical observation of consumer buying behavior and has been widely replicated. Its ubiquity has resulted in it being recognized as an empirically based theory rather than a mere model (Ehrenberg, 1995).

The five key theoretical assumptions underlying the Dirichlet are as follows (Goodhardt, Ehrenberg, & Chatfield, 1984):

i. Purchase activity for each buyer over time follows a Poisson distribution with a constant long run average purchasing rate.
ii. These average purchasing rates vary across the population of buyers according to a Gamma distribution.
iii. Over a series of purchases the supplier choices made by each buyer follow a zero order multinomial distribution with a steady probability that they will choose a particular supplier on any particular purchase occasion.
iv. These probabilities are distributed across the population of buyers according to a multivariate Beta distribution called the Dirichlet.
v. The supplier choice probabilities are distributed over the population independently of the average purchase frequency of each buyer.

The detailed distributional assumptions underpinning the model can be found in Goodhardt et al. (1984). These assumptions hold for conditions of stationary markets (i.e. approximately steady total volumes and supplier market shares) without market partitioning (i.e. no market segmentation) (Goodhardt et al., 1984; Sharp & Driesener, 2000). The Dirichlet successfully provides theoretical measures of market performance which closely match those observed in practice in a multiplicity of different consumer markets throughout the world. The interpretation of the assumptions in an industrial/organizational marketing context will be discussed in the following section. In Table 1 we provide a summary of the very limited range of published Dirichlet applications in industrial/organizational markets. We also highlight the differences between these previous studies and the empirical analyses reported in this paper. Uncles and Ehrenberg (1990) analyzed a selection of aviation fuel contracts awarded by airlines across different locations (airports). The analysis considered the contracts between airlines and their fuel suppliers at a particular point in time and did not take into account any renegotiation of these contracts. Airlines were observed to spread their purchases across several suppliers in close accord with the Dirichlet theoretical predictions; there were few 100% loyal buyers (and no segmentation). Similar patterns were seen in studies covering the prescribing behavior of physicians (Stern, 1994) and the foreign exchange market where Bowman and Lele-Pingle (1997) analyzed survey data from corporations purchasing financial services; here again the Dirichlet provided excellent predictions of the claimed behaviors. A study of the ready mixed concrete market by Pickford and Goodhardt (2000) used a survey to collect recall-based purchase histories (previous three months) and Juster scale-based purchase likelihoods (next three months). These were then used to operationalize the Dirichlet model, and the analysis also showed regular patterns of split loyalty.

Table 1
Overview of Dirichlet studies in organizational markets.

	Collaborative procurement	Public procurement	Timescale	Market dynamics
Aviation fuel (Uncles & Ehrenberg, 1990)	No	Partial[a]	1 year	Stationary
Prescriptions (Stern, 1994)	No	Yes	1 year	Stationary
Foreign exchange (Bowman & Lele-Pingle, 1997)	No	No	1 year	Stationary
Concrete (Pickford & Goodhardt, 2000)	No	No	3 months	Stationary
Surgical supplies [this paper] (2012)	Yes	Yes	3 years	Dynamic

[a] Includes state owned airline customers.

The studies listed in Table 1 show that the Dirichlet results can be replicated to a selection of different organizational market contexts. The analyses in the current paper build on the previous studies by presenting a highly differentiated replication in a collaborative public procurement environment where there are substantial dynamic changes in the patterns of buyer–seller interactions over an extended period.

2.2. The Dirichlet and markets-as-networks

It may seem that the concepts of long term buyer–supplier relationships embedded in the industrial marketing research tradition are inconsistent with the "as if random" purchasing behavior assumed by stochastic modeling approaches such as the Dirichlet. McCabe and Stern (2009) have shown how stochastic modeling and industrial networks offer complementary views of organizational purchasing behavior. In a systematic analysis of the ontological, epistemological and methodological similarities between stochastic modeling and industrial networks they demonstrate that despite the very different approaches both research traditions share important assumptions concerning the heterogeneity of individual network actors, the many and variable influences on buyer behavior, and the constraints on independent managerial action in a context of network interdependence or apparent "as if random" behavior.

This paper shows how the macro-level Dirichlet patterns can inform and complement further research at the level of the individual relationship and hence it is instructive to consider how three key concepts which underpin the Dirichlet can be interpreted in the context of long term relationships in an extended network of organizational interactions. These three concepts are:

- the market
- stationarity (stability) and
- non-partitioning.

2.2.1. Concepts of the market

The "market" in Dirichlet analysis is defined by the population of sellers of a product and the population of potential buyers for a specific product category. The relevant population of sellers is determined simply by substitution through the choices made by the buyers. The relevant population of buyers is defined by the scope of the analysis and may be bounded by the analyst on a regional basis (e.g. the concrete analysis by Pickford & Goodhardt, 2000), or by an industry structure determined by the activities of the buying organization (e.g. airlines Uncles & Ehrenberg, 1990), prescribing physicians (Stern, 1994). The measures used to parameterize the Dirichlet model are the market share and the penetration, both of which require a "closed" definition of the market. In contrast, the "market" as conceptualized in the markets-as-networks approach is "open" with dynamic boundaries determined by how actors

perceive the network interdependencies (Mattsson, 2003). These network interdependencies may be substitutive and complementary (Mattsson & Johanson, 2006) and can extend beyond the narrow definition of industry structure based on the substitutive products and services of the market participants to include other actors such as regulators or policy makers (Welch & Wilkinson, 2005).

This is not to say that the Dirichlet ignores the extent to which dyadic exchange relationships are embedded in the extended network or that the aggregation of exchange somehow implies homogeneity in the population of actors, all behaving in the same way. Instead, the observed behaviors are the result of the influence of all the individual interdependencies affecting the choices of a population of heterogeneous market participants. As seen in Fig. 1, the Dirichlet provides a view of the emergent behaviors arising from interactions in a bounded "network of overlapping networks" centered around buyer–seller dyads 1, 2, … $(n-1)$, n.

These networks may be overlapping with sellers serving more than one buyer, sellers sharing suppliers, buyers maintaining relationships with multiple sellers, and cross-industry influences such as collective purchasing organizations or regulatory bodies.

Although the Dirichlet is parameterized with a closed market definition, the patterns that emerge are the result of interactions in an extended network that is not constrained by the defined boundaries. Thus the requirement to circumscribe the market for the purposes of operationalizing the model does not preclude its use to describe behavior in an open network, as is proposed in this paper.

2.2.2. Concepts of stationarity

The Dirichlet assumption of stationarity would appear to be consistent with stable long term relationships. However, stationarity in a Dirichlet context refers to irregular but approximately steady aggregate measures of purchasing behavior (total sales, market share) which in turn lead to the assumption that individual buying propensities remain approximately stable over the short to medium term (Goodhardt et al., 1984). Market stationarity has been observed to persist into the long term without substantial changes in the size of the category or in the loyalty metrics for suppliers in the category (Sharp et al., 2012). Exceptions arise from temporary variations due to promotional activity or distribution problems (Ehrenberg, Hammond, & Goodhardt, 1994) or from permanent structural adjustments through strategic changes (e.g. withdrawal or entry of a supplier or innovation to create a new category) (Graham, 2009). It should be noted that short term in Dirichlet analyses is typically taken to be one to two quarters, medium term up to four quarters and long term three to six years. In the markets-as-networks approach, stability usually refers to the longevity and continuity of interfirm relationships which can persist over several decades (Dubois et al., 2003).

Low (1997, p. 190) notes that network relationships in mature industries are often stable, reflecting "the many hours spent in experimenting with various connections and combinations of actors' activities and resources". Established relationships are the outcome of adaptation and institutionalization of activities (Mattsson, 1997) and investments to overcome the uncertainties that would otherwise be barriers to exchange. Stability in relationships arises from the experience of existing and potential partners. In a similar fashion, the steady purchase propensities of the Dirichlet assumptions arise from experienced buyers who are not easily influenced by short term interactions. This does not mean that the Dirichlet is based on concepts of exchange that emphasize one-off transactions with no history and no future (McLoughlin & Horan, 2002). Experience of previous activities, transaction costs and perceived risks are subsumed into the model such that the observed activity takes into account what has gone before. Buyers are "busy cognitive misers" (Sharp et al., 2012) and supplier choice decisions on a given purchase occasion are typically made quickly with little information processing (Ehrenberg, Uncles, & Goodhardt, 2004; Popkowski Leszczyc & Bass, 1998). This type of decision-making can be compared with the way in which decision making within relationships may be routinized (Brennan, 2006) or how experienced network actors may use intuitive decision strategies over rational decision strategies (Vanharanta & Easton, 2010).

The stability of long term relationships in industrial markets is often contrasted with the free-for-all of perfectly competitive markets, where switching costs are low and customers can freely choose alternative suppliers for directly substitutable products (Easton, 1992; Ritter, Wilkinson, & Johnston, 2004). The prevalence of long-lasting relationships would appear to preclude the Dirichlet notion of buyers distributing purchases "as if random" between several suppliers. However, the market described by the Dirichlet does not imply that buyers will share their purchases between all of the potential alternative suppliers (Sharp et al., 2012). Buyers typically have a repertoire of known suppliers that they purchase from (or maintain relationships with). This repertoire may be as small as a single supplier (sole loyalty or single sourcing) and will vary across the population of buyers. The extent of single sourcing is an important feature of the market structure and may be relatively low (a *repertoire* market, characteristic of many packaged consumer good markets) or may be high (a *subscription* market, characteristic of markets dominated by long term contracts, e.g. utilities) (Sharp, Wright, & Goodhardt, 2002).

Over the medium to long term, the buyer's portfolio of relationships may change dramatically (Autry & Golicic, 2010; Dubois et al., 2003; Gadde & Mattsson, 1987; Kamp, 2005). These studies show

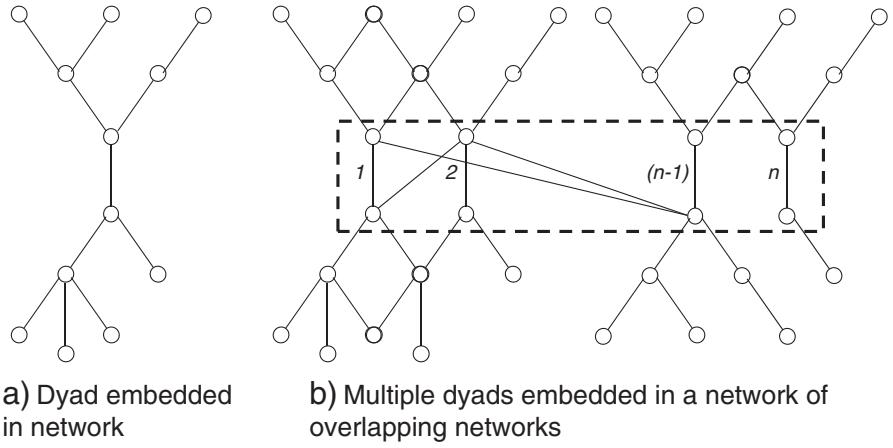

Fig. 1. Single network and network of overlapping networks.

that direct replacement of one supplier by another is quite unusual with the most frequent changes to the supply base being the addition or withdrawal of a supplier. Changes to the supply base usually involve growing or shrinking the repertoire rather than a like-for-like substitution of one supplier for another. As demonstrated in this paper, stochastic techniques can be used "to study the proportion of newly established, continuing and disrupted relationships" and "to analyze the total network with the idea of detecting patterns of structural change" (Gadde & Mattsson, 1987, p. 32).

The preceding discussion has several important implications for the interpretation of the Dirichlet patterns in terms of organizational relationships. Routinized decision making by experienced network actors is consistent with the underlying Dirichlet assumptions of steady (habitual) purchase propensities. Intuitive decision strategies which may be observed directly or indirectly (for example through the emergence of Dirichlet type patterns) prompt further research into the mechanisms that give rise to such strategies. The distinction between repertoire and subscription markets provides a framework for describing market structure and for identifying anomalies. For instance, an individual buyer that maintains a portfolio of supplier relationships is exhibiting behavior that is entirely consistent with behavior in a repertoire market but would be unusual in a subscription market. Changes in market structure over time can also be analyzed through a series of Dirichlet "snapshots" over an extended period of time. The changes in structure emerge from changes in individual interaction behaviors which can then be the subject of further focused research.

2.2.3. Concepts of non-partitioning (no segmentation)

The Dirichlet concept of lack of partitioning (a non-segmented market) means that the proportion of a particular buyer's purchases accounted for by any one supplier is independent of how the buyer distributes their purchases among the remaining suppliers (subject to the mathematical constraint that the individual choice probabilities must sum to one) (Goodhardt et al., 1984). The way that individual buyers distribute their purchases among their repertoire of suppliers is individual to each buyer. The markets-as-networks approach also recognizes the heterogeneity of network actors and their interactions although it focuses on individually significant relationships rather than describing how the heterogeneity is distributed across the network (Ford & Håkansson, 2006; Mattsson & Johanson, 2006).

A lack of segmentation can be interpreted as no special clustering of particular suppliers within the product category. This may be the case for directly substitutable products but functional sub-categories may exist within the category. There are no examples of this in the few Dirichlet studies that have been conducted in organizational markets but clustering has been observed in consumer's choice of restaurant based on the availability of vegetarian food (Sharp & Driesener, 2000), in a luxury car segment in the automobile market and between leaded and unleaded fuel (Ehrenberg et al., 2004). This kind of partitioning can be observed through the duplication of purchases between particular suppliers, i.e. the proportion of buyers of Supplier A who also purchase from Supplier B. The important point to note here is that these clusters emerge from the purchasing behavior of individual buyers and are not normative segments based on pre-determined attributes of the buying population.

Clusters that do emerge from individual interactions can be identified through the Dirichlet analysis, providing opportunities for further research, in particular into the mechanisms and factors that may give rise to such clusters.

2.3. Theory development and the Dirichlet

The process of theory development with the Dirichlet stresses the interactions between theory and empirical analysis whereby observed regularities lead to the establishment of empirically grounded theory. This in turn prompts more empirical work to test the theory more widely under different conditions to extend its generalizability, to develop it conceptually and to establish boundary conditions for its application. Data and theory are interdependent, combining in a creative process to produce new understanding and knowledge. In the markets-as-networks tradition this has been called "systematic combining" (Dubois & Gadde, 2002); Ehrenberg (1994) calls it "Empirical then Theoretical" (EtT).

As the population of buyers and suppliers in an organizational Dirichlet study is likely to be an order of magnitude lower than a typical consumer panel, there is the opportunity to develop theory with in-depth case research into individual relationships. For example, it has been suggested that network structure emerges from the constraints imposed by actor interdependence. If there is no interdependence there will be no structure and the resulting system will be stochastic; the extent of interdependence determines the extent of structure in the network (Easton, 1992). The Dirichlet provides a mechanism for elaborating market structure and differentiates between repertoire markets (high incidence of split loyalty, few sole buyers, less interdependence) and subscription markets (low incidence of split loyalty, many sole buyers, more interdependence). Comparing relationships in markets characterized by high interdependence with those of low interdependence will provide insights into the nature of interdependence and the multidimensionality of buyer–seller relationships (Zerbini & Castaldo, 2007). The size of the repertoire (the number of supplier relationships held by an individual buyer) will be determined by the balance between the benefits and costs of exploitation versus exploration (Wilkinson & Young, 2002). The Dirichlet analysis permits the comparison of individual buyer repertoires and leads to improved understanding of the environmental factors upon which repertoire size may be contingent.

The connectedness of relationships is expected to have constructive effects on network identity, through resource transferability, activity complementarity and relationship generalizability (Anderson, Håkansson, & Johanson, 1994). In the Dirichlet analysis, the extent of sole buying and the duplication of purchase are potential measures of connectedness that can be compared between individual actors in a market or between different market situations. The ability to make such comparisons assists in the identification of cases with specific characteristics to direct and inform further research into individual relationships and the network in which they are embedded.

Deviations from the Dirichlet model will also provide bases for further research. By searching for "exceptions or surprises" (Ryan, Tähtinen, Vanharanta, & Mainela, 2012) boundary conditions can be established and theory further developed. Deviations may be systemic and characteristic to organizational markets in which case the Dirichlet model may be extended to accommodate the specific conditions of business to business exchange. An example of such a deviation is a tendency to overpredict penetration and underpredict purchase frequency which may be attributed to the concentration of organizational purchasing into fewer, larger purchasers (Bowman & Lele-Pingle, 1997; McCabe, Stern, & Dacko, 2012). Other deviations may point to departures from the basic assumptions of stationarity and lack of partitioning, allowing the interpretation of dynamic situations, for example the gradual development of a new buyer–seller relationship (Ehrenberg et al., 2004).

The insights into market structure and organizational buyer behavior afforded by stochastic modeling permit a sequential analysis whereby the representations from stochastic modeling can direct purposeful interpretive research. The following empirical examples demonstrate this process in practice through the analysis of two dynamic collaborative purchasing situations with externalities impacting upon individual and network behaviors. In addition to a differentiated replication of the Dirichlet, the evolution of the purchasing patterns during the period of analysis provides insights into changes in market structure and individual firm behavior.

3. Empirical analysis

We examine two data sets which come from the same source and therefore have superficial similarities. During the period of analysis there are managerial interventions to change purchasing behaviors and thus the data sets provide an opportunity to study changes in market structure. We conduct analyses of the two markets, and the extent of their associated stationarity and lack of partitioning, revealing that superficial similarities mask differences in the network relationships and their evolution. These differences are explained through the lens of the Dirichlet.

3.1. Background

Purchase order data from a public healthcare collaborative purchasing organization were collected and analyzed. Group purchasing can deliver savings through consistent pricing, volume aggregation and product standardization (Bakker, Walker, & Harland, 2006; Chapman, Gupta, & Mango, 1998; Essig, 2000) and to aid this process, purchasing groups often collect data from their member organizations in order to monitor buying activity. The minimum data requirements to operationalize the Dirichlet are the identities of the buying organization and the supplying organization and the date of purchase. These data are typically available from the purchase order and when collected from the member organizations in the purchasing group they are analogous to those available from scanner data in a consumer marketing context although the number of buyers will typically be several orders of magnitude smaller than in studies of consumer buying behavior.

The analysis is carried out on two categories of surgical consumables — cardiac and ureteral stents. These are structural components used to maintain flow through damaged blood vessels or to facilitate surgery. Purchase data for three years, from 2006 to 2008, were collected, with 18 cardiac stent buyers making 402 purchases and 45 ureteral stent buyers making 591 purchases. During the period of analysis there are two distinct managerial interventions that attempt to change the buying behavior of the member organizations in the purchasing group. In the cardiac stent category the purchasing group introduced a set of framework agreements which were negotiated with all suppliers and were intended to deliver consistent pricing across the collaborative procurement organization with volume discounts agreed based on the existing portfolio of suppliers so that there was no imposed restriction on clinician choice. In the ureteral stent category the intervention took the form of increased sales and promotional activity by one supplier.

In both categories the observed purchasing data is used to operationalize the Dirichlet model. The model predictions are compared with the observed behaviors in order to assess the extent to which the Dirichlet holds for these data sets, representing differentiated replications in a collaborative purchasing environment characterized by substantial changes in buyer behavior over an extended period of time. The purchasing patterns are then analyzed to investigate where the stochastic modeling approach can direct further research to uncover the mechanisms that generate large scale regularities in buyer behavior, in particular in the emergent market structure, market making as evidenced by the changes in buyer behavior and the interpretation of deviations from the Dirichlet theoretical predictions.

3.2. Regular patterns of buyer behavior

Table 2 shows how the aggregated purchasing behaviors show consistent patterns in both categories. The performance metrics of penetration (the proportion of the buying population who purchase at least once from a particular supplier during the period), purchase frequency (the average number of purchases of a particular supplier made by purchasers of that supplier) and share of category requirements (SCR) (the proportion of a buyer's total purchases of a category that are fulfilled by the particular supplier) are used to compare the purchasing behaviors between periods and between observed values and theoretical predictions. The patterns seen in Table 2 are consistent with the patterns typically seen in Dirichlet markets.

Table 2
Purchasing patterns in average six month periods.

Base period	Supplier	Market share (%)	Penetration (%)	Purchase frequency	SCR (%)
(a) Coronary stents					
Average 6 months	A	50	18	8.4	75
	B	16	15	3.2	44
	C	13	12	3.2	33
	D	13	8	5.2	35
	E	8	8	3.0	25
(b) Ureteral stents					
Average 6 months	X	51	15	4.0	66
	Y	44	11	4.3	59
	Z	5	4	1.6	64

While the market shares and penetrations decrease greatly from large to small suppliers, purchase frequency and share of category (SCR) requirements generally vary much less. A typical sub-pattern is that buyers of low share suppliers also tend to purchase slightly less frequently, the so-called "Double Jeopardy" effect (Ehrenberg & Sharp, 2000) — with the reverse observed for buyers from high share suppliers. This pattern can be seen clearly in the ureteral stent case but two exceptions are noticeable in the coronary stent category. Supplier A has a purchase frequency that is high compared to the other suppliers in the category. This arises from one high frequency buyer being solely loyal to Supplier A throughout the period of analysis. Supplier D also has a higher purchase frequency than the other suppliers, a deviation from the expected pattern arising from one buyer making a large number of purchases in the last six months of the analysis period. The share of category requirements, which measures the extent to which buyers fulfill their category requirements from the particular supplier, indicates that in both categories buyers tend to split their purchases between several suppliers. In the coronary stent category, Supplier A is the only supplier that accounts for over half of its buyers' category requirements. Supplier E only fulfills about a quarter of its customers' category requirements meaning that their customers buy from other suppliers three times more than they buy from Supplier E. In the ureteral stent category all suppliers fulfill about 60% of their buyers' requirements.

3.3. Theoretical predictions

Tables 3 and 5 present the observed performance and the theoretical Dirichlet predictions for the coronary stent and ureteral stent categories respectively, details of the practical steps in fitting the model may be found in the Appendix A. While Table 2 shows the average observed behaviors over the entire three year period, Tables 3 and 5 show the changes in the observed behaviors as a series of "snapshots" taken in each of the three years of the analysis period. This means that the evolution of the market structure from year to year can be observed.

In the coronary stent case (Table 3) the purchasing behaviors are averaged over a twenty-four week period from each of the three years between 2006 and 2008. Two twenty-four week periods are included for 2008, representing the period before and after the implementation of the negotiated framework agreements. The table shows how the purchasing behaviors develop, in particular after the implementation of the framework agreements. Initially (2006 to 2007) the average supplier penetration falls from 18% to 10% as the number of purchasers decreases. The purchase frequency stays approximately constant until the last half of 2008. This constant purchase frequency is a feature of Dirichlet type markets and reflects the underlying assumption that buyers have a steady long term mean purchasing rate. However, there

Table 3
Coronary stent observed and theoretical performance measures.

Year	Supplier	Market share (%)	Penetration (%)		Purchase frequency		SCR (%)		Sole buyers (%)		Sole buyer purchase frequency	
			O	T	O	T	O	T	O	T	O	T
2006	A	**44**	**25**	32	**8.0**	6.2	**78**	46	**20**	18	**1.0**	1.6
	B	**13**	**15**	19	**4.0**	3.2	**33**	18	**0**	7	**0.0**	1.2
	C	**9**	**10**	14	**4.0**	2.8	**24**	14	**0**	6	**0.0**	1.1
	D	**17**	**15**	21	**5.0**	3.5	**26**	20	**33**	8	**6.0**	1.2
	E	**17**	**25**	21	**3.0**	3.5	**19**	20	**0**	8	**0.0**	1.2
	Average supplier		**18**	21	**4.8**	3.8	**36**	24	**11**	9	**3.5**	1.3
	r		0.79		0.91		0.95		0.42		−0.01	
	Mean Absolute Deviation		5		1.2		13		10		1.8	
2007	A	**57**	**15**	25	**9.3**	5.6	**78**	60	**33**	33	**19.0**	2.5
	B	**17**	**15**	13	**2.7**	3.2	**73**	25	**33**	13	**1.0**	1.4
	C	**12**	**10**	10	**3.0**	4.5	**50**	22	**0**	12	**0.0**	1.3
	D	**6**	**5**	6	**3.0**	2.6	**27**	18	**0**	10	**0.0**	1.3
	E	**8**	**5**	7	**4.0**	2.7	**50**	19	**0**	10	**0.0**	1.3
	Average supplier		**10**	12	**4.4**	3.7	**56**	29	**13**	15	**10.0**	1.5
	r		0.80		0.76		0.72		0.69		1.00	
	Mean Absolute Deviation		3		1.5		27		11		4.2	
2008 months 1–6	A	**60**	**10**	21	**13.0**	6.0	**81**	62	**50**	32	**21.0**	2.1
	B	**7**	**5**	6	**3.0**	2.4	**50**	15	**0**	8	**0.0**	1.1
	C	**12**	**15**	9	**1.7**	2.7	**26**	18	**33**	9	**2.0**	1.2
	D	**16**	**10**	12	**3.5**	3.0	**50**	22	**50**	11	**3.0**	1.2
	E	**5**	**5**	5	**2.0**	2.2	**33**	13	**0**	7	**0.0**	1.2
	Average supplier		**9**	11	**4.6**	3.3	**48**	26	**27**	13	**8.7**	1.4
	r		0.41		0.98		0.88		0.62		0.99	
	Mean Absolute Deviation		4		1.9		22		19		4.8	
2008 months 7–12	A	**44**	**15**	23	**11.7**	7.5	**66**	55	**67**	37	**10.5**	5.3
	B	**9**	**10**	6	**3.5**	5.4	**30**	33	**0**	20	**0.0**	3.3
	C	**21**	**15**	14	**5.7**	6.1	**71**	40	**33**	25	**1.0**	3.9
	D	**23**	**5**	14	**18.0**	6.2	**56**	40	**0**	25	**0.0**	4.0
	E	**3**	**5**	2	**2.0**	5.0	**100**	29	**100**	18	**2.0**	3.0
	Average supplier		**10**	12	**8.2**	6.0	**65**	39	**40**	25	**4.5**	3.9
	r		0.63		0.63		−0.11		0.06		0.82	
	Mean Absolute Deviation		5		4.3		26		33		3.3	

O: Observed.
T: Dirichlet theoretical predictions.

is an increase in purchase frequency after the introduction of the purchasing framework agreements (2008, months 7–12). This may indicate purchase deferment in advance of the implementation of the frameworks and a subsequent restocking at more advantageous prices after the implementation. If this was the case, after some time the purchase frequency would be expected to revert to the long run rates (Ehrenberg et al., 1994; Macé & Neslin, 2004).

It is also interesting to consider how the observed loyalty changes after the introduction of the framework agreements. Initially Supplier A satisfies about 80% of its buyers' requirements, a higher loyalty than that enjoyed by the other suppliers. However, this observed loyalty level drops to 66% after the implementation of the framework agreements, suggesting that buyers are now more prepared (or able) to split their purchases between different suppliers. The framework agreements may have enhanced the credibility and hence the perceived availability of alternative suppliers.

The Dirichlet predictions show a much poorer fit than that typically seen in consumer markets. Table 3 presents the most commonly used measures of fit, the correlation coefficient, *r*, and the Mean Absolute Deviation (MAD). The test is one of sameness; that the relationship between observed and expected measures should have similar levels of scatter to previous studies and without any systematic bias. In consumer studies these limits are usually interpreted as a MAD typically about 10% of the mean of the particular performance measure and a correlation coefficient, *r*, of 0.9 (Ehrenberg, 1994; Uncles et al., 1995).

The relatively poor fit (a deviation) provides a focus for further analysis which looks in more detail at the frequency of purchase. Separating out the top three purchasers gives a much improved fit as seen in Table 4.

A visual comparison of the deviations between the observed and expected behaviors shows a systematic tendency for the model to overestimate the number of buyers and to underestimate the purchase frequency of those buyers, which may be a characteristic of markets with a concentration of purchases in fewer, larger buyers (Bowman & Lele-Pingle, 1997), a description that corresponds to many organizational markets. There are also notable deviations between the observed and predicted loyalty values (Share of Category Requirements and sole loyalty) for all suppliers. The typical repertoire market Dirichlet patterns of sole loyalty are seen in 2006 with a relatively low proportion of sole buyers, and with the sole buyers purchasing at a relatively low frequency. This pattern is disrupted in 2007 and in the subsequent years by the evolution of one solely loyal, high frequency purchaser from Supplier A, leading to marked deviations between the observed loyalty and the Dirichlet predictions. It should also be noted that deviations such as those seen for Supplier E in 2008 months 7–12 can arise

Table 4
Goodness of fit for penetration in heavy and light purchasing segments.

Year	Correlation between observed and theoretical distributions (*r*)			Mean Absolute Deviation between observed and theoretical distributions (%)		
	All buyers	Heavy	Light	All buyers	Heavy	Light
2006	0.79	−0.61	0.8	5.0	3.1	3.0
2007	0.80	0.94	0.99	3.1	1.5	0.9
2008 months 1 to 6	0.41	0.60	0.97	4.1	2.3	0.4
2008 months 7 to 12	0.63	0.93	0.95	5.1	2.1	1.4

from the lack of opportunity that buyers of smaller (i.e. infrequently purchased) suppliers have to choose alternative suppliers.

Table 5 presents the ureteral stent market. The purchasing behaviors are averaged over a twelve week period from each of the three years and the table clearly shows how the market share of Supplier X decreases over the analysis period while that of Supplier Y increases. Unlike the coronary stent case, the ureteral stent category was not subject to any managerial intervention from the collaborative purchasing organization. However, the observed change in purchasing patterns coincides with an increase in promotional activity by Supplier Y and it may be considered that at least in part, the observed behavioral changes arise from a supply-side intervention. The individual measures of penetration, purchase frequency and SCR provide an indication of the changes in purchasing behaviors that lie behind the changes in market shares.

Supplier X loses market share because it loses buyers, not because its existing buyers buy less. Over the three years X's penetration falls from 18% to 8% while that of Y increases from 13% to 20%. The buyers of Supplier Y also increase their purchase frequency, perhaps because the new buyers of Y tend to be heavier purchasers. The increase in the number of buyers of Y and the increase in their rate of buying results in the observed change in market share. Buyers of X purchase at roughly the same frequency through the three years although there is an increase in 2008 as X's buyers are concentrated into a smaller number of heavier purchasers.

Over the three years of the analysis the observed loyalty levels decline as the heavy (and initially extremely loyal) purchasers of X add Y to their purchasing repertoires. In 2006, buyers of X and Y fulfilled almost all of their category requirements with their respective suppliers but by 2008 they were much more likely to split their purchases between the two suppliers. In contrast to the coronary stent example, in 2006 the proportion of ureteral stent buyers who are solely loyal shows more of the characteristics of a subscription market with relatively high levels of sole loyalty. By 2008 the market begins to look more like a repertoire market with lower levels of sole loyalty and the purchasing rates of solely loyal buyers lower than the average for the whole population of buyers. It should also be noted that the loyalty for Supplier Z is unusually high because the buyers of this supplier purchase relatively infrequently, giving few opportunities to satisfy requirements from alternative suppliers.

As with the coronary stents, the comparison between observed and theoretical measures presented in Table 5 shows that the fit is poorer than is typically seen in consumer studies with a systematic tendency to overestimate penetration and to underestimate purchase frequency and loyalty consistent with the effect of a small number of high frequency purchasers. Like the coronary stent market, the fit is improved when the heavy (high frequency) purchasers are analyzed as a separate segment (Table 6).

4. Discussion

The preceding empirical analysis demonstrates that the macro-level behavioral patterns typical of markets modeled by the Dirichlet can be observed in both categories of stent. The theory also provides benchmark norms against which to interpret changes in both supply and demand and the analysis suggests three areas where the stochastic modeling approach can fruitfully direct further research to uncover the mechanisms that generate such regular behaviors, namely, (1) market structure, including concepts of interdependence and connectedness; (2) market making under the influence of supply-side or demand-side interventions; and (3) the interpretation of deviations from the theoretical predictions. The following sections discuss each of these areas in turn.

4.1. The Dirichlet representations of market structure provide insights into interdependence and connectedness in the market under analysis

The two examples demonstrate how the Dirichlet represents market structure. In 2006 the coronary stent market has the characteristics of a repertoire market with low levels of sole loyalty and purchasers willing and able to split their purchases between suppliers. This implies low levels of interdependence (Easton, 1992) and may be characteristic of experienced buyers (physicians) maintaining relationships with a multiplicity of suppliers. The SCR for Supplier A is higher than the Dirichlet norm, a previously noted deviation that is usually attributed to availability, arising from distribution differences between larger and smaller suppliers (Fader & Schmittlein, 1993). By the end of 2008 the market appears to be more structured with higher average levels of sole loyalty and a higher average SCR. This suggests increased interdependence which may be a consequence of the concentration of buyers into fewer, larger purchasing centers. However, the SCR for Supplier A is now closer to the Dirichlet norm suggesting that the introduction of the framework agreements has mitigated some of the availability effects. Inclusion in the set of framework agreements gives alternative suppliers credibility and changes the balance of benefits and costs in the exploitation versus exploration consideration (Wilkinson & Young, 2002). In effect the collaborative procurement organization has taken on some of the burden of

Table 5
Ureteral stents observed and theoretical performance measures.

Year	Supplier	Market share (%)	Penetration (%)		Purchase frequency		SCR (%)		Sole buyers (%)		Sole buyer purchase frequency	
			O	T	O	T	O	T	O	T	O	T
2006	X	**67**	**18**	26	**2.9**	1.9	**95**	76	**86**	66	**3.2**	1.7
	Y	**26**	**13**	13	**1.6**	1.5	**89**	51	**80**	41	**1.8**	1.3
	Z	**7**	**5**	4	**1.0**	1.3	**100**	40	**100**	32	**1.0**	1.2
	Average supplier		**12**	14	**1.8**	1.6	**95**	56	**89**	46	**2.0**	1.4
	r		0.98		1.00		−0.22		0.47		0.98	
	Mean Absolute Deviation		3		0.5		39		42		0.7	
2007	X	**47**	**30**	31	**2.3**	2.3	**69**	58	**83**	39	**1.6**	1.7
	Y	**48**	**15**	31	**4.8**	2.3	**69**	58	**50**	41	**3.0**	1.8
	Z	**5**	**8**	5	**1.0**	1.5	**43**	30	**67**	19	**1.0**	1.2
	Average supplier		**18**	22	**2.7**	2.0	**60**	49	**67**	33	**1.9**	1.6
	r		0.74		0.76		1.00		−0.10		0.83	
	Mean Absolute Deviation		6		1.0		12		34		0.5	
2008	X	**38**	**8**	15	**4.0**	1.9	**60**	47	**33**	31	**1.0**	1.3
	Y	**59**	**20**	20	**2.4**	2.4	**63**	65	**75**	45	**1.0**	1.2
	Z	**3**	**3**	2	**1.0**	1.2	**100**	20	**100**	15	**1.0**	1.0
	Average supplier		**10**	12	**2.5**	1.8	**74**	44	**69**	30	**1.0**	1.2
	r		0.87		0.55		−0.88		−0.40			
	Mean Absolute Deviation		3		0.8		32		39		0.2	

Table 6
Goodness of fit for penetration in heavy and light purchasing segments.

Year	Correlation between observed and theoretical distributions (r)			Mean Absolute Deviation between observed and theoretical distributions (%)		
	All buyers	Heavy	Light	All buyers	Heavy	Light
2006	0.98	0.98	0.96	3.3	0.5	1.2
2007	0.74	0.99	0.94	6.4	0.4	3.1
2008	0.87	0.97	*	2.8	0.7	*

* Not possible to fit data for light segment in 2008 (all buyers make one purchase each).

exploration and overcome some of the barriers of uncertainty. The collaborative purchasing organization can be considered as a form of institutional connectedness that has a positive effect on the network identity of the supplier organizations (particularly smaller suppliers) (Anderson et al., 1994).

The ureteral stent example has a well-defined structure in 2006. There are two major suppliers with the high levels of source loyalty typical of a subscription market. This implies high levels of interdependence but by 2008, buyers appear to be much more willing to share their purchases between suppliers and the previously dominant supplier had lost almost half of its market share.

In both cases there are observed changes in market structure that indicate changes in the interdependence and connectedness of network actors that may not have been apparent from an isolated focal firm analysis. The representation of market structure provides a context to direct further research into the interactions that generate the observed structure. This includes the role of the collaborative purchasing organization in developing connectedness and changes in individual decision making processes that result in the market becoming more structured (more interdependent) during the period of analysis.

4.2. Observing the process of market making through changes in the patterns of network interactions

Two distinct approaches to market making are captured in the two examples presented. In the first instance, the coronary stent example shows how a collaborative procurement organization can create the conditions for exchange through the imposition of formal institutions (the framework agreements) on the existing social structures (Araujo, 2007). These agreements give credibility to potential partners, assisting the establishment of trust and overcoming some of the uncertainties that prevent exchange (knowledge of reciprocal wants, agreement on prices, confidence in specifications, confidence in mechanisms in case of default) (Araujo, 2007). The commercial decision to focus on collaborative purchasing of coronary stents was influenced by a perception that the market was fairly stagnant with comfortable relationships between suppliers and physicians. However, the Dirichlet analysis shows an active market where buyers distributed their purchases quite widely among the available suppliers. After the implementation of the frameworks the market appears to become more structured. In the ureteral stent example the market making is taken on by a supplier, gradually building a network position through more active interaction, establishing trust and developing new buyer–supplier relationships alongside the incumbent supplier. This is consistent with observations from previous studies demonstrating that change in the supply base occurs most often through gradual addition or withdrawal of suppliers (Dubois et al., 2003; Gadde & Mattsson, 1987). The Dirichlet patterns act as a lens through which to interpret the patterns and the behaviors of individual actors in each case, in particular the market makers and the response of purchasing entities to the market making activity. For example, a single buyer of coronary stents remains resolutely loyal to Supplier A even after the implementation of the framework agreements. Taken on its own, this is another example of a long-lasting buyer–seller relationship. However, when set against the background of a market structure where the norm is split loyalty purchasing, this solely loyal behavior becomes worthy of closer investigation to understand why exogenous changes affect some relationships differently to others.

The second example of ureteral stents shows how market making activities instigated by a supplier affect the network structure moving from a subscription-type market to one which is more typical of Dirichlet split loyalty.

4.3. Deviations from the Dirichlet benchmarks highlight opportunities for further research

Deviations from the Dirichlet norms are also potential areas for theory development. The over-prediction of penetration and the consequent under-prediction of purchase frequency are observed in both the coronary and ureteral stent markets. This phenomenon has been attributed to the particular nature of organizational markets, in particular a tendency to have a smaller number of larger, heavier purchasers (Bowman & Lele-Pingle, 1997). More research is required to determine whether this deviation can be replicated in other organizational markets, and if so, whether the Dirichlet model could be modified to accommodate the particular conditions of organizational markets.

Further research should focus on the underlying Dirichlet assumptions, in particular the assumption that the purchases of individual buyers are distributed Poisson (see Section 2.1). A concentration of heavy buyers means that the overall purchase frequency is higher than that predicted by a Poisson distribution. In addition, the nature of interorganizational relationships may mean that successive purchases are influenced by previous purchase history (particularly during a period of transition to a new relationship), violating the zero order assumption of the Poisson process. The assumption that individual purchase propensities are distributed across the population according to a Gamma distribution will be violated if there is an extra concentration of heavy buyers. Both of the empirical examples show how the fit of the model is improved by applying it separately to heavy and light buyers rather than the whole population.

These insights into market structure, market making and deviations from the theoretical norms help to focus future research questions towards developing integrated theory through in-depth case research. For example, comparing the two examples permits deeper understanding of how subscription and repertoire structures (more and less interdependence) emerge and what influences this emergence. The role of the collaborative purchasing organization in market making can be explored through the perceptions of the network actors, in particular considering the impact on the power relationships between sellers and an aggregated buying organization. The analysis does not consider the wider relationships between the selling and buying organizations, for example in other product categories. It is possible that stents represent a very small proportion of the business between a particular supplier and the buyer and that there is a "multiplexity" in the nature of the relationships depending on the product category (Zerbini & Castaldo, 2007). The extent to which network actors are aware of their network position is also of interest. A share of category requirements of 33% implies that a buyer is fulfilling two thirds of its category requirements from other suppliers. This may be well understood or it may come as a surprise to the supply organization. The way in which network actors perceive this is likely to influence the way they perceive their position in the network (Welch & Wilkinson, 2002). The stochastic modeling approach helps to focus attention on the emergence of new relationships, disrupted relationships and those relationships that are unchanged (Gadde & Mattsson, 1987) and instances where observed behaviors do not follow the same patterns as those in the overall network.

5. Conclusions

The paper contributes to industrial marketing management research firstly via a differentiated replication of the Dirichlet in a collaborative purchasing environment, characterized by substantial changes in market share and purchasing frequency over an extended period (Uncles & Kwok, in press). The resulting empirical analyses show how the phenomena observed through stochastic modeling techniques represent fruitful areas for the development of explanatory theory. The second contribution of this paper is to provide empirical evidence to demonstrate how regular patterns of behavior typical of Dirichlet markets are generated in industrial networks and how such patterns inform our understanding of interactions in network relationships. In particular, the analysis of the large scale regularities that emerge from interactions within a "network of overlapping networks" of multiple buyers and sellers in two product categories provides an overview of market structure that is not possible from a focal firm perspective. The application of the stochastic modeling approach over an extended period also permits changes in the relationship portfolio to be monitored and analyzed. Understanding how changes are manifest in observable purchasing behavior allows the underlying mechanisms that result in the formation of new relationships, the disruption of existing relationships and the stability of other relationships to be studied. Stochastic modeling and industrial marketing share important assumptions about the individuality of network participants and the constraints on independent actions imposed by network interdependence or the steady purchasing behaviors of experienced buyers (McCabe & Stern, 2009) and this paper extends the argument that both research perspectives can and should be used together to identify and explain organizational marketing and purchasing behavior.

In our third contribution we demonstrate how the deviations between the observed purchase behaviors and the theoretical predictions for the network provide another source of phenomena for further investigation and explanation, improving our understanding of network relationships.

In order to develop more general theories of industrial marketing, the onus is on researchers to focus empirical analysis and theory development in areas that build and extend the generalizability of existing theories or explain generalizable phenomena. This paper provides an empirical basis for the sequential application of stochastic modeling and in-depth analysis to make progress in the development of more integrated theory. The Dirichlet acts as an integrating framework to identify large scale regularities of interest that repeat across different industries, firms and relationships. Uncovering and explaining the associated structures and mechanisms that bring about the observed phenomena support the development of theories that apply across a wide range of contexts. This sequential application is entirely consistent with the realist ontology of much industrial marketing research (Mingers, 2003).

In addition to these direct implications for researchers in industrial markets and stochastic modelers, the adoption of modeling techniques has important implications for simulation of business networks. Agent-based computer simulations may use the regular patterns of the Dirichlet and the theoretical ideas about the generative mechanisms that bring about these patterns to simulate network behaviors (Welch & Wilkinson, 2002). Such virtual networks have the potential to be valuable tools for experimental research and teaching.

There are also important implications for management. The empirical analysis has shown how managerial intervention can disrupt established relationships and change long run purchasing behaviors. The understanding of how such interventions can work and of the nature of successful and unsuccessful interventions can provide normative guidance for managers seeking to bring about change in networks. Interventions must be sympathetic to the relationship conditions (Ritter et al., 2004) and must go with the grain of existing purchase behavior. A key lesson of "Dirichlet" markets with steady long run purchase rates is that gaining market share in a specific product category will generally mean following Willie Sutton's dictum and "finding new banks" i.e. acquiring more customers rather than persuading existing customers to buy more.

The combination of stochastic modeling and industrial marketing research presents an iterative process of theory development and empirical analysis that will inform our understanding of relationships in industrial networks. In turn, stochastic modeling gains from a deep and rich analysis to develop theoretical insights into the generative mechanisms underlying observed patterns and regularities. As Epstein (2008, p. 12) observes, "models can surprise us, make us curious, and lead to new questions". Purposeful empiricism takes these new questions and uses them to move the research agenda beyond structure and isolated studies towards a more integrated understanding and explanation of behavior in organizational markets.

Appendix A. Fitting the model

The approach described below is the one used in this research and also used in other operationalizations of the Dirichlet. The data required to fit the model for a chosen product category in a specific time period are as follows:

(i) The proportion of the population buying the category at all (B)
(ii) The average number of purchase occasions recorded for those in the population who purchase the category at all (W)
(iii) For each supplier, the proportion of the population buying from that supplier at all (b_i)
(iv) For each supplier, the average number of purchase occasions recorded for those in the population who purchase from that supplier at all (w_i).

Each of the leading suppliers is used to generate the model parameters in turn. The individual supplier parameters are then combined as a weighted average based upon market share.

The two structural parameters of the Dirichlet distribution, K and S, are characteristic of the product category and reflect the heterogeneity of the buying population. K can be considered as a measure of purchase rate diversity and S has been described as a switching parameter. A low value of S (<0.2) implies low levels of switching and a high proportion of sole loyalty; higher values of S imply more split loyalty purchase behavior (Li, Habel, & Rungie, 2009).

The method of fitting the model follows the procedures in Goodhardt et al. (1984) and Ehrenberg (1988). The parameter K is determined from the observed proportion of non-buyers of the category and can be determined from the sample, equated to the expected value from the Negative Binomial Distribution and the resulting equation solved for K. This equation cannot be solved directly and requires an iterative solution. The estimation of the S parameter is also by an iterative procedure, using non-buyers of the particular supplier to fit the model in the same way as for the NBD. This is repeated for the other suppliers and the overall Dirichlet parameter is calculated from a weighted average of the supplier S using the market shares of each supplier. The mathematics is complex but computer programs have been developed to calculate the Dirichlet parameters and the one used in this research was BUYER (Uncles, 1989). Another available program is DIRICHLET (Kearns, 2009) which provides details on data processing procedures.

Using the model

Having fitted the NBD-Dirichlet model, it is used to predict a range of metrics (Ehrenberg et al., 2004) for the time period of analysis and for time periods of different lengths. These metric predictions can then be compared to the observed measures.

Typical predicted measures include:

(i) Penetration of purchasers, i.e. the proportion of the population buying from that supplier

(ii) Average number of purchases from the supplier per buyer (of that supplier)
(iii) Share of category requirements, i.e. the share of requirements that buyers of a particular supplier actually meet from that supplier
(iv) Percentage of sole buyers, i.e. buyers who meet all their category requirements with a single supplier
(v) Rate of purchase of sole buyers
(vi) Duplication of purchase, i.e. what other suppliers are used by buyers of a particular supplier.

All of these measures are determined using the same software used to calculate the Dirichlet parameters. The calculations for each of the measures are described in Ehrenberg (1988).

Testing the model

Having derived the set of supplier performance measures, it is necessary to test whether the model holds i.e. the predicted values are indeed a good fit to the observed values.

The purpose of the goodness of fit test is not just to compare the distribution of measures from the data with the distribution predicted by the model to accept or reject the hypothesis, i.e. that the observed data can be described by the NBD-Dirichlet model. Just because a fit has been obtained at some confidence level does not mean that the model is correct (Schunn & Wallach, 2001). There are other models, other data sets that could lead to equally good fits. As Ehrenberg (1988, p.23) notes, "the important point is not so much whether the discrepancies are real (or merely sampling errors) but that the same theoretical formula accounts for the greater part of the observed variation and that the residual deviations are relatively small and more or less unbiased".

The most commonly used measures are the Mean Absolute Deviation and the correlation coefficient. A good (enough) fit is considered when the Mean Absolute Deviation is less than 10% of the mean of the particular performance measure and the correlation coefficient, r is greater than 0.9 (Ehrenberg, 1994; Uncles et al., 1995).

References

Anderson, J. C., Håkansson, H., & Johanson, J. (1994). Dyadic business relationships within a business network context. *Journal of Marketing*, *58*(4), 1–15.
Araujo, L. (2007). Markets, market-making and marketing. *Marketing Theory*, *7*(3), 211–226.
Autry, C. W., & Golicic, S. L. (2010). Evaluating buyer–supplier relationship-performance spirals: A longitudinal study. *Journal of Operations Management*, *28*(2), 87–100.
Bakker, E., Walker, H., & Harland, C. (2006). Organising for collaborative procurement: An initial conceptual framework. In K. Thai, & G. Piga (Eds.), *Advancing public procurement: practices, innovation and knowledge-sharing*. Boca Raton, FL: Academic Press.
Bowman, D., & Lele-Pingle, S. (1997). Buyer behavior in business-to-business services: The case of Foreign Exchange. *International Journal of Research in Marketing*, *14*(5), 499–508.
Brennan, R. (2006). Evolutionary economics and the markets-as-networks approach. *Industrial Marketing Management*, *35*(7), 829–838.
Chang, S. W. (2009). Health information technology as a tool, not an end. *Archives of Internal Medicine*, *169*(16), 1474–1475.
Chapman, T. L., Gupta, A., & Mango, P. D. (1998). Group purchasing is not a panacea for US hospitals. *The McKinsey Quarterly*, *1*, 160–165.
Cunningham, M. T. (1980). International marketing and purchasing of industrial goods — Features of a European research project. *European Journal of Marketing*, *14*(5/6), 322–328.
Dacko, S. G. (2008). *The advanced dictionary of marketing: putting theory to use*. Oxford: Oxford University Press.
Downward, P., Finch, J., & Ramsay, J. (2002). Critical realism, empirical methods and inference: a critical discussion. *Cambridge Journal of Economics*, *26*(4), 481–500.
Dubois, A., & Gadde, L. -E. (2002). Systematic combining: An abductive approach to case research. *Journal of Business Research*, *55*(7), 553–560.
Dubois, A., Gadde, L. -E., & Mattsson, L. -G. (2003). Change and continuity in the supplier base: A case study of a manufacturing firm 1964–2002. *Journal of Customer Behavior*, *2*(3), 409–432.
Easton, G. (1980). Stochastic models of industrial buying behavior. *Omega*, *8*(1), 63–69.
Easton, G. (1992). Industrial networks: A review. In B. Axelsson, & G. Easton (Eds.), *Industrial networks: A new view of reality* (pp. 3–27). London: Routledge.
Easton, G. (1995). Methodology and industrial networks. In K. Möller, & D. Wilson (Eds.), *Business marketing: An interaction and network perspective* (pp. 411–491). Norwell, MA: Kluwer Academic Publishers.
Ehrenberg, A. (1988). *Repeat-buying: Facts, theory and applications*. London: Griffin.
Ehrenberg, A. (1994). Theory or well-based results: Which comes first? In G. Laurent, G. L. Lilien, & B. Pras (Eds.), *Research traditions in marketing* (pp. 79–105). London: Kluwer Academic Publishers.
Ehrenberg, A. (1995). Empirical generalisations, theory and method. *Marketing Science*, *14*(3), G20–G28 (Part 2).
Ehrenberg, A., Hammond, K., & Goodhardt, G. (1994). The after-effects of price related consumer promotions. *Journal of Advertising Research*, *34*(4), 11–21.
Ehrenberg, A., & Sharp, B. (2000). Managerial uses of descriptive marketing models — The case of the Dirichlet. *Proceedings of the Australian and New Zealand Marketing Academy Conference* (pp. 296–301). Gold Coast, Queensland, Australia: School of Marketing & Management, Griffith University.
Ehrenberg, A., Uncles, M., & Goodhardt, G. (2004). Understanding brand performance measures: Using Dirichlet benchmarks. *Journal of Business Research*, *57*(12), 1307–1325.
Epstein, J. M. (2008). Why model? *Journal of Artificial Societies and Social Simulation*, *11*(4), 12.
Essig, M. (2000). Purchasing consortia as symbiotic relationships: Developing the concept of "consortium sourcing". *European Journal of Purchasing and Supply Management*, *6*(1), 13–22.
Fader, P. S., & Schmittlein, D. C. (1993). Excess behavioral loyalty for high-share brands: Deviations from the Dirichlet model for repeat purchasing. *Journal of Marketing Research*, *30*(4), 478–493.
Ford, D., & Håkansson, H. (2006). IMP — Some things achieved: much more to do. *European Journal of Marketing*, *40*(3/4), 248–258.
Gadde, L. -E., & Mattsson, L. -G. (1987). Stability and change in network relationships. *International Journal of Research in Marketing*, *4*(1), 29–41.
Goodhardt, G., Ehrenberg, A., & Chatfield, C. (1984). The Dirichlet: A comprehensive model of buying behavior. *Journal of the Royal Statistical Society*, *147*(5), 621–655.
Graham, C. D. A. (2009). What's the point of Marketing anyway? The prevalence, temporal extent and implications of long-term market share equilibrium. *Journal of Marketing Management*, *25*(9–10), 867–874.
Håkansson, H. (1982). *International marketing and purchasing of industrial goods*. Chichester: John Wiley.
Håkansson, H., & Wootz, B. (1979). A framework of industrial buying and selling. *Industrial Marketing Management*, *8*(1), 28–39.
Hubbard, R., & Lindsay, R. M. (in press). From significant difference to significant sameness: Proposing a paradigm shift in business research, *Journal of Business Research*. http://dx.doi.org/10.1016/j.jbusres.2012.05.002.
Hunt, S. D. (1983). General theories and the fundamental explananda of marketing. *Journal of Marketing*, *47*(4), 9–17.
Kamp, B. (2005). Formation and evolution of buyer–supplier relationships: Conceiving dynamism in actor composition of business networks. *Industrial Marketing Management*, *34*(7), 658–668.
Kearns, Z. (2009). Dirichlet vb. [online] Available from http://marketing-bulletin.massey.ac.nz/V20/Dirichlet%20vb.xls (Accessed 12 August 2012)
Li, F., Habel, C., & Rungie, C. (2009). Using polarization to reveal systematic deviations in Dirichlet loyalty estimation. *Marketing Bulletin*, *20*(1), 1–15.
Low, B. K. H. (1997). Managing business relationships and positions in industrial networks. *Industrial Marketing Management*, *26*(2), 189–202.
Macé, S., & Neslin, S. A. (2004). The determinants of pre- and postpromotion dips in sales of frequently purchased goods. *Journal of Marketing Research*, *41*(3), 339–350.
Mattsson, L. -G. (1997). "Relationship marketing" and the "markets-as-networks approach" — A comparative analysis of two evolving streams of research. *Journal of Marketing Management*, *13*(5), 447–461.
Mattsson, L. -G. (2003). Understanding market dynamics potential contributions to market(ing) studies from Actor-Network Theory. *19th IMP Conference, Lugano, Switzerland*.
Mattsson, L. -G., & Johanson, J. (2006). Discovering market networks. *European Journal of Marketing*, *40*(3/4), 259–274.
McCabe, J., & Stern, P. (2009). Stochastic modelling and industrial networks — Complementary views of organisational buyer behavior. *Journal of the Academy of Marketing Science*, *37*(2), 204–214.
McCabe, J., Stern, P., & Dacko, S. (2012). The power of before and after: How the Dirichlet can analyze the sales impact of a promotional activity. *Journal of Advertising Research*, *52*(2), 214–224.
McLoughlin, D., & Horan, C. (2002). Markets-as-networks: Notes on a unique understanding. *Journal of Business Research*, *55*(7), 535–543.
Mingers, J. (2003). The place of statistical modeling in management science: Critical realism and multimethodology. *Working Paper No. 45*. University of Kent, Canterbury Business School.
Peters, L. D., Pressey, A. D., Vanharanta, M., & Johnston, W. J. (2013). Theoretical Developments in Industrial Marketing Management: Multidisciplinary Perspectives. *Industrial Marketing Management*, *42*(3), 275–282.
Pickford, C., & Goodhardt, G. (2000). An empirical study of buying behavior in an industrial market. *Proceedings of the Academy of Marketing Annual Conference*. Derby, UK: University of Derby.
Popkowski Leszczyc, P., & Bass, F. (1998). Determining the effects of observed and unobserved heterogeneity on consumer brand choice. *Applied Stochastic Models and Data Analysis*, *14*(2), 95–115.
Ritter, T., Wilkinson, I., & Johnston, W. (2004). Managing in complex business networks. *Industrial Marketing Management*, *33*(3), 175–183.
Ryan, A., Tähtinen, J., Vanharanta, M., & Mainela, T. (2012). Putting critical realism to work in the study of business relationship processes. *Industrial Marketing Management*, *41*(2), 300–311.

Schunn, C. D., & Wallach, D. (2001). *Evaluating goodness of fit in comparison of models to data*. Unpublished manuscript, Learning Research and Development Center, University of Pittsburgh.
Sharp, B., & Driesener, C. (2000). The Dirichlet's buyer behavior assumptions really do matter. *Proceedings of the Australian and New Zealand Marketing Academy Conference* (pp. 1144–1148). Gold Coast, Queensland, Australia: School of Marketing & Management, Griffith University.
Sharp, B., Wright, M., Dawes, J., Driesener, C., Meyer-Waarden, L., Stocchi, L., et al. (2012). It's a Dirichlet world: Modeling individuals' loyalties reveals how brands compete, grow, and decline. *Journal of Advertising Research*, *52*(2), 203–213.
Sharp, B., Wright, M., & Goodhardt, G. (2002). Purchase loyalty is polarised into either repertoire or subscription patterns. *Australasian Marketing Journal*, *10*(3), 7–20.
Stern, P. (1994). *Patterns of pharmaceutical prescribing*, unpublished doctoral dissertation, University of London.
Stewart, D. W., & Zinkhan, G. M. (2006). Enhancing marketing theory in academic research. *Journal of the Academy of Marketing Science*, *34*(4), 477–480.
Sutton, R. I., & Staw, B. M. (1995). What theory is not. *Administrative Science Quarterly*, *40*(3), 371–384.
Uncles, M. D. (1989). *BUYER: Buyer behaviour software*. CMaC report. London Business School.
Uncles, M., & Ehrenberg, A. (1990). Industrial buying behavior: Aviation fuel contracts. *International Journal of Research in Marketing*, *7*(1), 57–68.
Uncles, M., Ehrenberg, A., & Hammond, K. (1995). Patterns of buyer behavior: Regularities, models, and extensions. *Marketing Science*, *14*(3), G71–G78.
Uncles, M. D., & Kwok, S. (in press) Designing research with in-built differentiated replication. *Journal of Business Research*. http://dx.doi.org/10.1016/j.jbusres.2012.05.005.
Vanharanta, M., & Easton, G. (2010). Intuitive managerial thinking; the use of mental simulations in the industrial marketing context. *Industrial Marketing Management*, *39*(3), 425–436.
Welch, C., & Wilkinson, I. (2002). Idea logics and network theory in business marketing. *Journal of Business to Business Marketing*, *8*(3), 27–48.
Welch, C., & Wilkinson, I. (2005). Network perspectives on interfirm conflict: Reassessing a critical case in international business. *Journal of Business Research*, *58*(2), 205–213.
Wilkinson, I., & Young, L. (2002). On cooperating: Firms, relations and networks. *Journal of Business Research*, *55*(2), 123–132.
Zerbini, F., & Castaldo, S. (2007). Stay in or get out the Janus? The maintenance of multiplex relationships between buyers and sellers. *Industrial Marketing Management*, *36*(7), 941–954.

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