Chapter 16
Predicting Volatile Consumer Markets using Multi-Agent Methods: Theory and Validation

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ABSTRACT
A behavioral model incorporating utility-based rational choice enhanced with psychological drivers is presented to study a consumer goods market, characterized by repeat purchase incidences by households. The psychological drivers incorporate purchase strategies of loyalty and change-of-pace, which affect the choice set of consumer agents in an agent-based simulation environment. Agent specific memories of past purchases drive these strategies, while attribute specific preferences and prices drive the utility-based choice function. Transactions data from a category in a supermarket is used to initialize, calibrate, and test the accuracy of predictions of the model. Results indicate that prediction accuracy at both macro and micro levels can be significantly improved with the incorporation of purchase strategies. Moreover, increasing the memory length beyond a certain limit does not improve predictions in the model, indicating that consumer memory of past shopping instances is finite and low and recent purchase history is more relevant to current decision making than the distant past.

INTRODUCTION
Markets, typically within the consumer goods industry, exhibit noisy dynamics in the form of volatile movements in market shares (Jager, 2007). Frequent competitive interventions by manufacturers—led by aggressive marketing policies such as multiple pricing and promotion strategies—is definitely one reason behind this widespread phenomenon (Ailawadi, et al., 2001; Blattenberg & Wisniewski, 1989). However, the presence of a wide variation in tastes and preferences amongst a reasonably large and demographically varied
consumer population is also a key factor leading to the noisy character (Allenby & Rossi, 1998; Sengupta & Glavin, 2010). Such markets do not lend themselves easily to traditional statistical and econometric analysis. Additionally, the presence of potential non-linear interactions such as social networks, word-of-mouth influences etc. means that they increasingly exhibit a “complex” character—hence making traditional techniques further redundant. Not surprisingly, markets in general and Consumer Packaged Goods (CPG) markets in particular, are increasingly being brought under the purview of “complex systems” analysis—whereby more modern “bottom up” methodologies such as agent based modelling are being used for analysis, inference and predictions (Gilbert, et al., 2007).

Systems which exhibit “emergent behavior” of some kind cannot be fully examined and analyzed by traditional “top-down” methodologies. Simulation based techniques—relying on agent based constructs—where constituents of the system (in this case, shoppers, firms etc.) are treated as individual modelling units (or agents) with the ability to follow independent rules of behavior and engagement have become increasingly popular and are widely advocated (Epstein & Axtell, 1996; Gilbert & Troitzsch, 2005; Tesfatsion, 2006). CPG markets have been extensively studied in the mainstream literature, but in spite of exhibiting many characteristics of a complex system, have only recently been brought within the purview of complex systems analysis (see North, et al., 2009; Sengupta & Glavin, 2010). This chapter builds a behavioral model of consumer choice, which is then incorporated within an agent based simulation framework to illustrate the accuracy and usefulness of such an approach in predicting market phenomena. It builds on an earlier simpler model by Sengupta and Glavin (2010) by incorporating crucial psychological factors into the choice model, modifying and extending the validation methodology and finally showing that both market and individual level predictions can be significantly improved by using enhanced choice models.

BACKGROUND

Sengupta and Glavin (2010) focused on developing a theoretical model of behavior, which took into account the heterogeneity in tastes within the consumer population and illustrated the link between this heterogeneity and the resultant volatility in overall market shares of brands and specific product characteristics. In order to carry out this analysis, the authors developed a rigorous methodology, which focused on out of sample predictions of both macro level market share movements and micro level household level choices. Results showed a reasonably high degree of accuracy with which market share movements as well as choices made by individual households could be predicted out of sample. These results were compared with a benchmark model, where agent level heterogeneity was ignored, and it showed that the former far outscored the latter at both the macro and micro levels.

However, the behavioral model presented in Sengupta and Glavin (2010) was restricted at a simple level where agents made rational ordinal utility-based choices—where the utility function depended solely on prices, product characteristics, and individuals’ preferences towards these characteristics. This restrictive utilitarian nature of the choice algorithm was intentional as the focus was establishing a validation methodology, which is able to capture the volatile dynamics of the market and subsequently, illustrate the link with agent level heterogeneity. This chapter aims to loosen this restriction by introducing an added layer of complexity into this framework—with, what are termed as “purchase strategies.” Purchase strategies refer to the psychological perspective in

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