A DYNAMIC VEHICLE PORTFOLIO DESIGN BASED ON PREDICTION OF WILLINGNESS-TO-PAY OF VEHICLE ATTRIBUTES: A FRAMEWORK

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ABSTRACT

In this paper, a framework of dynamic vehicle portfolio design is proposed. This portfolio focuses on forecasting an evolution of customer preferences of automobile products in terms of Willingness-To-Pay (WTP) of vehicle attributes. The proposed framework is developed by understanding the evolution of exogenous variables which affect the WTP over time. The forecasts of WTP, typically at a future date corresponding to the concept-release time, would be used within the planning framework. The best vehicle design or a set of designs for the future can be derived for various scenarios from the results of WTP prediction.

Keywords: Willingness-To-Pay, Prediction, Vehicle Portfolio Design

INTRODUCTION

Early stages of product development hinge heavily on understanding the needs of the potential customers. This helps the firm in optimally positioning a single new product or a line of new products constituting a portfolio to perform well on metrics such as contribution margin or revenue in a competitive market space. Where understanding the customer choices is more of an estimation problem, the positioning problem is an optimization problem which could include other engineering constraints. Though a disconnect exists, there is an inherent relation between both tasks as attributes considered for understanding customer preferences would also be used in modeling the objectives in the positioning stage. Krishnan and Ulrich (Krishnan and Ulrich, 2001) present an excellent review of literature on product development practice and reflect that frameworks and decisions adopted by the firms vary with the product offering. This is indeed true in cases of fast moving consumer goods. Here, lead time required for manufacturing and delivering the product to the customer encompasses a small window. The entire exercise of generating a new concept can be achieved in this small horizon. Many of existing techniques (Garcia, 2003; Louviere and Islam, 2008) that have been used in choice modeling approach for understanding customer needs assume time invariant behavior of the customer. These methods seldom consider the evolving nature of customer choice over time which can have a significant impact on market performance.

For product offerings where the product development window is quite large as is the case of an automobile where the concept-to-release time takes approximately 36-48 months, one would expect the customer preferences to have evolved during this period. As a result the vehicle portfolio designed based on past customer preferences would be suboptimal relative to market shares in the future and hence the need to capture the dynamics of the customer preferences arises. Customer preferences evolving over time must be accounted for within the product planning framework. In this work, a dynamic portfolio design framework to forecast the evolution of customer preferences (obtained from existing static models) is proposed. This framework is developed by understanding the evolution of exogenous variables which affect the customer preferences over time. Exogenous variables include various economic indicators, such as unemployment rate, consumer price index (CPI: a measure for inflation), housing starts, retail sales, stock market prices, consumer confidence index (CCI) etc. These forecasts, typically at a future date corresponding to the concept-release time, would be used within the planning framework. The best vehicle design or a set of designs and corresponding price levels for the future can be derived for various scenarios of competitive offerings. A graphical description of these ideas is presented in Figure 1a. The vehicle design pitched for time period $t+k$ using customer utilities at time t would be suboptimal especially in cases when k is large and customer utilities have evolved with the changing exogenous space.

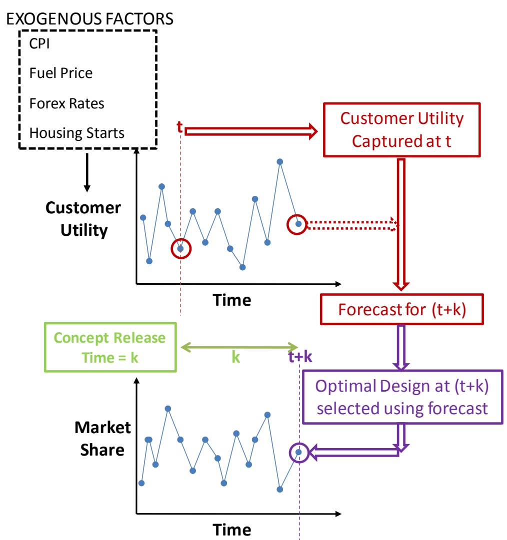

Figure 1a. Integrating forecasts into design for products with large concept-release time

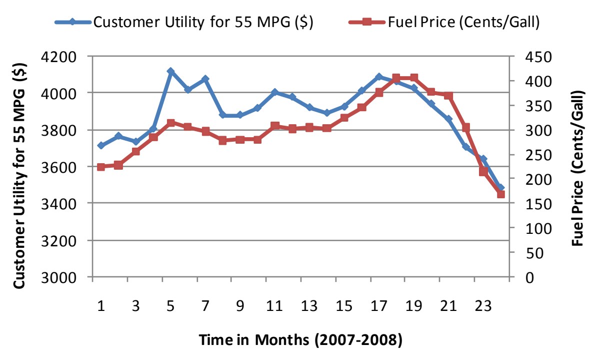

Figure 1b. Co-Evolution of utility for fuel economy of 55 mpg with fuel prices

Before embarking on details of the framework, a visual evidence for the proposed co-evolution is presented. Figure 1b shows a tracking of customer utility for fuel economy of 55 mpg measured in dollars per unit mpg for each month between January 2007 and December 2008. Simultaneously the average fuel prices observed during this period is also presented on the secondary axis of the plot. By observing from this plot, it has been shown that customer utility for a fuel economy of 55 mpg increases with increasing fuel price, and decreases when the fuel price decreases. This suggests some form of a co-evolution if not causality between the two variables. An alternative approach that can be used to model this co-evolution is to neglect the time component and model for the correlations between the observables. However such a static model would be severely limited as it would overlook effects of shock, sustenance or change in dynamics of the observables.

As discussed earlier, there is the need for a dynamic control framework wherein forecasts of customer preferences are included in design decisions. Engineering/Planning action at this stage would be required to analyze the feasibility of a design that is based on such forecasts, and finalize a plan for the future. Deliberations among stakeholders at this stage are required as decisions taken herein are not flexible to be modified in future. For instance, historic preference data might indicate high preference for trucks, while changing economic scenarios may indicate latent demand for sub-compacts. An investment plan for trucks that is based on today's preferences could backfire if future consumer preferences turn out otherwise.

Oftentimes, customer preferences are expressed in terms of willingness-to-pay (WTP) metric (Breidert, 2005), which refers to the maximum monetary amount a consumer is willing to pay for a good or service. In this paper, a framework of dynamic portfolio design which focuses on forecasting an evolution of customer preferences of automobile products in terms of willingness-to-pay (WTP) of vehicle attributes is proposed. The organization of the remainder of this paper is as follows: the next section provides details of a dynamic vehicle portfolio design framework. The last section is summary section.

A DYNAMIC VEHICLE PORTFOLIO DESIGN FRAMEWORK

We propose to incorporate time series methods into the modeling framework, by observing the characteristics of the WTP data obtained to explain its evolution over time with respect to the evolving exogenous space. The uniqueness of the proposed approach emerges from the augmentation of the current decision theory. The dynamic portfolio design framework is also proposed to include an adaptation stage in the framework wherein as actual observations are made on the realized market shares, forecast errors can be adjusted for, and used in making robust estimates. The vehicle design process will be treated as a dynamic system with three specific components of prediction, control and adaptation, each taking place at distinct time scales, illustrated in Figure 2.

Let WTP_t represent the customer willingness to pay for the different attributes of a vehicle at current time instant *t*. Also let Z_t be the current state of the various exogenous and endogenous variables affecting the customer WTP. As in figure 2, if the vehicle concept to release time takes *k* time units, the goal of engineering at *t* is to arrive at a feasible design to be released in the market at the time instant (*t*+*k*). The proposed models would provide a forecast at time *t* for the WTP realized by the customer at the time $(t+k)^{th}$ instant -$W\hat{T}P_{t+k}^{(t)}$. Herein we assume there is no lag between vehicle release in the market and realization of its market share i.e. both events are instantaneous. The forecasting model would take into account WTP_t & Z_t and their evolution over the *k* time units to arrive at $W\hat{T}P_{t+k}^{(t)}$. Using $W\hat{T}P_{t+k}^{(t)}$ we obtain $\hat{X}_{t+k}^{(t)}$ the vehicle design concept, which will realize maximum market share $\hat{M}_{t+k}^{(t)}$, suggested for implementation at time *t* for a release at instant *(t+k)*. Engineering action would require to analyze the feasibility of the proposed design $\hat{X}_{t+k}^{(t)}$ and based on the analysis arrive at X_t^a - the actual engineering action arrived at time *t* based on the feasibility analysis. Also at time instant *t* we would observe market shares realized for the vehicle design implemented at (*t*-*k*)th time instant. The prediction errors observe over a period of time can be modeled for and used in further strengthening our forecasts.

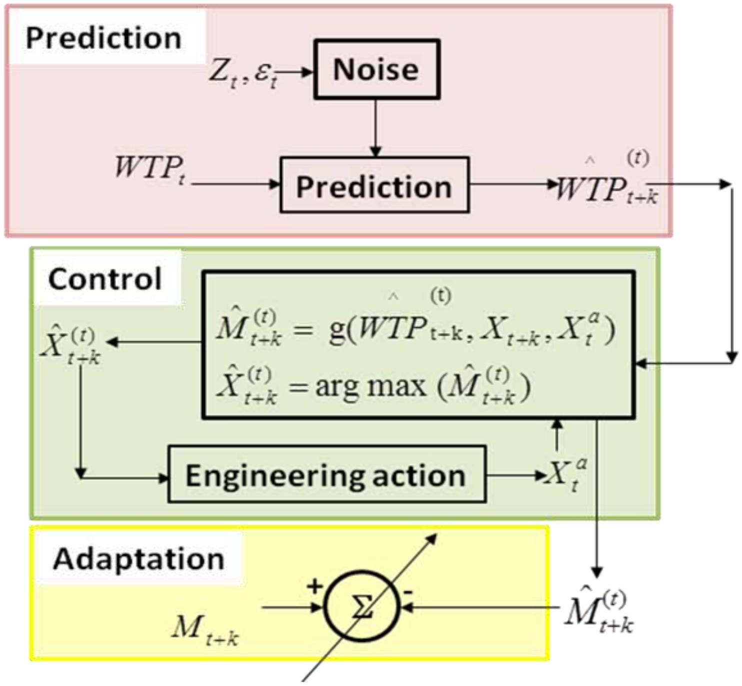

Figure 2: Proposed Framework for Dynamic Vehicle Portfolio Design

However before we set course in this direction, the available data needs to be classified and formatted for use within time series framework. Longitudinal tracking of the evolution of WTPs at individual customer level can be intractable if not infeasible. Therefore some form of customer aggregation becomes necessary towards the prediction of future WTP and preference evolution. On the contrary, tracking simple time aggregates of the WTPs disregarding the customer-level variations would be inefficient as time aggregates will not reflect and model for customer heterogeneity. In this regard, each customer is classified into Body Type (BT) segment based on their preferences. The main BT segments for the prediction are Sedan and SUV segments. Statistical techniques are used to identify time invariant attribute dimensions and the attribute dimensions which affect preference share computation the most for each BT segment.

Methodology currently used to estimate WTP in this research can be at the best classified as self explicated method (Breidert et al., 2006). Inputs from prospective customers elicited form on-line portals, social networks and blogs, as well as product clinics are being considered for the estimation of WTP (Tabin, 2008). Self explicated surveys are cheap, and can be done continuously over time. Each customer is classified to a particular prior, and based on the customer's inputs, a posterior distribution for the WTP for the customer is computed. Currently, the preference share computation for automobile's models and trims is done using this posterior mean of each customer, and obtained from a nested logit model.

Given customer preferences from an explicated survey vary over time, one would intuitively expect to see the preferences evolving with time especially with changing exogenous variable space. As an example in introduction section, an increase in fuel price may shift potential customers between brands and/or body type selections and hence possible cross shopping behaviors. Time series models could be used in this context to explain evolution patterns for these preferences as a function of the exogenous variables.

Keeping with the need to preprocess the data, the complexity of the data sets available for the prediction of future WTP necessitates significant efforts towards data preprocessing before getting in to develop the time series models. As in most self explicated surveys, two levels of data are collected: preference for a particular level of an attribute and the overall importance for the attribute when compared with other attributes. WTP computations for an attribute level are based on these two values. Information is collected from automobile customers on roughly 25 vehicle attributes and accounting for all possible levels of the attributes. The size of the WTP vector including attribute levels for each individual customer is 144.

SUMMARY

For product offerings where the product development window is quite large as is the case of an automobile where the concept-to-release time takes approximately 36-48 months, one would expect the customer preferences to have evolved during this period. In this paper, a framework of dynamic vehicle portfolio design is proposed. This portfolio design focuses on forecasting an evolution of customer preferences of automobile products in terms of willingness-to-pay (WTP) of vehicle attributes. The proposed framework is developed by understanding the evolution of exogenous variables which affect the WTP over time. The forecasts of WTP, typically at a future date corresponding to the concept-release time, would be used within the planning framework. The best vehicle design or a set of designs for the future can be derived for various scenarios from the results of WTP prediction.

REFERENCES

Breidert, C., 2005. Estimation of willingness-to-pay. Theory, measurement, and application, WU Vienna University of Economics and Business. WU Vienna University.

Breidert, C., Hahsler, M., Reutterer, T., 2006. A review of methods for measuring willingness-to-pay. Innovative Marketing.

Garcia, P.M., 2003. Measuring Willingness-To-Pay in Discrete Choice Models with Semi-Parametric Techniques. Economics and Econometrics Research Institute (EERI).

Krishnan, V., Ulrich, K.T., 2001. Product development decisions: A review of the literature. Management Science 47, 1-21.

Louviere, J., Islam, T., 2008. A comparison of importance weights and willingness-to-pay measures derived from choice-based conjoint, constant sum scales and best-worst scaling. Journal of Business Research 61, 903.

Tabin, J.Z., 2008. Method and Apparatus for Interactive Criteria-based Commodity Comparisons, in: Patent, U.S. (Ed.), USA.