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A note on budget allocation for market research and advertising

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ABSTRACT

Firms that introduce new products often conduct market research to reduce the substantial uncertainty in demand. When a fixed budget is assigned to marketing-oriented activity, investments in market research must be balanced against other advertising expenses. We characterize a firm's optimal marketing and production decisions for a new product. The larger a firm's production cost, the higher is the cost associated with unsold products. Market research increases the forecast accuracy and thus reduces the risk of overage. As a consequence, one might expect that a firm's investment in market research should be higher if it faces higher production costs. Interestingly we find that an increase in the production cost may sometimes lead to a decrease in the optimal investment in market research, even when the marketing budget is not restrictive.

1. Introduction

The nature of new products implies that their demand is highly uncertain. BlackBerry overestimated the popularity of its PlayBook handset, which was released in April 2011. BlackBerry Internet Service also suffered from a massive outage in September 2011. This outage coincided with the announcement of the launch of Apple's iPhone 4S. As a consequence, especially due to the introduction of Apple's iPhone, BlackBerry lost substantial market share and took a $485 million writedown against unsold stock (Arthur, 2012). There are numerous factors, such as the availability of product substitutes/complements, changes in consumer demographics, and the state of the economy, that can affect demand and thus increase uncertainty (Raju and Roy, 2000).

One approach to reduce demand uncertainty is to conduct market research. For example, Walmart, Procter & Gamble, Heineken USA and Levi Strauss & Co. all invest significantly in market research to obtain more precise demand predictions (Aviv, 2001). However, with limited financial resources, firms often have a fixed overall budget for marketing activities (Weber, 2002; Lachowetz et al., 2009; Fischer et al., 2011). Therefore investments in market research (to reduce demand uncertainty) have to be balanced against other marketing activities, such as advertising (to support the scale of market demand).

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Decisions regarding the marketing mix have direct implications on a firm's production decisions, and failure to coordinate the decisions along these dimensions can have severe financial consequences. For example, HP invested in advertisements to sell its Touch Pad which then was more popular than expected and stocked out quickly, leaving customers complaining (Phones Review, 2011). Similarly, after extensive advertisements for its products, Apple was surprised to see demand surpass its rosiest sales predictions, leading to shortages (Bertolucci, 2010).

Due to the complex interactions between marketing and operations, determining optimal marketing and production decisions is anything but simple. Managers often refer to simple heuristics (Bigne, 1995); however, empirical evidence shows that the results are far from optimal (Weber, 2002; Fischer et al., 2011). Therefore, research is needed on how marketing spending should be allocated at the strategic level (Marketing Science Institute, 2010).

There is wide research that investigates the interface between marketing and operations. Tang (2010) and Martínez-Costa et al. (2013) provide detailed classifications of mathematical models used in this research stream. In particular, our paper relates to the literature that studies how advertising increases demand under uncertainty, in a newsvendor setting. Khouja and Robbins (2003) and Lee and Hsu (2011) examine the impact of advertising when demand is an increasing and concave function of advertising expense. Ma et al. (2013) consider a setting where the supply chain consists of a manufacturer and a retailer, either of which can be the Stackelberg leader. Investigating the effort that these two firms exert under different strategies, they find that if one firm does not commit to an effort level, the other firm reduces its level of effort. Lee (2014) considers a setting where the decision maker uses an order-up-to policy when facing stationary and non-stationary demands which are auto-correlated. The firm sets inventory levels using a Bayesian averaging technique. Mesak et al. (2015) investigate the effects of two competing firms' marketing investments and order quantities in an asymmetric duopoly. They find that marketing investments have a larger impact than quantity decisions and that the optimal behavior is strongly affected by firm size. They also show that when the two competitors cooperate, the larger firm continues to invest in marketing, whereas the smaller firm reduces its marketing investment. Our paper also relates to the literature that studies how market research can reduce demand uncertainty. Raju and Roy (2000) considered a scenario where competing firms forecast demand using market information-gathering techniques. They find that, when demand uncertainty is large, improvements in a firm's forecast precision have a large positive effect on the firm's profit. Hess and Lucas (2004) analyzed how market research affects decisions that are made when only prior information is used. They modeled this process using the current level of knowledge and the expected outcomes of market research. Gal-Or et al. (2008) studied whether a manufacturer should share demand information with its retailers and how this decision affects prices when various firms in the system have differing degrees of accuracy concerning their demand signals. They found that when transmitting information is costly, the manufacturer may share information only with the less-informed retailer. When budgets are low, Christen et al. (2009) investigated whether a manufacturer should learn a great deal about a narrow range of markets or learn a little about many markets. They considered a scenario where a firm has an a priori belief about market demand and conducts market research to update these beliefs using a Bayesian approach. They found that focusing the resources on a few markets is optimal when processing information is costly. Concentrating on a few markets can also be optimal when the firm has accurate prior knowledge about the unknown parameters and when it is efficient in processing information.

In this paper, we consider a firm that is selling a product with uncertain demand. The firm has an initial demand estimate and it needs to decide how to allocate its marketing budget between two investments. It can invest in market research to increase the accuracy of its forecast, or in advertising to increase the expected demand of the product. In addition, the firm must decide how many units to produce for the selling season.

We find that the optimal investments in the two marketing activities are strongly related to the profitability of the product and the financial consequences of failing to match supply and demand. Specifically, the optimal investment in advertising should be small when stockouts are costly, whereas investments in market research are less valuable when the product profit margin is large. A firm should invest less in market research when the production cost is small, since then a large production quantity is more effective in mitigating the consequences of demand uncertainty. However, even when a firm's marketing budget is not restrictive, we find that the investment in market research can decrease in the production cost. This is because market research minimizes the consequences of demand-supply mismatch. When the production cost is large, a firm incurs more cost due to any unsold products, but at the same time, since the profit margin is smaller, the financial consequences of stockouts are small. Therefore market research may at times be less valuable if production costs are higher.

2. Mathematical model

A manufacturer produces products at a per-unit production cost c for sale at a unit retail price r. Demand for the product, D, is uncertain and the firm needs to decide the number of units to produce for the selling season, q. In case of a shortage, the firm faces a unit penalty cost g. Any products unsold at the end of the season can be salvaged at a per-unit value v. To avoid trivial or nonsensical scenarios, we assume $r > c > v \geq 0$ and $g \geq 0$.

The demand D is distributed following a distribution $F_{\mu,\sigma}(D)$, with mean μ and standard deviation σ. We use $f_{\mu,\sigma}$ and $F^{-1}_{\mu,\sigma}$ to denote the corresponding density and inverse function, respectively. Similar to Zhang (2005) and Yan and Zhao (2011), we make the following assumption.

Assumption 1. $F_{\mu,\sigma}(D)$ belongs to the location-scale family.

The location-scale family is a family of distributions parametrized by a location parameter (e.g., mean) and a scale parameter (e.g., standard deviation). Many distributions, such as uniform, beta, triangular, normal, lognormal, weibull and gamma distributions, belong to the location-scale family.

Assumption 2. $\lim_{p \to 0} pF^{-1}_{\mu,\sigma}(p) = \lim_{p \to 1}(1-p)F^{-1}_{\mu,\sigma}(p) = 0.$

Assumption 2 requires that the two tails of the distribution are sufficiently thin; this assumption can be shown to hold for many different distributions (for example, uniform, beta and symmetrical triangular distributions).

The firm decides to invest in advertising, $i_a \geq 0$, to increase the expected demand $\mu(i_a)$ and in market research, $i_{mr} \geq 0$, to reduce the standard deviation $\sigma(i_{mr})$. Specifically, we assume investment in advertising increases the expected demand $(\mu'(i_a) > 0)$, and investment in market research reduces the standard deviation $(\sigma'(i_{mr}) < 0)$, and that both investments have decreasing marginal effects $(\mu''(i_a) < 0$ and $\sigma''(i_{mr}) > 0)$. Consistent with the related literature (e.g., Raju and Roy, 2000; Ataman et al., 2008; Gal-Or et al., 2008; Christen et al., 2009), we assume that advertising only changes the expected demand, that the firm's forecast is unbiased, and that market research does not change the expected value. The firm decides the marketing investments i_a and i_{mr}, given a constrained budget B. It also decides the production quantity q. Hence, the firm faces the optimization problem:

$$\max_{i_a, i_{mr}, q} \pi = rE[\min(D,q)] - cq - gE[D-q]^+ + vE[q-D]^+ - i_a - i_{mr} \tag{1}$$

$$\text{s.t. } i_a + i_{mr} \leq B$$

where E is the expectation over demand.

3. Analysis

For any given marketing investments, we have the standard newsvendor problem, so

$$q = F^{-1}_{\mu(i_a),\sigma(i_{mr})}(k) \quad \text{and}$$

$$\pi = -g\mu(i_a) + (g+r-v)\int_{-\infty}^{F^{-1}_{\mu(i_a),\sigma(i_{mr})}(k)} y f_{\mu(i_a),\sigma(i_{mr})}(y)\,dy - i_{mr} - i_a,$$

where $k = (g+r-c)/(g+r-v)$.

In order to analyze the firm's optimal marketing strategy, we standardize the distribution to one with a mean of zero and a standard deviation of one. Lemma 1 provides the production quantity and the expected profit based on such a standardized distribution.

Lemma 1. *Optimal production quantity and expected profit.*

1. $q = \mu(i_a) + F^{-1}_{0,1}(k)\sigma(i_{mr})$
2. $\pi = (r-c)\mu(i_a) + (g+r-v)\left(\int_{-\infty}^{F^{-1}_{0,1}(k)} y f_{0,1}(y)\,dy\right)\sigma(i_{mr}) - i_a - i_{mr}$