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THE EFFECT OF PRODUCTION UNCERTAINTY ON THE OPTIMAL PRODUCTION AND SALES PLANS FOR NEW PRODUCTS

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ABSTRACT

Once a new product is available, if the company starts the sales without building an initial inventory (*myopic* policy), the demand for the product grows rapidly due to extensive word of mouth spreading from past sales and soon may exceed the firm's capacity resulting in lost sales. To avoid this problem, companies generally delay product launch to build sufficient inventory prior to starting sales (*build-up* policy). In this study, we use simulation to evaluate the expected profit and risk associated with myopic and build-up policies under production uncertainties. The results show that ignoring production uncertainties can result in potentially incorrect decisions regarding the number of inventory build-up periods and product launch time. We also show that the policy with the maximum expected profit does not necessarily minimize risk.

1 INTRODUCTION

New products are highly important in today's competitive marketplace constituting more than 30% of the overall sales of companies. Decision making regarding an appropriate production-sales policy for a new product requires a deep understanding of the underlying diffusion dynamics and can be difficult even for companies with a lot of experience in successful new product launches. For instance, Sony lost $1.8B in its game division and eventually laid off 3% of its workforce due to over-anticipation of the demand for PlayStation®3 (Los Angeles Times 2007) that led to excessive production and inventory costs. In another case, Motorola who manufactured Power Mac G4 chips for Apple, was unable to keep up with the rapid growth of the demand for the computer (New York Post 1999). Bandai Co. faced a similar problem in 1996 when the demand for Tamagotchi™, the first virtual pet, rapidly grew beyond expectations and led to lost sales. The company lost even more money when demand declined right after they expanded their capacity in 1998 resulting in a $123 million in after-tax losses (Higuchi and Troutt 2004). As another example, in 2001, Microsoft delayed the launch of Xbox® in Japan for one year and in the US by a week since it failed to meet the targeted initial inventory (New York Times 2001b, New York Times 2001a).

Several studies have addressed the problem of finding the optimal production-sales policy. However, existing literature ignores an important characteristic of any manufacturing environment: production uncertainty. Production systems exhibit significant uncertainties due to machine breakdowns, stochastic processing/tool changeover/setup times, labor availability, and quality uncertainty. Therefore, the current literature leaves an important question unanswered: *How does uncertainty in production yield affect the company's choice of the production-sales plan and launch time?* Moreover, existing studies use the expected profit as the only criterion to select the optimal policy while risk measures (which are generally important for managers when making any financial investment) have been ignored. This work aims to address these gaps through the use of simulation that allows us not only to model production uncertainties but also characterize the risk associated with different policies.

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2 METHODOLOGY

A Monte Carlo simulation model of new product diffusion is developed where a single firm markets a new product and its production yield at each time step varies around the average production level. The product demand in each time period consists of two components: (1) number of imitator adopters that is proportional to the cumulative sales up to that period (representing the effect of word of mouth); and, (2) number of innovators that will adopt the product independently of the word of mouth influence. As a result, variations in production yield not only affect supply and sales at the current time step, but also have an impact on future demand dynamics. The model keeps track of production and inventory costs, cost of backlogged demand, and revenue from sales as the diffusion proceeds. Once the potential market is almost entirely exhausted, the Net Present Value (NPV) of profit over the diffusion time is calculated based on a given discount rate. The experimental design consists of 404,352 configurations of different production and population-related factors. The expected NPV of profit and its 25^{th} and 75^{th} percentiles (measures of risk) are used to determine the optimal number of build-up periods under each parameter setting.

3 RESULTS

The first research question to be answered is whether the best policy can change due to variation in production yield. In order to answer this question, for each performance measure, we first identify the scenarios where the best number of build-up periods for the deterministic case is different from the best policy with production yield variation taken into account. For the resulting two candidate policies, Welch's t-test is used to test the difference in average NPV of profit while non-parametric tests are used to compare the 25th and 75th percentiles of profit. The results are inline with our expectation from empirical findings that supply uncertainties affect the optimal number of build-up periods and thus product launch time.

Next, we investigate whether the optimal policy is different when considering risk as the primary criterion. In order to answer this question, we identify configurations where the best number of build-up periods based on the expected NPV of profit is different from the best policy selected based on the 25th or 75th percentiles. Non-parametric statistical tests are then performed to detect statistical difference between the corresponding percentiles of the resulting candidate policies. The results show that the policy with the highest NPV of profit does not necessarily have the minimum risk. In other words, the decision on the production-sales plan can change if the primary criterion is risk rather than the expected profit.

4 CONCLUSIONS AND FUTURE WORK

Through extensive experimentation using Monte Carlo simulation, we investigate the effect of production uncertainty on the optimal production and sales plan for new products. The findings have significant theoretical and managerial implications and provide deeper insights for both researchers and practitioners. As a limitation of the current work, the only type of uncertainty considered in this model is the variation in production yield. Different sources of uncertainties exist in a supply chain which makes the study of the impact of other types of uncertainties on diffusion dynamics an interesting area for future research.

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