Omega 51 (2015) 107–120

Contents lists available at ScienceDirect

Omega

journal homepage: www.elsevier.com/locate/omega

New product development and the effect of supplier involvement ☆

Seung Ho Yoo [a], Hojung Shin [b,*], Myung-Sub Park [b]

[a] Division of Business Administration, Sunmoon University, Tangjeong-myeon, Asan, Chungnam 336-708, Korea
[b] Department of Logistics, Service & Operations Management, Korea University Business School, Anam-dong, Seongbuk-gu, Seoul 136-701, Korea

ARTICLE INFO

Article history:
Received 20 June 2013
Accepted 11 September 2014
Processed by Campbell
Available online 22 September 2014

Keywords:
New product development
Supplier involvement
Design quality
Transactional inefficiency

ABSTRACT

This study investigates the problem of new product development (NPD) under supplier involvement (SI) program in a supply chain comprising a single supplier and a single buyer. The buyer, the Stackelberg leader in the supply chain, configures the design quality of the product and determines the extent of SI – the degree to which the supplier is involved in the NPD project – in order to utilize the complementary capability of the supplier. The supplier in charge of production determines the level of conformance quality to design specifications. Using the principal-agent paradigm, we propose an analytical framework that investigates the role of the SI program in the NPD project, incorporating essential factors such as the R&D cost, the transactional inefficiency, the production cost, and the transfer payment. We provide rich managerial insights into the decentralized NPD practice by analyzing the equilibrium behaviors of major decision variables (design quality, conformance quality and SI extent) with respect to internal and external environmental conditions.

1. Introduction

Contemporary firms tend to focus on core processes and outsource others from the suppliers, which may possess cost advantages or technical expertise in the product development and production processes. The more sophisticated technologies a new product requires, the more the firm needs to collaborate with its suppliers because it is inefficient and virtually impossible to command all the relevant technologies necessary to satisfy customers' needs. As a result, new product development (NPD) processes are often decentralized across the supply chain. For example, Nike outsources almost 100% of its athletic shoe production, and often cooperates with its suppliers in the development of athletic products such as football shoes [1]. Apple does not manufacture the majority of its products and frequently involves key suppliers in Asia such as LG, and Samsung, and Foxconn (a contract assembly company for Apple) in the product development stage [2].

The literature in general supports that supplier involvement (SI) programs are beneficial in NPD projects because an SI program may help enhance overall product quality and reduce the time to market and costs required for development and production [3–7]. In contrast, some studies address that the benefits of SI could be altered depending on the dimensions of operational performance [8–10]. For instance, Primo and Amundson [8] found that supplier involvement helps improve product quality but critical suppliers can hurt the progress of projects. It is possible that active supplier involvement slows down the pace of product development [11], and the importance of the supplier's role and the frequency and timing of supplier involvement do not always affect new product success [12,13].

In addition, partitioning of product development processes over the supply chain yields a broad variety of externalities and transactional inefficiencies as the level of supplier involvement increases and the required technologies become progressively more sophisticated [9,10]. For example, Boeing experienced severe communication difficulties with its suppliers in coordinating technological issues as the company's project for developing “787 Dreamliner” stretched out worldwide. Boeing believes that “supplier involvement in the development and design of the 787 is significant,” but many “blame the repeated Dreamliner delays on a splintered engineering strategy and a complex supply chain of about 50 partners [14].”

A typical supplier in the supply chain is an independent economic entity that makes rational decisions. If any SI program does not secure the supplier's profit in the long run, the supplier may deviate from the governing SI program proposed by the buying firm. Therefore, the buyer should not only assess the supplier's capability and willingness to cooperate, but also provide incentives and collaboration mechanisms to motivate the supplier's action [9,10,15]. Taking these conflicting issues into consideration, we investigate the problem of NPD under the SI program in the Original Equipment Manufacturer (OEM) supply chain comprising a single supplier and

☆ This manuscript was processed by Associate Editor Campbell.

* Corresponding author. Tel.: +82 2 3290 2813; fax: +82 2 922 7220.
E-mail addresses: shy1228@sunmoon.ac.kr (S.H. Yoo), hojung_shin@korea.ac.kr (H. Shin), mspark@korea.ac.kr (M.-S. Park).

http://dx.doi.org/10.1016/j.omega.2014.09.005
0305-0483/

a single buyer. We propose two-stage profit-maximization models, using the principal-agent paradigm to capture the decision dynamics between the buyer and the supplier. With the proposed model, the primary objective of the present study is to identify the favorable business conditions for a success of SI programs and to suggest the guidelines for an effective use of SI program.

In many OEM supply chains in practice, the buying firm (e.g., Apple Inc.) is the focal company that leads the NPD project and determines the contractual terms and product specifications. The supplier (e.g., Foxconn) is responsible for complete production. Therefore, in the first stage, the buyer configures the design quality[1] and specifications of the product based on market (or consumers) preferences. The buyer then determines the extent of SI, the degree to which the supplier is involved in the NPD project. The buyer's objective for involving the supplier in NPD is to utilize the supplier's expertise and complementary capability. In the second stage, the supplier determines the level of conformance quality to design specifications. The buyer, acting as a Stackelberg leader, adopts a compensation mechanism to control the supplier's selfish but rational behavior to maximize its own profit. In devising the compensation mechanism, the buyer considers both parties' transactional inefficiencies that may arise during the implementation of the SI program.

Analyzing the properties of proposed models, the following research questions will be addressed:

1) What are the favorable environmental conditions for a successful SI program?
2) To what extent, should the buyer involve the supplier in NPD projects under various conditions?
3) How do possible transactional inefficiencies interfere with the efficacy of SI programs?
4) How can the buying firm coordinate the SI program, using compensation or penalties?

Although supplier involvement in NPD projects has become popular in practice, analytical research addressing the integrated issues with NPD and SI program in the supply chain is rather sparse. Without consideration of possible use of SI, the extant analytical studies concentrate on various NPD decisions of a single firm, including product positioning, concurrent engineering, and component commonality [19–21]. In contrast, we focus on the decision dynamics between a buyer and its supplier that may be attributed to supplier involvement in the NPD project. The primary contribution of this research is to propose an analytical model that investigates the role of the SI program in the NPD project under a variety of conditions, incorporating essential factors including the R&D cost, the transactional inefficiency cost, the production cost, and the transfer payment. To the best of our knowledge, no previous research has modeled the problem of creating a collaborative NPD environment by simultaneously determining the appropriate levels of design quality, supplier involvement, incentives, and conformance quality.

The remainder of this study is structured as follows. In Section 2, we discuss the relevant literature associated with the NPD project and the SI program. In Section 3, we formulate the problem described above and provide detailed explanations regarding the proposed model. In Section 4.1, we obtain a benchmark solution for perfect coordination in which the buyer can fully monitor and control the supplier. The benchmark solution is the basis with which solutions from the alternative cases are compared. In Section 4.2, we obtain the solution for a moral hazard case in which the supplier deviates from the first-best SI program proposed by the buyer to maximize its own profit. In Sections 5 and 6, we investigate the equilibrium behaviors of the buyer and the supplier by conducting extensive comparative static analyses and numerical experiments in various operating environments. In Section 7, we provide a summary of managerial insights based on the analytical results. This paper concludes with a discussion on limitations and future directions in Section 8.

2. Literature review

Most of the extant analytical studies on NPD investigate a variety of factors that may affect the success and efficacy of NPD projects, but their scope is limited to a single firm's operational environment without considering the possibility of supplier involvement. These NPD studies deal with overall quality decisions in competitive environments [22,23], technology dependency of a new product [19,24], reservation prices and new product diffusion [25], the effects of functional interaction [20], component commonality in a product line design [21], multi-attribute product design [26,27] and product modularity. In particular, product modularity is one of the popular subjects associated with NPD for which a vast amount of research has been conducted. Modularity in product design, development, and engineering leads to a broad spectrum of operations which may involve multifunctional team-based activities [28]. Product modularity may affect the design of new products in terms of buyer-supplier communication during the designing phase, time to market, product testing, experimentation of new ideas [29]. For a comprehensive review of the literature on product modularity, refer to Salvador [28].

Karmarkar and Pitbladdo [22] investigate the joint determination of product performance and conformance in several competition settings in which product performance is modeled as a vector of attributes of customer preferences. Banker et al. [23] study the effect of competitive intensity on overall product quality and represents product quality as an aggregate single dimension for design and conformance. Carrillo [24] studies the NPD clock speed and the number of new products generated in the planning horizon, and finds that the NPD clock speed can be constrained by the firm's internal capability or the supplier's technology. Jain and Ramdas [19] evaluate an optimal product positioning strategy under uncertainties and demonstrate that late positioning may outperform early positioning in certain conditions. Schmidt and Druehl [25] develop a new product diffusion model, using the customers' linear reservation price framework for the product and technology. Bhuiyan et al. [20] present a simulation model and assess the effect of functional interaction in the NPD process and show that concurrent engineering is appropriate under low environmental uncertainty whereas sequential engineering is preferred under high uncertainty. Gupta and Krishnan [21] assess the effects of the supplier and component commonalities on product family design and show that excessive commonality may increase development costs. Shi et al. [26] develop an optimization framework for a multi-attribute product design to

[1] Among a variety of definitions of "quality" in economics, marketing, and operations management (OM), we focus on *design quality* and *conformance quality*, conventionally accepted in the OM area – See the detailed explanations in Brown et al., p. 290–291 [16], Jacobs and Chase, p. 136 [17], and Stevenson, p. 405 [18]. The product design stage is the starting point to decide upon the level of product quality to be achieved. Specifically, *design quality* relates to determining the level of design specifications or characteristics of a product in the NPD stage that can fulfill consumers' needs and preferences. It is one of the most important strategic decisions in the NPD process, depending on the firm's interpretation of various market needs. Associated with design quality is conformance quality. *Conformance quality* represents the degree to which the product meets the design specifications as the product is manufactured. The level of conformance quality depends on the various factors in the manufacturing process, such as process variability, material quality, understanding of design specifications, training of people, etc.