Int. J. Production Economics 131 (2011) 505–518

Contents lists available at ScienceDirect

Int. J. Production Economics

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

Product price and performance level in one market or two separated markets under various cost structures and functions

Li Qian *

Department of Engineering Technology & Management, Solberg Hall 115B, South Dakota State University, Brookings, SD 57006, USA

ARTICLE INFO

Article history:
Received 31 May 2010
Accepted 22 January 2011
Available online 12 February 2011

Keywords:
Pricing
Product quality or performance level
Attribute-dependent demand
Cost structure
Market characteristic
Product or service development

ABSTRACT

Market characteristics, including intrinsic demand and customer sensitivity on price and product performance level, are distinct at different markets. Comparisons of various product development strategies in one market or two geographically separated markets are conducted for three classes of products: development intensive products (DIPs) with constant unit cost, marginal cost-intensive products (MIPs) with constant fixed cost, and marginal and development intensive products (MDIPs) with non-constant unit cost and fixed cost. Results show that larger demand size, less customer sensitivity on price and/or more sensitivity on performance level lead to more profit, a higher sale price and a not-lower product performance. The customer reservation or the saturation performance level should be generally adopted though the optimal performance level does exist occasionally. Unit cost and/or fixed cost must increase in performance at an increasing rate for the existence of one optimal performance level. Due to the impact of demand size, one high-end (low-end) MDIP or DIP could be introduced into one low-end (high-end) market at a different price if the demand size is significantly large in the low-end market. For DIPs, offering one niche high-end product is not worse than offering the low-end product into two markets. For MIPs with negligible fixed cost, the product line strategy is not worse than the standard product development strategy. Additionally, the product cost reduction approach adopted in one product line has significant effects on the best product development strategy and sequence.

1. Introduction

Customers have different preferences on quality or performance level of a product or service. The interchangeable term quality or performance level could be defined as the level of some attribute or a vector of several attributes (Chambers et al., 2006). All customers agree that a higher performance level is preferable than a lower one even they may be not willing to pay more for one product or service. A performance level could be scored as a weighted value of several attributes considered and those attributes could include service level, lead time, functionality, reliability, etc. A higher product performance level results in more purchases from consumers. Moreover, various products/services with different prices and performance levels are developed to generate ideal product/services for different markets. Those products/services could be composed into one family or line for cost effectiveness. Generally speaking, a higher-level product should be sold at a higher price due to more costly or more extensive features (Freiesleben, 2010). Consequently, product price and performance level should be determined jointly.

Many researchers modeled product or product line design problem with a utility function that is linear in attributes. Mussa and Rosen (1978) considered the monopoly's problem with self-selection constraints and assume the unit and marginal cost to be increasing functions of quality. Moorthy and Png (1992) studied the sequential or simultaneous introduction of new products for two market segments differing only in quality. Their results show that it is never optimal to introduce the low-end product before the high-end product. Further, Kim and Chhajed (2002) investigated a product line design with multiple attributes for two market segments and concluded that single-product offering strategies are never optimal when fix cost and economies of scale are not taken into account. Krishnan and Gupta (2001) illustrated that the costs and benefits of the platform-based product family development in comparison with the independent product development, one standardized product for both segments and one niche product addressing only the high-end market. Their results indicate that platforms are not appropriate for extreme levels of market diversity or high levels of non-platform scale economics. They also pointed out that introduction sequence decisions are significantly affected by the presence of platforms. Chambers et al. (2006)

* Tel.: +1 605 6886419; fax: +1 605 688 5041.
E-mail address: li.qian@sdstate.edu

0925-5273/$ - see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.ijpe.2011.01.016

examined various piecewise-linear cost functions and non-linear functions to show dramatic impacts of function shapes on product positions and profitability with price and quality competition. Krishnan and Zhu (2006) studied the family design of development-intensive products (DIPs) that the fixed development costs are far outweighing the unit variable costs as in pharmaceutical, information, and entertainment industry. Under this circumstance, they proposed that a low-end product could be differentiated on additional quality dimensions instead of a subsumed high-end product. Lacourbe et al. (2009) grouped attributes into the feature choice and the quality-like attributes to study the optimal product portfolio. They concluded that portfolio composition decisions are dependent on the product cost structure and the consumer preferences.

In joint price–production decisions, instead of using self-selection constraints, linear or non-linear attribute-dependent demand functions are commonly applied to describe customer preferences under different market segments (Petruzzi and Data, 1999). For example, in choosing price and lead time or service level for product differentiation, many researchers employed linear or non-linear demand functions in respect of price, lead time and/or service level (Palaka et al., 1998; Boyaci and Ray, 2003; Bernstein and Federgruen, 2004; Liu et al., 2007). Those attribute-dependent demand models are also found in papers related to product or service differentiation decisions on price and quality. Banker et al. (1998) and Matsubayashi (2007) modeled demand as a linear function of price and quality to study the relationship between quality and competition for two firms. Wu et al. (2006) used a log-linear demand function of price and warranty length that is determined by product quality.

Total cost of one product could comprise two components: fixed production cost (fixed investment during product design and production system development) and per-unit variable production cost. The product performance level chosen by a firm could affect variable production cost and/or fixed production cost. Generally speaking, investment in quality enhancement increases fixed production costs (Krishnan and Zhu, 2006). Those fixed costs arise because of new investment for high-reliability equipment, employee training, and/or additional efforts to design the product or manufacturing system to achieve the desired performance level. For example, to have more functions of software, namely higher performance level of software, more design and programming efforts must be made, which increase fixed cost. As another example, to make a better movie, better actors, better equipment, and more skilled technical supporters must be employed, resulting in a higher fixed cost. In this way, we could assume that the product development cost be an increasing function of product performance level. With a standard definition of product quality or performance level, higher performance means more or better product features (Freiesleben, 2010). Accordingly, performance level also has an impact on variable cost due to more expensive material, more skilled labor, more components, and/or longer production labor time for more or better features. There are lots of real-world examples where higher product performance can only be achieved at higher variable cost (Chambers et al., 2006). A wide range of cost structures and cost shapes were employed in literature: constant in unit cost and linear models in fixed cost (Boyaci and Ray, 2003), linear models in unit-cost and quadratic cost models in fixed cost (Banker et al., 1998; Matsubayashi, 2007) and quadratic cost models in both cost components (Krishnan and Gupta, 2001; Lacourbe et al., 2009), negligible fixed cost (Mussa and Rosen, 1978; Moorthy and Png, 1992; Kim and Chhajed, 2002; Chambers et al., 2006) and negligible unit cost (Krishnan and Zhu, 2006). Additionally, Wu et al (2006) assumed product unit cost be a function of quality and sales volume as Gjerde and Slotnick (2004) incorporated three types of quality-dependent costs.

Indeed, a particular form of cost structure could be more applicable in some specific cases. First, if spending on product design is a relatively small portion of overall product cost, this kind of products could be named as *marginal cost-intensive products* (MIPs). For a MIP fixed product cost is often insignificant in comparison with variable cost, especially for a product with a high sales volume. Second, products that fixed costs of development far outweigh unit-variable costs could be defined as *development cost-intensive products* (DIPs) (Krishnan and Zhu, 2006). DIPs have the following characteristics: (1) the product performance is determined primarily by the product development effort; and (2) the performance directly affects the fixed development cost, but does not have a significant impact on variable cost. Performances of DIPs, such as branded drugs and software, are dominated by fixed costs of product development or investment on R&D. Particularly, the variable cost of a DIP could be very small in comparison to its development cost and it could be considered negligible. Examples of DIPs exist in several industries such as pharmaceutical, information, and entertainment industry. For example, Pfizer Inc. spends 15% of its revenue in R&D. As a matter of fact, a branded drug sold at $300 per case can cost less than $25 in manufacturing. Here, high margins ensure the payback of the high research and development cost of the drug (Krishnan and Zhu, 2006). As another example, for Adobe System Inc., the R&D spending is about 20% of the total revenue while the percentage on variable production cost is just 8%. Some Hollywood movies may cost several hundreds of millions dollars in developing and making, but cost a little to make a DVD copy or be played in theaters. In comparison, offering MIPs, General Motors and Caterpillar only invest 3.5% and 3.4%, respectively, of their revenue on the product research and design. In point of fact, products with small sale volumes and high development cost, such as expensive equipment used in a limited number of scientific labs and high-end medical equipment used in large hospitals, could be treated as DIPs. Additionally, the product performance level could affect variable production cost and fixed production cost simultaneously (Banker et al., 1998). Here, we refer products with non-negligible fixed cost and non-negligible variables cost, both being mainly determined by product performance level, as *marginal and development cost-intensive products* (*MDIPs*). In literature, most research studies MIPs, considering the fixed cost as a constant or negligible (Mussa and Rosen, 1978; Moorthy and Png, 1992; Kim and Chhajed, 2002; Chambers et al., 2006). Krishnan and Zhu (2006) studied product line design for DIPs. Krishnan and Gupta (2001) and Lacourbe et al. (2009) considered both design cost and unit production cost as functions of product performance, namely MDIPs, in product line design. But, as pointed out by Chambers et al. (2006), results given by researchers based on models with narrow cost functional forms might be cautious and could not be robust for products with different cost structures and forms.

For better robustness of results in joint decisions on price and performance level, this paper employs a general cost structure and a broad family of cost shapes and only assumes that variable cost per unit and fixed cost are positive and strictly non-decreasing in performance level. Consequently, three kinds of product cost structures are considered to derive optimal solutions in one single market or two geographically separated markets: constant or negligible variable cost for DIPs, constant or negligible fixed development cost for MIPs, and non-constant variable costs and fixed costs for marginal cost-intensive and development-intensive products (MDIPs). Here sale price and performance level are attributes to define a product and the product cost is totally determined by the performance level. The attribute-dependent demand in a market is a function of market characteristics composed of potential intrinsic demand, customers' sensitivity on price