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A model of product line design and introduction sequence with reservation utility

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ABSTRACT

Cannibalization is a major concern for a firm when designing a product line. In addition, external options from outside the firm's product line may also play a significant role. In this paper, we investigate the impact of external options, represented by reservation utility, on product line design and introduction sequence. We find that: (a) heterogeneous reservation utility defines the relative attractiveness of segments and corresponding product line; (b) reservation utility makes it more favorable to introduce products sequentially rather than simultaneously; (c) aggregating segments is an effective way to mitigate cannibalization when it becomes too difficult to manage with different values of reservation utility across multiple segments; and (d) introducing products in a non-monotone order of quality can improve profit from simultaneous introduction when the value of reservation utility of a middle segment is particularly high.

1. Introduction

Product differentiation through quality is widely observed in many industries. For example, Dell offers different sizes of memory for its laptops, SONY offers different screen sizes for its TV, and UPS offers different delivery speeds. When offering a product line differentiated through quality, cannibalization is a major concern. For example, when high-end and low-end microwaves are on the market, high-end consumers may find the low-end product is more appealing and vice versa (Kim and Chhajed, 2000). It is very important to choose the price and quality values for different products to address the cannibalization concern, in order to sell products to their target market segments.

However, cannibalization is not the only concern when designing a product line: consumers have other choices apart from the product line offered by a particular firm. Take software purchase as an example. When consumers consider purchasing an operating system from Microsoft, they not only examine and compare different editions of XP, but they also, at the same time, compare Microsoft products with other options unrelated to Microsoft. These external options may include the options to use substitute products from competing firms, to develop software instead of buying, to use a custom-designed product (Chen and Seshadri, 2007), or to buy a pirated version (Sundararajan, 2004). External options are not unique to the software industry, but also exist in other industries. When consumers consider buying a car from Renault, they not only compare different vehicles of Renault, such as Twingo, Clio, Megane, with one another, but they also consider cars offered by rivals, such as Peugeot and Ford, or consider the option of using a taxi or public transport, etc. In the microwave example, consumers not only compare different microwaves offered by a particular company, but they also consider microwaves offered by other companies, second-hand ones at the flea market, and other alternatives of cooking. The presence of such external options raises additional challenges for product line design: not only do the product attributes have to be chosen to address the cannibalization concerns, but, at the same time, they also need to be competitive with respect to the external options of different segments.

From a modelling perspective, there are two basic ways to model external options, endogenous and exogenous. The endogenous way is to model external options as a strategic competitor, the exogenous way as reservation utility. Strategic competition with differentiated product line is very difficult to analyze, so existing works on competition are limited to the setting where each competing firm has a single product (Moorthy, 1988; Desai, 2001). In order to analyze product line design in the presence of external options, the existing literature (Chen and Seshadri, 2007) model external options as exogenously given reservation utility, which is a "reduced form" of competition to allow tractability.

The existence of reservation utility naturally raises the issue regarding their relative values across segments, which may significantly impact product line design. Chen and Seshadri (2007) justify heterogeneous reservation utility with different costs of adopting a new product for different consumers. The reservation utility of wealthy consumers at the high-end segment may be higher for several reasons. First, it is observed that high-end consumers' time is more costly (Hill, 1985); therefore, it is more difficult for them to take time to switch to a new product. Second,

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when more firms wish to serve the wealthy consumers at the high-end, this results in more fierce competition, which may also lead to higher reservation utility at the high-end since these consumers have more alternatives. Third, as consumers get wealthier, the options available for them to spend money are also growing, which may lead to choosier consumers.

In the absence of reservation utility, the high-end segment always receives higher surplus and is the more attractive segment. Therefore, it should be given priority in terms of quality choice and introduction sequence (Moorthy and Png, 1992; Krishnan and Gupta, 2001). If reservation utility is very high at the high-end segment, this raises the interesting question whether the high-end segment is necessarily the more attractive segment. High-end consumers are conventionally considered wealthier and place greater value on product quality. However, they may also be harder to please due to the reasons previously mentioned. There is anecdotal evidence that the high-end segment may be less attractive than the low-end segment because surplus at the high-end is competed away. For example, in recent years, the traditional mobile phone manufacturers, such as Nokia, see their high-end phones hit by the growing popularity of smart phones, such as the iPhone. However, mobile phones belonging to the low-end segment somehow helped the company because the competitive landscape there has not really changed (http://www.sunstar.com.ph/cebu/business/2011/06/15/nokia-launches-2-dual-sim-phones-161356). In the example of the automobile industry, Dacia has been very successful in Europe and worldwide due to its low price and relatively high quality. In authors' conversation with an executive at Renault, Dacia has no serious competitors at the price range of 5000–8000 Euros, but Renault faces fierce competition from many car makers at the price range of 8000–12000 Euros. Consequently, Dacia has a 6% margin (http://www.dacia-sandero.org/page/6/), while the Renault company as a whole has only 3.2%. Similar examples can also be found in service industries. When Southwest became the first low-cost air carrier with a very creative business model, it also enjoyed high profitability in a market segment with little competition. Even with low fares, it was more successful than many traditional airlines that face fierce competition. In the examples mentioned above, it may not be true that all firms in those industries find the high-end segment to be less profitable; but, for some firms with a given business model and inherent technological capabilities, the high-end segment is not the most profitable.

The heterogeneity of reservation utility has important implications for product line design and introduction sequence. When reservation utility is sufficiently high, the high-end segment is no longer the more attractive segment and should not enjoy such priority. How should the firm incorporate this new information? In this paper, we try to answer three questions concerning the impact of reservation utility:

1. What is the impact of heterogeneous reservation utility on product line design?
2. What is the impact of reservation utility on introduction sequence?
3. What is the impact of reservation utility on product line design and introduction sequence when there are more than two segments?

The remainder of the paper is organized as follows. Section 2 reviews related literature. Section 3 introduces the model set-up. Section 4 analyzes the product line design and introduction sequence when there are two market segments. Section 5 studies the product line design with three market segments. Section 6 concludes the paper.

2. Related literature

Vertical differentiation refers to the differentiation of product performance quality in a market space where consumers are ranked according to their willingness to pay (WTP) for quality (Moorthy, 1984; Tirole, 1988; Moorthy, 1988). Vertical differentiation models are used extensively in the product line design literature (Moorthy and Png, 1992) and have extended into product component commonality or product platform (Krishnan and Gupta, 2001; Kim and Chhajed, 2000; Desai et al., 2001), remanufacturing (Debo et al., 2005; Ferrer and Swaminathan, 2010) and software packages (Raghunathan, 2000). The key finding in Moorthy and Png (1992) is that high-end consumers should be served first and with efficient quality; the product serving low-end consumers has to reduce its quality below efficient quality to reduce cannibalization and can only be introduced after the high-end product in sequential introduction. Such results are partly driven by the assumption that high-end consumers always receive a higher surplus than low-end consumers. There are several papers that change this assumption with multiple quality dimensions (Vandenbosch and Weinberg, 1995; Krishnan and Zhu, 2006; Kim and Chhajed, 2000). Another way to change the assumption is to add reservation utility. That is, the high-end consumers with higher quality evaluation – but also higher reservation utility – may not have higher surplus. Reservation utility has been investigated in several economics papers which study its impact on quality distortion when cost is constant and does not depend on quality (Laffont and Martimort, 2002; Maggi and Rodirguez-Clare, 1995; Julien, 2000; Srinagesh and Bradburd, 1989), and also in the field of Information Systems when marginal cost of production is negligible but development cost is significant (Chen and Seshadri, 2007). Vertical differentiation has also been studied jointly with horizontal differentiation where consumers have different tastes for features (Desai, 2001; Lacourbe et al., 2009; Matsubayashi et al., 2009). Tang and Yin (2010) studied product line design with capacity constraints, and Matsubayashi (2007) studied the impact of vertical integration with complementary products.

Product line design literature is not limited to vertical differentiation models. Among the most influential tools are multidimensional scaling (MDS) and conjoint analysis approaches. Conjoint analysis is a statistical technique used in market research to determine what combination of product attributes is optimal in product line design. MDS is a statistical technique to visually display the perceptions of customers on a grid. Green and Krieger (1989) provided an excellent review of multidimensional scaling and conjoint analysis approaches in optimal product design and market segmentation models. Many papers using conjoint analysis or MDS constructed effective heuristics and genetic algorithm (Kohli and Krishnamurti, 1989; Schön, 2010a,; Alexouda and Paparrizos, 2001; Gruca and Klemz, 2003; McBride and Zufryden, 1988; Dobson and Kalish, 1988; Kohli and Sukumar, 1990; Krieger and Green, 2002). Genetic algorithm is also used to optimize product line together with pricing decision (Day and Venkataramanan, 2006; Kraus and Yano, 2003) or in a dynamic competitive setting (Tsafarakis et al., 2011).

The decision concerning product introduction sequence is an important one (Krishnan and Ulrich, 2001). Most existing works also use vertical differentiation models to study this topic. Moorthy and Png (1992) propose sequential introduction as an alternative to simultaneous introduction when cannibalization pressure is high. Bhattachaya et al. (2003) discover that it may be optimal to introduce a low-end product first to accommodate technology improvement over time. Padmanabhan et al. (1997) consider the impact of network externality in product introduction sequence. Biyalogorsky and Koenigsberg (2008) and Tyagi (2006) show that