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Optimal versioning strategy for information products with behavior-based utility function of heterogeneous customers

Minqiang Li *, Haiyang Feng, Fuzan Chen, Jisong Kou

College of Management and Economics, Tianjin University, Tianjin 300072, PR China

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ABSTRACT

This paper reconsiders two fundamental assumptions (i.e., on the quality of information product and the self-selection behavior of customers) that decide the optimality of versioning strategy (or vertically differentiated product line) for information products. The quality of an information product is clarified in terms of functional and nonfunctional features. The customers' behavior of self-selection among multiple versions of an information product is examined, and the disability of linear valuation function for exactly capturing customers' valuation on information products is clarified. The required quality is introduced to depict a customer's requirement on the quality of an information product, and a behavior-based utility function is thus defined, where a customer has a marginal decrease (different from the constant marginal in linear valuation function) on the valuation of versions with quality levels higher than the required, but the valuation of a customer diminishes quickly on versions with quality levels lower than the required. Then, a bilevel programming model is built to represent the task for optimizing the strategy of versioning an information product, with the monopolist as the leader and all customers as followers. Optimal quality levels and prices for multiple versions are obtained for a given number of versions. To deal with the nonlinearity and multimodality of this model due to correlated decision variables, a steady-state evolutionary algorithm, hybridized with the local search method (called the hybrid steady-state evolutionary algorithms), is developed to improve the global optimality of versioning schemes. Numerical experiments are conducted on the bilevel programming model with specific parameterization by using the hybrid algorithm. Experimental results verify the optimality of multi-version strategy and reveal various facets of its property. With the behavior-based valuation function of heterogeneous customers, the multi-version strategy is superior to the one-version scheme. The total profit increases logarithmically with the maximal number of versions, which means that the introduction of a new lower-quality version contributes less to the total profit of a monopolist. Furthermore, when a lower quality level version is offered to the market, higher quality versions are priced higher than they were in previous versioning schemes, indicating that a multi-version scheme can make more detailed segmentation of the market. Therefore, a monopolist is able to gain greater revenue via price discrimination on heterogeneous customers through vertically differentiating information products.

1. Introduction

Although Shapiro and Varian [20] presented the clear-cut advantage of the versioning strategy for information products[1] through profound qualitative analyses and successful industrial instances, there have been controversial conclusions on the optimality for vertically differentiating an information product [14,4,5,8].

For instance, the versioning was proved to be suboptimal [4,11,6,25] when customers' valuation or willingness to pay (WTP) for an information product was defined as a linearly multiplicative function of customer type and product quality, e.g., customer WTP function: $W(v,q)=vq$, customer utility function: $U(v,q,p)=vq-p$, where v indicates customer type or preference (marginal valuation), p is the price of version with quality q, $v\in[0,v_{max}]$, $q\in(0,q_{max}]$, v_{max} is the maximal marginal valuation, q_{max} is the maximal quality. All potential customers were usually assumed to be uniformly distributed with regard to their types or preferences. Based on this linear valuation function of customers, the introduction of a low-quality version of an information product will not surely lead to greater revenue for a monopolist when there has been a high-quality version in the current market. Customers with lower preference usually buy the low-quality

* Corresponding author. Tel./fax: +86 22 27404796.
E-mail addresses: mqli@tju.edu.cn, mqli2@hotmail.com (M. Li), hyfeng@tju.edu.cn (H. Feng), fzchen@tju.edu.cn (F. Chen), jskou@tju.edu.cn (J. Kou).

[1] Information products mean anything that can be digitized and transmitted based information and communication technologies (ICT), including various softwares, digitized contents on the Internet, and information services, etc.

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version. Meanwhile, some customers with higher preference will probably shift to purchase the low-quality version. This strategy induces customers' self-selection between two versions based on their utilities. The income brought by the low-quality version may be offset by the profit loss of high-quality version when the low-quality version cannibalizes a large market share of the high-quality version. There exist many factors that determine the optimality of two-version scheme (or multi-version schemes with more than two versions of different quality levels), including customer distribution, marginal cost of an information product, position of quality levels, and prices of different versions. Bhargava and Choudhary [4,5] proved that versioning became optimal for a monopolist only when the highest-quality version of an information product had the best benefit-to-cost ratio or if the relative valuation decreased with customer preference. Jing [11] pointed out that positive network effect would make the versioning optimal.

There are two fundamental assumptions (explicitly or implicitly assumed) in previous researches on the optimality of versioning information product. The first one is about the self-selection behavior of customers when multiple versions are available in the market. A customer with marginal valuation v selects the version that brings him/her the greatest utility, $q^* = \max\{U(v, q_H, p_H), U(v, q_L, p_L)\}$, where $\{q_H, q_L\}$ denote the high-quality version and the low-quality version respectively, $\{p_H, p_L\}$ indicate prices of high-quality version and low-quality version respectively, and $U(v, q_H, p_H) = vq_H - p_H$, $U(v, q_L, p_L) = vq_L - p_L$. Suppose that a monopolist offers two versions $q_H = 1, q_L = 0.2$ at prices $p_H = 0.95$, $p_L = 0.1$, and then a customer with $v = v_{\max} = 1.0$ selects the low-quality version instead of the high-quality version by $U(v, q_H, p_H) = 0.05 < U(v, q_L, p_L) = 0.1$. However, the exact situation is that a customer chooses either the low-quality version or the high-quality one just based on his/her need for quality.

The second assumption is that information products share identical quality concept with physical products. According to the Mussa and Rosen [19], the quality of physical products refers to performance measures [15]. Customers prefer high-quality products, as indicated by the linear valuation function. For instance, a notebook PC becomes more attractive when it has a faster CPU, a bigger memory size, a larger hard-disk capacity, and a higher maximum resolution for LCD screen. A computer firm usually offers simultaneously a basic model with fundamental specifications and more advanced models with extended specifications. The basic model meets the fundamental requirements of all customers, and advanced models accommodate the preference of customers with higher quality requirements. Previous researches also adopted the linear utility function to investigate the optimal versioning strategy of information products. However, information products have a concept of quality different from that of physical products.

The definition of software quality is referred to the ISO 9126-1.[2] Software quality consists of six main features: functionality; reliability; usability; efficiency; maintainability; and portability. With commercial softwares, customers are most concerned about functionality, reliability, usability, and efficiency. These qualities meet customers' functional or nonfunctional requirements. Customers in need of the high-quality software version rarely install low-quality versions. The software version that does not provide functions and nonfunctional performance that a customer requires is unacceptable in the real world. Otherwise, users would have their work efficiency negatively affected in application. For instance, the IBM DB2 is an object-relational database software for multiple platforms of operating systems.[3] It has many versions developed for Linux, UNIX, and Windows, including enterprise server edition, workgroup server edition, express edition, and Express-C (for free). Suppose that a firm needs the enterprise server edition for high-performing, robust, on-demand enterprise solution on parallel servers, it will definitely not choose the express edition even if it is much cheaper (entry-level price for small and medium businesses). Similarly, if the express edition meets the requirements of a small firm, this firm will not valuate the enterprise server edition much more than the express edition because it does not use the extra functions in the enterprise server edition. Customers choose “just right” versions as indicated by the Goldilocks selection [20,9].

Therefore, the customer self-selection behavior on multi-version information products is different from that on physical products in the real world. Hence, this feature requires reconsideration on customers' valuation or utility function of information products. Some studies have been conducted in this stream of research.

Sundararajan [21] considered the nonlinear usage-based pricing for information products to make customer discrimination. Customers were charged according to their expected usage of the software through a usage-based contract, in which the expected usage of the software indicated that there was a continuum of customer types and a continuum of version quality in the vertical differentiation strategy. The quality was proportionate to the feature number of an information product.

Krishnan and Zhu [14] investigated the differentiation of development-intensive products (DIPs, including information products) for heterogeneous customers, in which the fixed cost of product development was much greater than variable cost. They introduced the concept of reservation quality and saturation quality to model customer utility as a piecewise linear function. Reservation quality was defined as the minimal quality level below which a customer would not value corresponding versions positively. Saturation quality was the quality level above which a customer had a zero marginal WTP, or the customer did not value the version with higher quality more than the version with saturation quality. A customer had a linearly increasing WTP from the reservation quality to the saturation quality. This piecewise linear utility function provided a different way to deal with managerial challenges on customers' self-selection of information products.

Hui et al. [9] analyzed the discrepancy between research suggestions for offering only one or two versions of an information product to customers and firms' actual practice of vertical differentiation with more than two versions. By considering versioning as a type of customized bundling of information product attributes, different versions form a menu of different-sized bundles serving as a self-select device. In their study, $W(v, q) = v_0(q - q^2/2\theta)$ for $q \le \theta$, and $W(v, q) = v_0\theta/2$ for $\theta \le q \le Q$, where $q \in [0, Q]$ indicates the number of attributes (or quality level), $\theta \in [0, Q]$ defines a customer's consumption level (or customer type), v_0 is fixed and represents the common valuation of all customers on the basic quality level of an information product. This function indicated that customers did not have a continuously increasing marginal valuation for an information product when its quality was higher than what was required. Hence, a lower-type customer does not have a marginal valuation that increases monotonically with quality due to redundant attributes of high-quality versions.

[2] ISO/IEC 9126-1 to 9126-4 in JTC 1/SC 7-Software and systems engineering. http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_tc_browse.htm?commid=45086.

[3] DB2 database software. http://www-01.ibm.com/software/data/db2/.