Monopoly Versioning of Information Goods When Consumers Have Group Tastes

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Abstract

Large sunk costs of development, negligible costs of reproduction and distribution, and substantial economies of scale distinguish information goods from physical goods. Price discrimination and product differentiation through versioning are prospective ways firms my take advantage of these specific characteristics. However, a critical result in monopoly versioning of information goods is that in a baseline model where consumers have different individual tastes for quality, the monopolist only offers one version. Thus, our research is focused on exploring formulations that add features to the baseline model that result in a monopolist offering multiple versions. We examine versioning where consumers have different individual tastes for quality, and add a feature whereby separate groups of consumers that are delineated by segments of these individual tastes define groups of consumers that share the same group taste. We find that if groups have some mutually exclusive characteristics that they value and as long as the shared characteristics that they value are not too valuable relative to the mutually exclusive ones, then versioning is optimal. In addition, when group tastes are hierarchical such that higher taste groups value characteristics that lower taste groups value but not vice versa, as long as the overall valuation of the higher taste group is not too much higher than the next lowest taste group versioning is also optimal.

Keywords: Information Goods, Market Segmentation, Product Differentiation, Versioning Strategies, Pricing Strategies.

1 Introduction

Information goods such as computer software, online services, online content and digitalized music, movies and books have become an indispensable part of our life. The greatest distinction between information goods and physical goods is reproduction costs where the former incurs large sunk costs of development but negligible costs of reproduction and distribution. Broad adoption of e-commerce, secure and convenient online payments and high-speed Internet connections have greatly lowered transaction costs and made information goods more appealing. In addition to production costs, several other features make information goods different from many other products: due to developments in software engineering, the functionality of some information goods such as computer software can be easily restricted or recombined to generate different versions, popularity of modularity in software design brings more flexibility in delivery of various versions, and information goods are durable goods in that a consumer typically purchases at most one unit of a specified version of the good during its life cycle.

Price discrimination and product differentiation are broadly adopted strategies firms use to take advantage of the specific characteristics of information goods. As consumers can easily compare and select their favorite goods online, third degree price discrimination, which assumes consumers from one segment cannot cross-purchase goods from another segment, is less likely. Choudhary, Ghose, Mukopadhyay and Rajan (2005) proposed personalized pricing (PP) where firms perfectly identify valuations of heterogeneous consumers and target them individually with vertically differentiated goods. However, consumers can easily communicate with each other or disguise their patterns to respond strategically to firm's pricing strategy, hence PP has not been widely adopted.

Another common practice firms use to sell information goods is to offer a menu of goods and prices, and each consumer chooses based on their preference: second degree price discrimination. In this context one method used to increase monopoly profits is bundling. Bakos and Brynjolfsson (1999) found that bundling large numbers of unrelated information goods can be profitable, but Geng, Stinchcombe and Whinston (2005) found when different groups of consumers differ systematically in their valuations for goods, simple bundling is not optimal. Another method used to increase monopoly profits is nonlinear pricing. Sundararajan (2004) showed that for information goods, fixed-fee and usage-based pricing can be used together to maximize a monopolist's profit. Nonlinear pricing can also be adopted by undifferentiated sellers to avoid direct competition. Using a duopoly model, Choudhary (2010) showed that different pricing schemes such as per user pricing and site licensing can be adopted by competing sellers to differentiate themselves.

An alternative to bundling and non-linear pricing for information goods is versioning. In previous literature, versioning through vertical differentiation and corresponding pricing strategies have been modeled in contexts such as network externalities (Jing 2007, Cheng and Tang 2010), competition (Jones and Mendelson 2010, Wei and Nault 2006), anti-piracy (Wu et al. 2003, Chellappa and Shivendu 2005), and interorganizational systems (Nault 1997). They all conclude that versioning is not optimal without certain constraints, consistent with Bhargava and Choudhary (2001). Indeed, a surprising and critical result in monopoly versioning of information goods when consumers have different tastes for quality is that only one version is offered. However, this critical result is in contrast to numerous observations that information goods monopolies or near-monopolies use versioning as a strategy. Like similar inconsistencies in many other sciences, this has given rise to an emergent research program that provides alternative explanations through alternative analytical model formulations. Thus, the research program in versioning information goods is directed towards showing conditions under which a monopolist offers multiple versions, and the importance of contributions to this program are judged in terms of modeling quality and correspondence with observation.

In addition to enhancing the problem setting with externalities, competition, anti-piracy and interorganizational systems as described above in order to obtain a result whereby versioning is used, prior work has also focused on refining utility function specifications – that is, on the structure of consumer preferences. Adopting a quadratic utility function form, Ghose and Sundararajan (2005) proposed optimal solutions with multiple versions. Chen and Seshadri (2007) introduced convex reservation utilities when consumers have multiple outside options to explain the existence of multiple versions. Bhargava and Choudhary (2008) examined a more general nonlinear utility function form and proposed that versioning is optimal when lower type consumers have greater ratios of valuations than higher type consumers. Lacourbe, Loch and Kavadias (2009) show that when consumers are heterogeneous in their tastes for different features (a horizontal dimension) and in their tastes for quality (a vertical dimension), and when variable costs are volume-dependent, a monopolist offers a mix of vertically and horizontally differentiated products. For information goods where development costs dominate and variable costs are zero, the monopolist's optimal portfolio of products is based solely on horizontal differentiation.

Although these prior modeling results are consistent with many empirical observations, there are other observations of industry practice that are not effectively explained. The most well-known are the different editions in the individual generations of Microsoft's Operating Systems. Windows XP, first released in 2001, has five editions: Home, Professional, Media Center, Tablet PC and Professional x64. The Home edition and Professional edition are vertically differentiated in that the functionality of the Home edition is only a subset of the Professional edition. However, the others are horizontally differentiated – each contains specialized functionality. Windows Vista, fully released in 2007, has four editions: Home Basic, Home Premium, Business, and Ultimate. The Home Basic has the least functionality, and Ultimate has all the functions. Home Premium and Business editions share some functionality, but each also includes distinct functions (windows.microsoft.com/en-US/windows-vista/products/compare). Thus, Home Premium and Business are horizontally differentiated, whereas Home Basic and Home Premium/Business and Ultimate are vertically differentiated. Matlab delivers a standard software module together with separate add-on products so that consumers can select their favorite add-on products (modules) to generate their customized versions. These customized versions can also be either horizontally or vertically differentiated (http://www.mathworks.com/products/matlab/?sec=extending).

There are many other examples of information goods versioning, but to make our analysis concrete we will focus on two examples – one horizontal and one vertical. A classic horizontal differentiation example is Kurzweil's product line of software-based voice recognition products (Shapiro and Varian 1999). Kurzweil offers seven versions and among them Office Talk is designed for office staff, Law Talk for lawyers, Voice Med for medical staff, and Voice

Ortho for surgeons. Each version is priced differently based on different vocabulary sets, and all of the versions share a certain amount of common vocabulary (about 20,000 words). The high-end version for surgeons is priced a hundred times higher than the entry-level VoicePad Pro version.

Our vertical differentiation example is Windows 7, released in 2009. Although there are six different editions, only Home Premium, Professional, and Ultimate are widely available. Within the six editions, there is increasing functionality for each edition, indicating vertical differentiation (see comparison table in en.wikipedia.org/wiki/Windows_7_editions). Moreover, Home Basic is only offered in emerging markets such as Argentina, Brazil, the People's Republic of China, Colombia, India, Pakistan, the Philippines, Mexico, Russia, Thailand, and Turkey. It is not available in first world countries including in Western and Central Europe, North America, Hong Kong, Australia and Saudi Arabia. Thus, the emerging market is large enough so that providing an extra version for that market may be profit maximizing, and restricting availability indicates sensitivity to cannibalization of Home Premium in First World markets. These and other versioning examples are given in Table 1.

In current literature, whether in product line design or versioning, some articles treat consumers as a continuum of types (Jing, 2007; Bhargava and Choudhary 2001, 2008) while others treat consumers as a set of discrete types (Jones and Mendelson 2009; Moorthy 1984). The heart of the novelty and contribution of our work is that we introduce a group taste to link both: individual tastes are continuous while group tastes are discrete. With this structure, we can not only explain when versioning is optimal, but also provide information goods vendors with powerful tools to analyze versioning strategies. Thus, our contribution

Industry Examples	Versions Offered	Targeted Groups
Windows 7	Starter	Entry level consumers, pre-installed by OEMs
	Home Basic	Entry level consumers in emerging market
	Home Premium	A majority of proficient individual users
	Professional	Users associated with small business
	Enterprise	Advanced business users in managed environment
	Ultimate	PC Enthusiasts
Kurzweil Voice Recognition Software	VoicePad Pro	Entry level consumers
	Personal	A majority of individual consumers
	Professional	Proficient consumers
	Office Talk	General office staff
	Law Talk	Legal officials
	Voice Med	Medical officials
	Voice Ortho	Special purpose medical officials
Stata	Stata/MP	Multicore/multiprocessor computers
	Stata/SE	Large datasets
	Stata/IC	Moderate-sized datasets
	Small Stata	Small datasets
Adobe Creatice Suite 5	Design Premium	General purpose designers
	Web Premium	Web designers
	Production Premium	Video editors and motion graphic designers
	Master Collection	Full range creative tools for enthusiastic users
Oracle Database 11g	Oracle Database Enterprise Edition	Single and clustered servers with no socket limitation
	Oracle Database Standard Edition	Servers with up to four sockets
	Oracle Database Standard Edition One	Single servers with maximum capacity of two sockets

Table 1: Industry Examples of Versioning

lies in the introduction of group taste to explain two dimensions of versioning – horizontal and vertical, and in the conditions we provide to determine when versioning is an optimal strategy for the monopolist. The deepest managerial insight is that versioning must based on existing market segments – natural segments defined by group tastes.

Consequently, essential to our model is the definition of an individual consumer taste for quality, and a group taste that is correlated with the individual taste. That is, we add a feature whereby separate groups of consumers that are delineated by segments of these individual tastes define groups of consumers that share the same group taste. We show in our specification that if there is only one group, then the classic result of no versioning – that is, the monopolist offers only a single version - found by others, holds. We then examine two separate utility specifications and show how each supports versioning. To begin, for multiple groups we specify a preference structure such that some of the information good's characteristics are only valuable to one group and other characteristics are valuable to all groups – effectively defining utility with some mutually exclusive characteristics and some shared characteristics. We find that when different groups place sufficient value on the mutually exclusive characteristics relative to the shared characteristics, versioning using horizontally differentiated information goods is optimal. Moreover, as the utility gained from the shared characteristics increases with quality, our results tend toward the single product solution, i.e., the amount of the lowest-priced group decreases.

Next, using the same underlying preference structure with correlated individual and group tastes, for multiple groups we specify a preference structure with hierarchical characteristics where higher taste groups value characteristics that lower taste groups value, but not vice versa. From this we derive sufficient and necessary conditions based on group tastes and the distribution of individual tastes that determine when versioning using vertically differentiated goods is optimal – effectively this condition holds when the overall valuation of the higher taste group is not too much higher than the next lowest taste group. Furthermore, we provide conditions for the monopolist to determine which groups should be served with separate customized versions when versioning is implemented.

The rest of the paper is organized as follows. We set up our notation and assumptions in Section 2. We introduce a baseline model where there is only one group in Section 3. We investigate versioning based on horizontal differentiation when there are multiple groups with mutually exclusive characteristics in Section 4. We then examine versioning based on vertically differentiated goods when there are multiple groups with hierarchical characteristics in Section 5. Section 6 discusses our contributions, limitations and possible future research.

2 Model Notation and Assumptions

Following the hedonic hypothesis that "goods are valued for their utility-bearing attributes or characteristics" (Rosen 1974, pp. 34), we define information goods as a combination of characteristics, and the quality of the information good is defined as an aggregation of values that consumers get from these characteristics. Thus, the quality of information goods is determined by the set of characteristics they include, and more characteristics are normally considered higher quality. It may be helpful to think of characteristics as functionality or as content. We denote quality as $q \in R^+$. We presume that complexity of information goods does not jeopardize their quality levels and that unused characteristics can be freely disposed of or ignored in use. We recognize that in reality, increasing complexity from additional characteristics may influence quality in the sense that this complexity may cause information goods to consume more computing resources and lower speed. We do not model this effect because according to Moore's law, computing power continues to increase rapidly with decreasing price, rendering the effect less important.

Following Bhargava and Choudhary (2001), and a broad literature on vertical differentiation, we take consumers to be heterogeneous and continuously distributed in their individual taste for quality. We denote the individual consumer taste for quality as $\theta \in [\theta_0, \theta_h]$. Over the population of consumers θ has density and cumulative density functions $f(\theta)$ and $F(\theta)$, respectively, so that consumers are normalized with a unit population. The density is positive over its support and continuously differentiable. Following Bhargava and Choudhary (2001), Jing (2007) and Sundararajan (2004), we make the following assumption about the distribution of consumer taste:

Assumption 1 *The reciprocal of the hazard function, $\frac{1-F(\theta)}{f(\theta)}$, is non-increasing in θ.*

Assumption 1 assures unique solution for $\theta = \frac{1-F(\theta)}{f(\theta)}$ by ensuring that if a lower taste consumer obtains positive utility from purchasing, then a higher taste consumer will also obtain positive utility from purchasing. This assumption is satisfied by common distributions such as the uniform, normal, logistic, chi-squared, exponential, and Laplace distributions, and any distribution with increasing density (Bhargava and Choudhary, 2001).

Examining consumer tastes more closely, consumers are not only individually heterogeneous, they also belong to groups. When a consumer belongs to a particular group, that consumer together with all other consumers in the group have similar preferences for certain characteristics. For example, if we define two groups such as students and professors, then although students are individually different they share preferences for certain characteristics and thus show similar valuations as other students. Apart from professions, other indicators such as demographics and geographic location are also commonly used to define groups. This is traditionally how firms define market segments (Frank, Massy and Wind, 1972). When a monopolist develops goods targeted to certain groups, it accentuates characteristics for which members of the group have similar preferences. This explains why Microsoft develops functions for Windows Vista such as "Easily make DVDs" and "Create high-definition movies" specifically for the Home Premium Edition, and at the same time includes functions such as "Remote desktop connection" and "Windows fax and scan" for the Business Edition.

To capture preferences that are common to all individuals within a group, we define a second dimension that determines an individual's taste for quality: a group taste. We divide consumers into h separate groups and directly relate these groups to individual tastes by defining each group as a segment of the distribution of individual tastes. Effectively this means that individual taste and group taste are positively related so that consumers with higher group taste are associated with higher individual taste.

Definition 1 (Group Tastes) *Consumers with individual taste in segment* $[\theta_{n-1}, \theta_n)$ *belong to group* $n, n \in \{1, \cdots, h\}$*. Consumers in the same group* n *share the same group taste* $k_n \in R^+$ *and groups from higher individual taste segments have greater group tastes for quality, which means* $k_{n+1} > k_n$*.*

Our definition of group tastes is based on, and limited by, the relationship between individual and group taste. Hence, our definition implies a strong ordering between individual and group tastes, and does not admit a consumer with lower individual taste than another consumer also having higher group taste. To implement our combination of individual and group tastes, we represent the taste for quality as a product of the individual and group taste. This implies little loss of generality as we can simply rescale q (or θ), and is our next assumption:

Assumption 2 (Multiplicative Utility) *The utility function of consumers $\theta \in [\theta_{n-1}, \theta_n)$ (belonging to group n) who purchase information good with quality q is $U(q, \theta, k_n) = k_n \theta q$.*

Figure 2 illustrates how the utility function becomes piecewise linear over the range of individual tastes due to the steps in group taste.

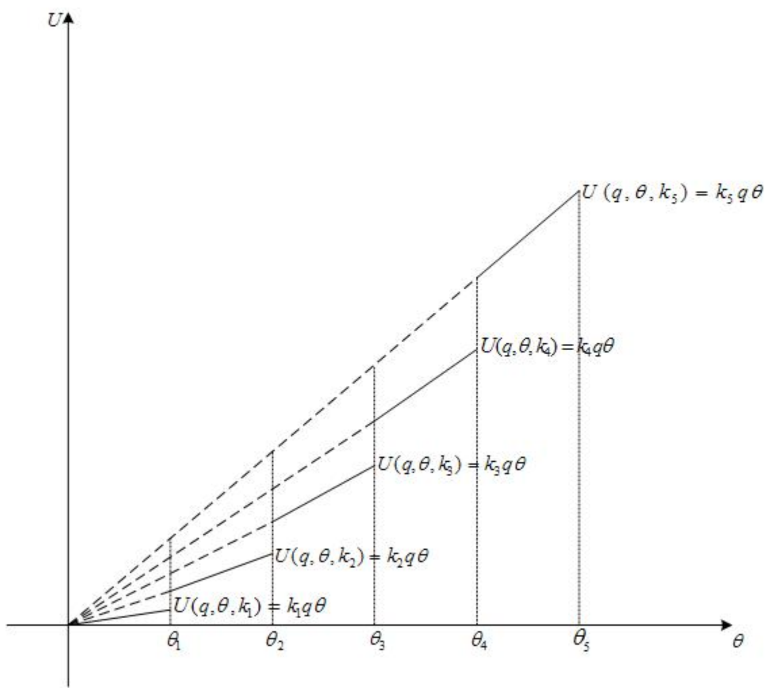

Figure 2: Utility Functions of Consumers in Different Segments

For analytical convenience, we scale the utility function $U(q, \theta, k_n)$ in value terms so that it can be directly compared with prices. This combination of individual and group tastes allows us to represent discontinuous consumer heterogeneity, and proposes a hierarchical structure of consumers that is frequently observed in practice. For example, consumers in Asian countries such as China and India systematically have lower willingness to pay for information goods than consumers in North American countries such as US and Canada. Even within the same geographic area, students are systematically willing to pay less for certain information goods than professors. In both cases, group features amplify individual differences. Varian (2000) also divides consumers into groups (clubs) by their willingness to pay when investigating optimal solutions for buying, sharing and renting information goods. Our assumption is restrictive in the sense that the group taste measure is linearly homogeneous – that is, it is multiplicatively separable from individual taste. Moreover, it is correlated with individual taste in that group taste is weakly increasing in segments of individual consumer taste.

Our additional group taste dimension follows a substantial literature where groups of consumers have the same taste or consumers are modeled as having multiple dimensions of taste. Moorthy (1984) treated different groups of consumers as discrete points so that each consumer in the group has the same taste, and Jones and Mendelson (2010) modeled individual consumer taste with uniform distribution, implicitly assuming there is only one group in the market. Indeed, all models that have high and low types of consumers effectively define homogeneous consumer groups. Vandenbosch and Weinberg (1995) used two continuous consumer taste dimensions in an additive utility function where each taste is multiplied by a characteristic of the good. Caplin and Nalebuff (1986) used n dimensions of consumer tastes matched to n characteristics in a Cobb-Douglas utility function with each characteristic raised to its taste parameter – taking the log yields the form used by Vandenbosch and Weinberg (1995). Canoy and Peitz (1997) had a taste parameter for quality and another taste in a horizontal dimension. Even closer to our specification, Corstjens and Lal (2000) defined taste based on consumer income and used a bimodal distribution over a parameter representing brand inertia, effectively defining groups based on brand inertia. Finally, Bonatti (2008) used a brand-specific premium proportional to quality that depends on consumer taste and preference for a particular brand. Empirically, Sultan and Chan (2000) studied how individual adoption of software was affected by characteristics of the individual, group and firm, showing that group characteristics play a definitive role in individual valuation.

We extend our basic utility structure that includes group tastes for multiple groups in two separate specifications. To begin, we define a utility structure where all consumers can derive value from a shared set of information good characteristics, while other characteristics provide value for specific groups. Based on product line engineering, different versions within a product line normally share a common, managed set of characteristics (Birk et al. 2003), while others can be designed for specific customer groups. Thus, the value that consumers can derive from specific sets of additional characteristics is mutually exclusive between groups. Here we take $q_a \in R^+$ to be the quality of the shared characteristics alone, and for a consumer belonging to group n we take $q_n \in R^+$ to be the quality of the information good with specific characteristics for group n, and consequently $q_n \geq q_a$. This leads our utility structure with mutually exclusive characteristics:

Assumption 3 (Utility with Mutually Exclusive Characteristics) *If a consumer $\theta \in [\theta_{n-1}, \theta_n)$ (belonging to group n) purchases the information good customized for group n, then their utility is $U(q_n, \theta, k_n) = k_n \theta q_n$. If a consumer $\theta \in [\theta_{i-1}, \theta_i)$ where $i \neq n$ (not belonging to group n) purchases the information good customized for group n, then their utility is $U(q_n, \theta, k_i) = k_i \theta q_a$.*

The critical feature of Assumption 3 is that the additional characteristics that each group values are mutually exclusive. If a consumer from group n purchases the information good customized for group n, then the consumer receives the full utility embedded in the characteristics of the good. Otherwise, if a consumer purchases the "wrong" information good (one customized for another group), then the consumer only gets utility from the shared characteristics, those in q_a. An example that fits utility with mutually exclusive characteristics is Kurzweil's voice recognition software. The shared characteristics are the interface and the common vocabulary. The group-specific characteristics are profession-related such as specific vocabulary for lawyers and physicians whereby lawyers do not value the medical vocabulary and vice-versa for physicians and legal vocabulary.

Next, we consider a utility structure in which information goods characteristics designed for each group are hierarchical. We start with the shared set of characteristics, which yields quality q_a, which we can rename as q_1 for reasons that will be evident shortly. All consumers receive value from q_1. The hierarchical structure of characteristics is defined through our quality measure, q. If a set of additional characteristics is related to group n, then not only consumers in group n value the characteristics embedded in q_n, all the higher taste groups value this set of characteristics and all lower taste groups do not. Thus, here q_n represents a quality aggregation of the information good characteristics valued by groups $\geq n$. The utility structure for hierarchical characteristics is our Assumption 4:

Assumption 4 (Utility with Hierarchical Characteristics) *If a consumer $\theta \in [\theta_{n-1}, \theta_n)$ (belonging to group n) purchases the information good customized for group n, then their utility is $U(q_n, \theta, k_n) = k_n \theta q_n$. If a consumer with $\theta < \theta_{n-1}$ belonging to a lower taste* *group $i < n$ purchases the information good customized for group n, then their utility is $U(q_n, \theta, k_i) = k_i \theta q_i$. If a consumer with $\theta \geq \theta_{n-1}$ belonging to a higher taste group $j > n$ purchases the information good customized for group n, then their utility is $U(q_n, \theta, k_j) = k_j \theta q_n$.*

The key feature in utility with hierarchical characteristics is that consumers in lower taste groups do not value characteristics designed for higher taste groups. Using our example of Windows 7, characteristics designed for the Home Premium edition are valued by home and power users, and special characteristics such as server functions designed for Professional edition are only valued by power users. Moreover, server functions and other functionality in the Professional edition are valued by power and enterprise users, but multi-display support and distributed cache together with other industrial-level functions available in the Ultimate edition are only valued by enterprise users.

Our utility with mutually exclusive characteristics (Assumption 3) and utility with hierarchical characteristics (Assumption 4) are related through the group taste and the characteristics, as measured through the different qualities q_i, to which individual and group tastes apply. If a consumer purchases the good customized for their group, then they receive the same value in both utility specifications: $k_n \theta q_n$. If a consumer purchases a good that is not customized for their group, then they only receive the utility associated with their group from the characteristics from which the group can derive value: for utility with mutually exclusive characteristics it is the shared characteristics q_a, and for utility with hierarchical characteristics it is minimum of the characteristics designed for their group and lower groups or the characteristics of the purchased good.

To provide a separate version for different groups of consumers may incur additional costs which we refer to as "versioning costs". Versioning costs could include additional development, marketing and managerial costs. Technology development such as software engineering has greatly lowered additional development costs for versioning and broad adoption of e-commerce has minimized additional marketing and managerial costs for providing an extra version. Thus, we make the following limiting assumption about versioning costs:

Assumption 5 *Versioning costs are zero after the highest quality information goods have been produced.*

In practice, software developers usually develop a flagship version with the full set of features, where the features can be different combinations of functionality and content. Then developers can progressively disable features to generate versions. The result is either a sequence of increasingly less capable versions, or a base version with additional optional components. This is common in statistical software where Stata offers a set of increasingly restricted versions, and where SAS offers a base version to which modules can be added.

Individual Rationality and Incentive Compatibility Across our two different utility structures defined in Assumptions 3 and 4, we can state generic individual-rationality (IR) and incentive-compatibility (IC) conditions that apply to consumers deciding which version to purchase. These two conditions serve as constraints in the monopolist's profit maximizations. The IR condition requires that for a consumer to purchase they must be better than not purchasing – that is, their utility less price must be positive. The IC condition requires that when there are multiple versions, each consumer maximizes their utility less price by choosing the version that has been customized for them. Both must hold because of the revelation principle. In our context the revelation principle says that the monopolist can restrict attention to prices such that consumers truthfully reveal their types, meaning that profits for the monopolist can be optimized by setting prices such that consumers choose the information good that is customized for their group (see Fudenberg and Tirole, 1991).

In segment n where the consumer only chooses between purchasing the good customized for their group and not purchasing, we define the IR condition so that the consumer receives non-negative value from purchasing:

$$U(q_n, \theta, k_n) - p_n \geq 0, \;\; \theta \in [\theta_{n-1}, \theta_n). \quad\quad \text{[IR]} \tag{1}$$

In segment n where the consumer chooses between purchasing the good customized for their group n and a good customized for another group i, we define the IC condition so that the customer weakly prefers to purchase the good customized for their group:

$$U(q_n, \theta, k_n) - p_n \geq U(q_i, \theta, k_n) - p_i, \;\; \theta \in [\theta_{n-1}, \theta_n). \quad\quad \text{[IC]} \tag{2}$$

For the indifferent consumer, $\tilde{\theta}_n$, either the IR condition in (1) is binding, the IC condition in (2) is binding, or both.

The profit maximization for a monopolist that considers serving up to h groups is

$$\max_{\tilde{\theta}_1, \cdots, \tilde{\theta}_h} \Pi(\tilde{\theta}_1, \cdots, \tilde{\theta}_h) = \max_{\tilde{\theta}_1, \cdots, \tilde{\theta}_h} \Big\{ \sum_{n=1}^{h} p_n [F(\theta_n) - F(\tilde{\theta}_n)] \Big\} \;\; \ni \;\; \text{[IR]}, \;\; \text{[IC]}, \;\; \tilde{\theta}_n \in [\theta_{n-1}, \theta_n). \tag{3}$$

We know at the optimum the [IR] and [IC] conditions in (1) and (2) hold for all groups served in (3) because of the revelation principle.

3 The "No Versioning" Result

If all consumers are in one group, and hence share the same group taste, then the monopoly solution is to offer only one version. Referring to Assumption 2, and normalizing k to unity, we have $U(q, \theta) = \theta q$. Suppose the monopolist segments the market into h versions, providing the information good with quality levels $q_1, \ldots, q_h$ where quality is increasing in the subscript. The highest quality q_h is developed first, and the increasingly degraded qualities $q_{h-1}, \ldots, q_1$ are produced through versioning.

The provision of h different quality levels divides the market into $h+1$ segments, where the additional segment contains consumers that do not purchase. The monopolist sets a price for each version, or segment. In segment 1 where the consumer chooses between purchasing the good customized for her segment and not purchasing, we define $\tilde{\theta}_1$ as the indifferent consumer and the price assignment is $p_1 = U(q_1, \tilde{\theta}_1) = \tilde{\theta}_1 q_1$. This price assignment embeds the IR condition such that those consumers with $\theta < \tilde{\theta}_1$ do not purchase and those with $\theta \geq \tilde{\theta}_1$ purchase. In segment i ($2 \leq i \leq h$) where the consumer chooses between purchasing q_i and q_{i-1} customized for its closest segment $i-1$, we define $\tilde{\theta}_i$ as the indifferent consumer and the price assignment is

$$p_i = p_{i-1} + U(q_i, \tilde{\theta}_i) - U(q_{i-1}, \tilde{\theta}_i) = p_{i-1} + \tilde{\theta}_i q_i - \tilde{\theta}_i q_{i-1}.$$

This price assignment embeds the IC condition so that consumers select the good that provides them with the greatest value. In our formulation the monopolist chooses the set of indifferent consumers to maximize profits, which is common in the versioning literature and equivalent to choosing prices.

$$\max_{\tilde{\theta}_1,\cdots,\tilde{\theta}_h} \Big\{[1 - F(\tilde{\theta}_h)][\tilde{\theta}_1 q_1 + \sum_{j=2}^{h}[q_j - q_{j-1}]\ \tilde{\theta}_j] + \sum_{i=2}^{h-1}[F(\tilde{\theta}_{i+1}) - F(\tilde{\theta}_i)][\tilde{\theta}_1 q_1 + \sum_{j=2}^{i}[q_j - q_{j-1}]\tilde{\theta}_j]$$

$$+[F(\tilde{\theta}_2) - F(\tilde{\theta}_1)]\tilde{\theta}_1 q_1\Big\}, \ \ni \ \theta_0 \leq \tilde{\theta}_1 \leq \ldots \leq \tilde{\theta}_h \leq \theta_h, \ \text{IR}, \ \text{IC}.$$

The IR and IC conditions used here are defined in (1) and (2). The first-order conditions imply that each element in the set of optimal indifferent consumers, $\{\tilde{\theta}_1, \ldots, \theta_h\}$ satisfies $\tilde{\theta}_i = \frac{1-F(\tilde{\theta}i)}{f(\tilde{\theta}_i)}$. By Assumption 1, the optimization has unique solution. In this case, it is a corner solution for all but one in the set of indifferent consumers: $\tilde{\theta}_i = \theta_0 \ \ \forall i < h$, and an interior solution for $\tilde{\theta}_h$. Effectively this means that the monopolist prices all of the versions with lesser quality than the high quality version so that consumers are better off purchasing the high quality version or not purchasing at all. The result is that only one version is offered: consumers in $[\tilde{\theta}_h, \theta_h]$ purchase the highest quality version while consumers in $[\theta_0, \tilde{\theta}_h)$ do not purchase.

This is the traditional "one-size-fit-al result where only one version is offered in the market. In practice, a single version is observed for many types of information goods such as online movies, digital music, photos and books. For these goods, because every consumer in the market has the same group taste, even with different individual tastes for quality, the monopolist maximizes profit treating the market as a single group with a single version.

4 Mutually Exclusive Characteristics and Horizontal Differentiation

In this section, we examine the potential for versioning when a monopolist faces different groups of consumers that have utility with mutually exclusive characteristics as per our

Assumption 3 such as voice recognition software (Kurzweil) with medical vocabulary for physicians and legal vocabulary for lawyers. In this case it is natural to segment consumers by group. Taking the different versions $q_1, \ldots, q_h$ across the h groups, the profit maximization is the one in (3) where prices of each version are determined by the optimal solution. For consumers in groups n that are served (i.e., purchase a version), $n \in \{1, 2, \cdots, h\}$, the optimal prices must satisfy the IR and IC conditions in (1) and (2). However, in order to prevent consumers in the high taste groups from purchasing goods customized for lower taste groups, the profit maximizing monopolist may not serve consumers in some lower taste groups according to the revelation principle. And for the groups that are not served the IR condition does not hold.

The IC condition in (2) must also hold for the combinations of goods where the IR condition (1) holds. If the IC condition is binding, then it is when the indifferent consumer in the highest taste group obtains the same value from purchasing the lowest priced version. The comparison with the lowest priced version is because if a consumer purchases a good customized for another group, then that consumer only obtains utility from the shared characteristics q_a, regardless which other group the purchase is from. Restating the IC condition for this specific case,

$$U(q_h, \tilde{\theta}_h, k_h) - p_h \geq U(q_a, \tilde{\theta}_h, k_h) - p_n. \tag{4}$$

If the IC condition binds, it is where p_n is the minimum over $n \in \{1, \ldots, h-1\}$. Recognizing that when the IR constraint is binding the left hand side is zero, and in this case p_n is also set from the IR constraint, substituting from Assumption 3, we have

$$\frac{q_a}{q_n} \leq \frac{k_n \tilde{\theta}_n}{k_h \tilde{\theta}_h}, n \in \{1, \cdots, h-1\}, \tag{5}$$

Equation (5) is the special case of the more general condition $U(q_a, \tilde{\theta}_h, k_h) \leq U(q_n, \tilde{\theta}_n, k_n), n \in \{1, \cdots, h-1\}$ whereby the utility an indifferent consumer from a lower taste group obtains from the good customized for their group is at least as great as the utility obtained by the indifferent consumer in the highest taste group from the shared characteristics from a good customized for other groups. Because consumers with high individual tastes also have high group tastes, consumers in group h have the highest utility for shared characteristics, and are the most likely to purchase goods customized for other groups. We can now state our versioning theorem for utility with mutually exclusive characteristics. The proofs of this and subsequent results are in the Appendix.

Theorem 1 (Versioning for Utility with Mutually Exclusive Characteristics) *A sufficient condition for multiple versions is that there exists an $n \in \{1, \cdots, h-1\}$ where (5) holds.*

Critical to the condition in (5) is the proportion of quality that comes from shared characteristics – in our Kurzweil example the shared characteristics is the vocabulary that is common among versions. If the condition in (5) holds for all groups ($\forall n \in \{1, \ldots, h-1\}$), then the shared characteristics do not provide enough value for consumers in group h to purchase goods customized for any of the other groups. In this situation, it is profit maximizing for the monopolist to provide each group with one version that is customized for it. The rationale is simple. As compared to the value of group-specific characteristics, if the value of shared characteristics is relatively low, then each consumer chooses the right version for their group – that is, the good customized for it. In the special case when there are no shared characteristics, each group values only its own mutually exclusive characteristics, and we have a "perfect horizontally differentiated market". In such a market, a variant of third degree price discrimination applies (Frank, Massy and Wind, 1972).

If the condition in (5) is not satisfied for at least one group, then there exists a lower taste group where at least one consumer from the highest taste group with the potential to be better off purchasing the good customized for the lower taste group. In other words, there is a threat of cross-purchasing. In this case the result of the monopolists profit maximization is that the IC condition is binding and a lesser number of consumers in the lower taste group purchase – indeed, this is why the condition in (5) is not necessary for versioning in Theorem 1 as versioning may still be optimal through the binding IC condition when the IR condition is not binding. If the value of the shared characteristics reach certain level, then the monopolist is better off not serving the lower taste group at all. Consequently, the monopolist offers fewer versions than the number of consumer groups. In the Kurzweil example this may be the reason why different versions are not offered for some professions like engineers and accountants, but are offered for lawyers and physicians. If the IC condition drives all groups with lower taste other than the highest taste group to be closed, then versioning is no longer optimal, and only one version is offered. This reasoning forms the basis of our comparative statics below.

4.1 Comparative Statics of Shared Characteristics

From the perspective of information goods development, shared characteristics may ensure quality, improve efficiency and provide better manageability (Birk et al., 2003). We examine what occurs as the quality from shared characteristics increases - as typically would happen if there were additional shared characteristics. Beginning with the case where there are no shared characteristics, the optimization in (3) becomes a separate optimization problem for each consumer group:

$$\theta_n^* \in \{\theta : \frac{F(\theta_n) - F(\theta)}{f(\theta)} = \theta, \theta \in [\theta_{n-1}, \theta_n)\}, \tag{6}$$

for $\theta_n^*, n \in \{1, 2, \cdots, h\}$. From Assumption 1, we know the inverse hazard function is non-increasing, so that

$$-\frac{[f(\theta)]^2 + [1 - F(\theta)]f'(\theta)}{[f(\theta)]^2} \leq 0.$$

Because $F(\theta_n) \leq 1$, the first derivative of $\frac{F(\theta_n)-F(\theta)}{f(\theta)}$ with respect to θ is also non-increasing for $\theta \in [\theta_{n-1}, \theta_n)$,

$$-\frac{[f(\theta)]^2 + [F(\theta_n) - F(\theta)]f'(\theta)}{[f(\theta)]^2} \leq 0.$$

So there is at most one interior solution for θ_n^*, $\theta \in [\theta_{n-1}, \theta_n)$. If there is no interior solution, then the monopolist sets $\theta_n^* = \theta_{n-1}$ to maximize profits for group n, which means everyone in this group purchases. In this case of no shared characteristics, the condition in (5) holds with weak inequality for all $n \in \{1, \ldots, h-1\}$.

As the quality of the shared characteristics increases, at some point the condition in (5) binds for the lowest priced group. When (5) is binding for one or more groups, the monopolist no longer prices versions customized for different groups independently. To satisfy the IR and IC conditions, the monopolist has to adjust its pricing scheme to make sure consumers in each group choose the good that is customized for them. The following proposition describes the adjustment.

Proposition 1 *When the IC condition is binding, an increase in the quality of the shared characteristics reduces the proportion of the lowest priced group that is served.*

The result of the proposition is that as the quality of the shared characteristics increases, the group-specific characteristics becomes less a source of utility, and cross-purchasing from higher-taste groups to lower-quality (and priced) versions becomes more of a problem. Consequently, to prevent consumers from the highest taste group receiving greater utility net of price from the lowest priced information good than from the information good that is customized for them, the monopolist increases the price of the lowest priced good to eliminate cross-purchasing – thereby maintaining the IC condition. The outcome for the consumers in the lowest priced group is that fewer of them find it individually rational [IR] to purchase, and the proportion of that group which is served is reduced. In the case when the highest taste group is not covered – that is, when not all consumers in the highest taste group purchase, downward adjustments also occur to the price of the good customized for the highest taste group, which in turn would increase the proportion of consumers that are served from the highest taste group.

A Numerical Example. To better illustrate our theorem and proposition, we construct the following numerical example. Suppose there are three groups of consumers in the market. Individual consumers are uniformly distributed across $[0, 1]$. Consumers with individual taste θ in segments [0, 0.3), [0.3, 0.7) and [0.7, 1] belong to groups 1, 2 and 3, respectively. The group tastes are $k_1 = 1$, $k_2 = 2$ and $k_3 = 3$. We set the quality of the three different versions to be the same, which is normalized to unity.

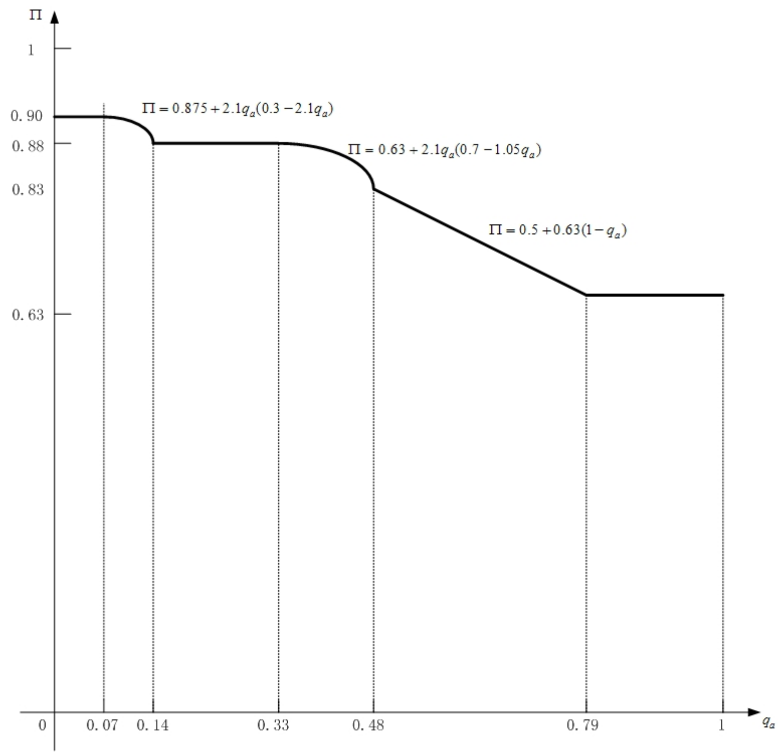

Figure 4.1: Example with Mutually Exclusive Characteristics

Figure 4.1 shows how a monopolists versioning strategies change with an increase in the quality of shared characteristics. In this example, when $0 \leq q_a < 0.07$, the three groups are treated separately and three different versions are offered. When $0.07 \leq q_a < 0.14$, condition (5) binds and market for the lowest quality group, group 1, shrinks. When $q_a \geq 0.14$, condition (5) is no longer satisfied and as a result, group 1 is no longer served.

When $0.14 \leq q_a < 0.33$, groups 2 and 3 are treated separately and two different versions are offered. When $0.33 \leq q_a < 0.48$, condition (5) binds and market for group 2 shrinks. For $0.48 \leq q_a < 0.79$, the IC condition for group 3 binds and market for group 2 remains the same. Consequently, the price for the high quality version decreases with increases in the quality of the shared characteristics, q_a. When $q_a \geq 0.79$, it is optimal for the monopolist to stop serving group 2 with a separate version, and only one version is offered.

This result explains why in our observations about information goods versioning in practice, there are normally fewer versions offered by the monopolist than the potential number of distinct groups in the consumer population. For example, although Kurzweil offers seven versions of its voice recognition software, it is far from covering all the potential groups in this market. Our model implies that the monopolist only provides customized versions to groups with high willingness to pay or with requirements that can be sufficiently differentiated from other groups so as to be able to satisfy IC conditions to prevent cross-purchasing.

5 Hierarchical Characteristics and Vertical Differentiation

In this section we examine versioning when different groups of consumers have utility with hierarchical characteristics as per our Assumption 4. The key feature in this utility structure is that lower taste groups do not value features designed for higher taste groups. However, a consumer in a higher taste group receives full value from features designed for lower taste groups. In our Windows 7 example, server functionality in the Professional edition is not valued by home users, and multiple-display and distributed cache in the Ultimate edition are not valued by power users but are valued by enterprise users. Even the more restricted functionality of the Home Premium edition are valued by power and enterprise users, and the server functionality of the Professional edition is valued by enterprise users.

The monopolist chooses the number of versions to offer through its choice of indifferent consumers in each group to maximize its profits as per (3). From the IR and IC conditions in (1) and (2), we have the following lemma:

Lemma 1 *For a lower taste group to be provided with an information good customized for it, all higher taste groups must be covered.*

From Lemma 1, except for the lowest taste group that is served, all other groups that are served must be covered – that is, all consumers in the higher taste groups purchase. Suppose i is the lowest taste group that is served. Then only the price for the lowest taste group, p_i, is determined by the binding IR condition. The price for all the higher taste groups, p_n for $n > i$, is determined by the binding IC conditions. In the Windows 7 example, focusing on the three widely available versions, Lemma 1 means that the monopolist sets the prices of the Professional and Ultimate editions based on restricting cross-purchasing so that even the lowest taste enterprise user prefers the Ultimate edition to the Professional and Home Premium editions, and all power users prefer the Professional edition to either the lower quality Home Premium edition or the higher quality Ultimate edition.

With Lemma 1 we can restate the profit maximization in (3) as the optimal choice of a single indifferent consumer across the consumer groups:

$$\max_{\tilde{\theta}_i} \Pi(\tilde{\theta}_i) =$$
$$\max_{\tilde{\theta}_i} \Big\{ k_i\tilde{\theta}_i q_i[F(\theta_i) - F(\tilde{\theta}_i)] + \sum_{n=i+1}^{h} [k_i\tilde{\theta}_i q_i + \sum_{m=i+1}^{n} k_m\theta_{m-1}[q_m - q_{m-1}]][F(\theta_n) - F(\theta_{n-1})] \Big\}$$
$$\ni i \in \{1, \cdots, h\},\ \tilde{\theta}_i \in [\theta_{i-1}, \theta_i),\ \text{IR},\ \text{IC}. \tag{7}$$

The profit maximization in (7) does not necessarily ensure that each higher taste group than i is provided with a separate version. That is, multiple adjacent groups may share the same version such that, for example, a given group $m+1$ shares the same version as group m and then $q_{m+1} = q_m$. Breaking the summation of the second part of (7) and combining all the $\tilde{\theta}_i$ and $\theta_n, n \in \{i, \ldots, h\}$, we restate the monopolist's profit maximization as

$$\max_{\tilde{\theta}_i} \Pi(\tilde{\theta}_i) = \max_{\tilde{\theta}_i} \Big\{ k_i \tilde{\theta}_i q_i [1 - F(\tilde{\theta}_i)] + \sum_{n=i+1}^{h} k_n \theta_{n-1} [q_n - q_{n-1}][1 - F(\theta_{n-1})] \Big\}. \tag{8}$$

Using Assumption 1, we denote the unique solution for $\theta = \frac{1-F(\theta)}{f(\theta)}, \theta \in [\theta_0, \theta_h]$ by $\tilde{\theta}_e$, which is in group e. Consequently, $\theta[1-F(\theta)]$ increases with θ when $\theta < \tilde{\theta}_e$ and decreases when $\theta > \tilde{\theta}_e$. This can be seen as follows: define a function $\psi(\theta) = \theta[1-F(\theta)]$, then $\psi'(\theta) = f(\theta)[\frac{1-F(\theta)}{f(\theta)} - \theta]$ and $\psi'(\tilde{\theta}_e) = 0$. Because $\frac{1-F(\theta)}{f(\theta)}$ is non-increasing in θ, we get $\psi'(\theta) > 0$ when $\theta < \tilde{\theta}_e$ and $\psi'(\theta) < 0$ when $\theta > \tilde{\theta}_e$. From Lemma 1 and given that $\tilde{\theta}_e$ is unique, lower taste groups than e are not served.

Given that group e refers to the group in which the interior solution to the monopolist's profit maximization occurs, if the optimal indifferent consumer $\tilde{\theta}_e$ belongs to the highest taste group, $\tilde{\theta}_e \in [\theta_{h-1}, \theta_h)$, then the monopolist provides only one version of the information good. Otherwise, the monopolist may provide up to $h-e+1$ versions. Below is our versioning theorem for utility with hierarchical characteristics.

Theorem 2 (Versioning for Utility with Hierarchical Characteristics) *A necessary and sufficient condition for multiple versions is that there exists a $\tilde{\theta}_i \in [\theta_{i-1}, \theta_i)$ where $e \leq i < h$ such that*

$$\frac{\tilde{\theta}_i [1 - F(\tilde{\theta}_i)]}{\theta_{h-1}[1 - F(\theta_{h-1})]} > \frac{k_h}{k_i}.$$

Due to the hierarchical structure of our Assumption 4, the versioning condition in Theorem 2 is independent of quality. Consequently, the theorem depends only on consumer preferences, partially separating the versioning decision from the decision of how to design the customized versions. In terms of our example of Windows 7, it means that whether versioning occurs depends on the relative differences in the preferences of different groups of users – enterprise, power or home users. Although the condition in Theorem 2 ensures versioning, it does not ensure that each group is offered a customized version. If there are multiple groups that satisfy the sufficient condition for multiple versions in Theorem 2, then the monopolist still has to decide whether to offer a customized version for each of those groups. We derive a condition for the monopolist to decide whether to customize a version for a specific group.

Proposition 2 *The necessary and sufficient condition for group g to be provided with a separate customized version is that for $\theta \in [\theta_{g-1}, \theta_h]$, $k_g\theta[1-F(\theta)]$ is maximized when $\theta = \tilde{\theta}_g$ where $\tilde{\theta}_g$ is the indifferent consumer in group g.*

Proposition 2 implies that the highest quality version q_h is always offered to the highest taste group h only. The indifferent consumer in the lowest taste group that is served, $\tilde{\theta}_i$, always has the highest value for $k_i\theta[1-F(\theta)]$ for $\theta \in [\tilde{\theta}_i, \theta_h]$. For any group g, if $\tilde{\theta}_g$ does not yield the maximum $k_g\theta[1-F(\theta)]$ for $\theta \in [\theta_{g-1}, \theta_h]$, then group g is either not served $g < i$, or served with the same version as a lower taste group $g-1$. Thus, Proposition 2 provides a means to determine how many versions are offered.

In practice we observe that although Windows 7 is available in six different editions, only Home Premium, Professional and Ultimate are widely available. As we wrote in the Introduction, Windows 7 Home Basic is only available in emerging markets such as Argentina, Brazil, People's Republic of China, Colombia, India, Pakistan, Philippines, Mexico, Russia, Thailand, and Turkey. It is not available in first world countries including in Western and Central Europe, North America, Hong Kong, Australia and Saudi Arabia. Our model explains that because the group of home users (perhaps more novice users) of Windows 7 in emerging markets is large enough, providing an extra version for those users can be profit enhancing. However, in first world countries, the number of possible customers for Windows 7 Home Basic is relatively small so that the potential cannibalization to the Home Premium edition dominate and Home Basic is not offered.

6 Conclusions

In this research we investigated conditions that determine when an information goods monopolist chooses to implement versioning strategies. We showed that versioning strategies can be implemented if different groups of consumers can be clearly defined. In other words, versioning cannot be used to segment a market, rather, versioning strategies must fit the existing market segments. This result is more evident when consumers have utility with hierarchical characteristics as the versioning condition is based only on features of consumer tastes. Our optimal versioning conditions are also in accordance with Shapiro and Varian's (1999) suggestion that versions should be customized to accentuate the differences in tastes between groups.

Following the research program in versioning – a program that aims to find conditions under which versioning occurs – we demonstrated that for utility with mutually exclusive characteristics, versioning is possible when the quality (hence, value) of shared characteristics is sufficiently low so that cannibalization from a lower version can be covered by its revenue increase. When the value of shared characteristics is relatively higher (as shown in our numerical example), the monopolist shrinks the market share for the lower-taste group by raising the price of the lower-quality version to effectively reduce the cannibalization of profits from the higher-quality version. Ultimately the process of increasing the value of shared characteristics results in a single version. In the case of utility with hierarchical characteristics, versioning is optimal only if all the consumers in the highest taste group choose to purchase. Given the highest taste group is covered, we provided a straightforward (necessary and sufficient) condition for when versioning occurs, a condition that only depends on consumer preferences. We further derive conditions under which a customized version is offered to each group. By deriving conditions under which a customized version is offered to each group, we are able to derive conditions under which versioning is optimal and if so, how many products should be offered.

Although we make the assumption that group tastes increase with increasing segments of individual taste, for the most part our results hold as we demonstrated when group tastes are equal across individual tastes. Group tastes being equal across individual tastes is distinct from group tastes being the same across individual tastes, as the former continues to allow our assumptions of utility with mutually exclusive characteristics and of utility with hierarchical characteristics to be operationalized as in our analysis. Equal group tastes also smoothens the gaps between consumer segments in Figure 1. Further details are available.

Contributions Our contributions lie in two aspects, and are based on consumers with utility that includes individual and group tastes. First, most of the previous research on information goods (Bhargava and Choudhary 2001, Jones and Mendelson 2010, Jing 2007 and Wu et al. 2003) focuses on vertical differentiation. In contrast, we treat information goods as a combination of characteristics, and in doing so we can analyze horizontal differentiation and vertical differentiation under the same modeling framework based on group tastes. Second, much of the previous research (Bhargava and Choudary 2001, Jones and Mendelson 2010) using multiplicative utility without group tastes found only one version is optimal. To extend this basic result, many researchers have explored conditions when versioning is optimal. Conditions such as network externalities (Jing 2007, Cheng and Tang 2010), non-linear utility (Ghose and Sundararajan 2005, Bhargava and Choudhary 2008) and consumers' outside options (Chen and Seshadri 2007) have been needed to show that multiple versions can be optimal. Our definitions of two separate multiplicative utility functions, one with mutually exclusive characteristics and the other with hierarchical characteristics, allowed us to show that for each utility function there are reasonable conditions when versioning is optimal.

Limitations There are several limitations in our modeling framework. In our model we assume zero versioning costs. If versioning costs are significant, then the presence of these costs may reduce the number of versions offered. If costs of offering an extra version are higher than the incremental profits from versioning, then the monopolist will simply remove this version from its versioning package (Bhargava and Choudhary 2008). Our modeling results are based on assumptions of multiplicative utility and a positive relationship between group taste and individual taste, together with mutually exclusive or hierarchical characteristics.

Together, these impose significant structure on consumer preferences. Comparing our model to the classic work of Maskin and Riley (1984) that in the context of quality differentiation results in versioning for industrial goods, there are two critical differences. The first is on the cost side whereby they assume convex costs of quality so that each quality level has a cost such that versions have variable costs proportional to quality – which is critical to their versioning result, as opposed to our implicit assumption that the highest quality information good (flagship version) has already been developed (at some fixed cost) and our explicit assumption that versioning costs (hence variable costs) are zero. The second is on the utility side where Maskin and Riley suppose that the implied demand curves can be characterized through a single parameter representing individual taste, whereas the aspect that is essential to our versioning results is a second parameter representing group taste with mutually exclusive or hierarchical characteristics.

Future research may relax some of the assumptions we make, and can address additional issues. For example, using network externalities, Cheng and Tang (2010) explore conditions under which a free trial version is offered, whereas in our model – that does not include network externalities – the lower quality version has a non-zero price. Including network externalities in our model may explain the existence of free trial version. Dogan et al. (2010) consider versioning in a two-period model where a lower-quality version is provided in the first period with the possibility of upgrade in the second period, and Wei and Nault (2011) consider a two-stage model with multiple versions and uncertain quality where consumers that choose a lower-quality version in the first stage may learn from experience and upgrade in the second stage. In that latter model, the low quality version can be offered for free. In contrast, our analysis only examines versioning in a single period. Previous research (Ghose, Smith and Telang 2006) demonstrates empirically that in the Internet-based book market used-book sales cannibalize new-book purchases at least to some extent, and increases welfare through the expansion of the total sales in the market. There is no similar empirical research on cannibalization or increases in total sales and social welfare when information goods are versioned.

In addition, our paper studies monopoly versioning strategies, and we expect that competition can potentially make a significant difference in these strategies. As discussed in Johnson and Myatt (2003), firms may alter their versioning strategy when facing competition either through product line pruning or introducing low-end brands. Research examining versioning and competition in the context of information goods includes Jones and Mendelson (2010) and Wei and Nault (2006).

7 References

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8 Appendix

A.1. Proof of Theorem 1

Proof. If (5) holds, then IR and IC are satisfied for groups n and h, which implies each of these groups is provided with different versions. □

A.2. Proof of Proposition 1

Consider an increase in the quality of the shared characteristics when the IC condition is binding. Denote the lowest priced group as i. To maintain the (binding) IC condition, the monopolist changes prices in both groups i and h. From (4), $\tilde{\theta}_h$ is the consumer in group h that is indifferent between purchasing goods q_h and q_i, and from (1) $\tilde{\theta}_i$ is the consumer in group i that is indifferent between purchasing good q_i and not purchasing. Depending on whether the highest taste group h is covered – that is, whether all consumers in the highest taste group purchase, there are two cases.

Case 1: Group h Is Not Covered

In this case IR binds at $\tilde{\theta}_i < \theta_{i-1}$ and $\tilde{\theta}_h > \theta_{h-1}$. Substituting (1) [IR] and (2) [IC] into (3), only considering groups i and h, we have

$$\max_{\tilde{\theta}_i,\tilde{\theta}_h} \Pi(\tilde{\theta}_i,\tilde{\theta}_h) = \max_{\tilde{\theta}_i,\tilde{\theta}_h} \left\{ k_i\tilde{\theta}_i q_i[F(\theta_i)-F(\tilde{\theta}_i)] + k_h\tilde{\theta}_h q_h[1-F(\tilde{\theta}_h)] \right\} \ni \tilde{\theta}_i \in [\theta_{i-1},\theta_i), \tilde{\theta}_h \in [\theta_{h-1},\theta_h).$$

From the first-order condition with respect to $\tilde{\theta}_i$, recognizing that changes in $\tilde{\theta}_i$ affect $\tilde{\theta}_h$ through the IC condition, we have

$$q_a[F(\theta_i) - F(\tilde{\theta}_i) - \tilde{\theta}_i f(\tilde{\theta}_i)] + q_h[1 - F(\tilde{\theta}_h) - \tilde{\theta}_h f(\tilde{\theta}_h)] = 0.$$

From the crossing point in (6), we know that $F(\theta_i) - F(\tilde{\theta}_i) - \tilde{\theta}_i f(\tilde{\theta}_i) = 0$ when $\tilde{\theta}_i = \theta_i^*$, and that for θ_h we have $1 - F(\tilde{\theta}_h) - \tilde{\theta}_h f(\tilde{\theta}_h) = 0$ when $\tilde{\theta}_h = \theta_h^*$. Because both $\frac{F(\theta_i)-F(\theta)}{f(\theta)}$ and $\frac{1-F(\theta)}{f(\theta)}$ are non-increasing, we have $\tilde{\theta}_i > \theta_i^*$ and $\tilde{\theta}_h < \theta_h^*$.

Case 2: Group h Is Covered

In this case IR binds at $\tilde{\theta}_i < \theta_{i-1}$ only and the monopolist can only adjust $\tilde{\theta}_i$. Thus the monopolist's profit maximization is

$$\max_{\tilde{\theta}_i} \Pi(\tilde{\theta}_i) = \max_{\tilde{\theta}_i} \left\{ k_i\tilde{\theta}_i q_i[F(\theta_i)-F(\tilde{\theta}_i)] + [k_h\theta_{h-1}[q_h-q_a] + k_i\tilde{\theta}_i q_i][1-F(\theta_{h-1})] \right\},\ \tilde{\theta}_i \in [\theta_{i-1},\theta_i),$$

where the price of the highest taste good $k_h\theta_{h-1}[q_h - q_a] + k_i\tilde{\theta}_i q_i$ is obtained from the binding IC condition. From the first-order condition with respect to $\tilde{\theta}_i$, we have

$$[F(\theta_i) - F(\tilde{\theta}_i) - \tilde{\theta}_i f(\tilde{\theta}_i)] + [1 - F(\theta_{h-1})] = 0.$$

Because $F(\theta_i) - F(\tilde{\theta}_i) - \tilde{\theta}_i f(\tilde{\theta}_i) < 0$, it follows that $\tilde{\theta}_i > \theta_i^*$. $\square$

A.3. Proof of Lemma 1

Suppose q_i and q_n are information goods customized for groups i and n, where $n > i$. From the IR condition, for consumers who purchase q_i, $k_i\theta q_i - p_i \geq 0$ for $\theta \in [\theta_{i-1},\theta_i)$, and from the IC condition,

$$k_n\theta q_n - p_n \geq k_n\theta q_i - p_i > k_n\theta q_i - k_i\theta_i q_i > 0,\ \theta \in [\theta_{n-1}, \theta_n).$$

This means that the IR condition for group n cannot be binding, which indicates that group n is fully served. This applies to any higher taste group than i. □

A.4. Proof of Theorem 2

The proof proceeds by first establishing that the condition is necessary and sufficient for more than one group to be served. Then we show that it is optimal to version.

Necessity: Suppose the condition in the premise cannot be satisfied. Using Lemma 1, the monopolist's profits from serving group i and covering all the higher taste groups are

$$\begin{aligned}
\Pi(\tilde{\theta}_i) &= k_i\tilde{\theta}_i q_i[1-F(\tilde{\theta}_i)] + \sum_{n=i+1}^{h} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})] \\
&= k_i\tilde{\theta}_i q_i[1-F(\tilde{\theta}_i)] + \sum_{n=i+1}^{h-1} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})] \\
&\quad + k_h\theta_{h-1}[q_h - q_{h-1}][1-F(\theta_{h-1})] \\
&< k_h\theta_{h-1} q_i[1-F(\theta_{h-1})] + \sum_{n=i+1}^{h-1} k_h\theta_{h-1}[q_n - q_{n-1}][1-F(\theta_{h-1})] \\
&\quad + k_h\theta_{h-1}[q_h - q_{h-1}][1-F(\theta_{h-1})] \\
&< k_h\theta_{h-1} q_{h-1}[1-F(\theta_{h-1})] + k_h\theta_{h-1}[q_h - q_{h-1}][1-F(\theta_{h-1})] \\
&= \Pi(\theta_{h-1}),
\end{aligned}$$

noting that $k_h\theta_{h-1}[1-F(\theta_{h-1})]$ can be taken outside the summation in the first right hand side expression. This means that profits from serving more groups than just the highest taste group are less than profits from serving, and covering, the highest taste group. Thus, it is optimal for the monopolist to serve only one group.

Sufficiency: Suppose the monopolist only provides two versions, one for group $i < h$ and the other for group h. Consumers in groups $i, \ldots, h-1$ choose q_i and consumers in group h choose q_h. The monopolist's profits are

$$\Pi(\tilde{\theta}_i) = k_i \tilde{\theta}_i q_i [1 - F(\tilde{\theta}_i)] + k_h \theta_{h-1} [q_h - q_i][1 - F(\theta_{h-1})] > k_h \theta_{h-1} q_h [1 - F(\theta_{h-1})] = \Pi(\theta_{h-1}).$$

Thus, the monopolist increases profits by serving at least two groups with q_i and q_h.

Versioning: Suppose $\tilde{\theta}_i \in [\theta_{h-2}, \theta_{h-1})$ so that two groups are served. Then the monopolist can offer either q_h, q_{h-1}, or both. From Assumption 4 and the IR condition, if either q_h or q_{h-1} are offered, then the price is $k_{h-1} \tilde{\theta}_i q_{h-1} \geq p_h = p_{h-1}$. If the monopolist offers q_h and q_{h-1}, then from the IR condition prices are

$$k_h \theta_{h-1} q_h \geq p_h \text{ and } k_{h-1} \tilde{\theta}_i q_{h-1} \geq p_{h-1}.$$

From the IC condition

$$k_h \theta_{h-1} q_h - p_h \geq k_h \theta_{h-1} q_{h-1} - p_{h-1} > k_{h-1} \tilde{\theta}_i q_{h-1} - p_{h-1} \geq 0.$$

As $q_h > q_{h-1}$, then $p_h > p_{h-1}$, and it is more profitable to version. □

A.5. Proof of Proposition 2

We examine three cases: 1) g is the lowest taste group served, which means $g = i$; 2) g is the highest taste group, which means $g = h$, and 3) g is a middle taste group, which means $i < g < h$.

Case 1: g is the lowest taste group that is served

Necessity: Suppose the condition in the premise does not hold. Assume there exists a $\tilde{\theta}_m \in [\theta_{g-1}, \theta_h]$ belonging to group $m > g$ so that $k_m \theta [1 - F(\theta)]$ is maximized at $\tilde{\theta}_m$. Then

$\Pi(\tilde{\theta}_m) =$

$$k_m\tilde{\theta}_m q_m[1-F(\tilde{\theta}_m)] + \sum_{n=m+1}^{h} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})]$$
$$= k_m\tilde{\theta}_m[1-F(\tilde{\theta}_m)]\{q_g + \sum_{n=g+1}^{m}[q_n - q_{n-1}]\} + \sum_{n=m+1}^{h} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})]$$
$$> k_g\tilde{\theta}_g q_g[1-F(\tilde{\theta}_g)] + \sum_{n=g+1}^{m} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})] + \sum_{n=m+1}^{h} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})]$$
$$= \Pi(\tilde{\theta}_g).$$

This shows that profits increase by not serving groups $g, \ldots, m-1$, which contradicts that group g is served.

Sufficiency: Because $k_g\theta[1-F(\theta)]$ is maximized at $\tilde{\theta}_g$ for $\theta \in [\theta_{g-1}, \theta_h]$, we have

$$\Pi(\tilde{\theta}_g) =$$
$$k_g\tilde{\theta}_g q_g[1-F(\tilde{\theta}_g)] + \sum_{n=g+1}^{h} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})]$$
$$= k_g\tilde{\theta}_g q_g[1-F(\tilde{\theta}_g)] + k_{g+1}\theta_g[q_{g+1} - q_g][1-F(\theta_g)] + \sum_{n=g+2}^{h} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})]$$
$$> k_{g+1}\theta_g q_{g+1}[1-F(\theta_g)] + \sum_{n=g+2}^{h} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})]$$
$$= \Pi(\tilde{\theta}_{g+1}).$$

Thus, profits decrease when group g is not provided with a customized version.

Case 2: g is the highest taste group

In this case it is always true that $k_g\theta[1-F(\theta)]$ is maximized at $\tilde{\theta}_g$ for $\theta \in [\theta_{g-1}, \theta_h]$. From the proof of Proposition 2, the highest group h is always served with the highest version q_h which is customized for it.

Case 3: g is a middle taste group

Necessity: Suppose the condition in the premise does not hold. As in Case 1, assume there exists a $\tilde{\theta}_m \in [\theta_{g-1}, \theta_h]$ belonging to group $m > g$ so that $k_m\theta[1-F(\theta)]$ is maximized at $\tilde{\theta}_m$.

Then we have

$$\begin{aligned}
\Pi(\tilde{\theta}_i) &= k_i\tilde{\theta}_i q_i[1-F(\tilde{\theta}_i)] + \sum_{n=i+1}^{h} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})] \\
&= k_i\tilde{\theta}_i q_i[1-F(\tilde{\theta}_i)] + \sum_{n=i+1}^{g-1} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})] \\
&\quad + \sum_{n=g}^{m} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})] + \sum_{n=m+1}^{h} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})] \\
&< k_i\tilde{\theta}_i q_i[1-F(\tilde{\theta}_i)] + \sum_{n=i+1}^{g-1} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})] \\
&\quad + \sum_{n=g}^{m} k_m\theta_{m-1}[q_n - q_{n-1}][1-F(\theta_{m-1})] + \sum_{n=i+1}^{g-1} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})] \\
&= k_i\tilde{\theta}_i q_i[1-F(\tilde{\theta}_i)] + \sum_{n=i+1}^{g-1} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})] \\
&\quad + k_m\theta_{m-1}[q_m - q_{g-1}][1-F(\theta_{m-1})] + \sum_{n=m+1}^{h} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})].
\end{aligned}$$

This shows that profits increase when $q_{g-1} = \ldots = q_{m-1}$, which means consumers in groups $g, \ldots, m-1$ purchase the same version as group $g-1$. That is, groups $g, \ldots, m-1$ are pooled together. Thus, there is no separate version customized for group g.

Sufficiency: Because $k_g\theta[1-F(\theta)]$ is maximized at $\tilde{\theta}_g$ for $\theta \in [\theta_{g-1}, \theta_h]$, we have

$$\begin{aligned}
\Pi(\tilde{\theta}_i) &= k_i\tilde{\theta}_i q_i[1-F(\tilde{\theta}_i)] + \sum_{n=i+1}^{h} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})] \\
&= k_i\tilde{\theta}_i q_i[1-F(\tilde{\theta}_i)] + \sum_{n=i+1}^{g-1} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})] \\
&\quad + k_g\theta_{g-1}[q_g - q_{g-1}][1-F(\theta_{g-1})] + k_{g+1}\theta_g[q_{g+1} - q_g][1-F(\theta_g)] \\
&\quad + \sum_{n=g+2}^{h} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})] \\
&> k_i\tilde{\theta}_i q_i[1-F(\tilde{\theta}_i)] + \sum_{n=i+1}^{g-1} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})] \\
&\quad + k_g\theta_{g-1}[q_g - q_{g-1}][1-F(\theta_{g-1})] + k_g\theta_{g-1}[q_{g+1} - q_g][1-F(\theta_{g-1})] \\
&\quad + \sum_{n=g+2}^{h} k_n\theta_{n-1}[q_n - q_{n-1}][1-F(\theta_{n-1})]
\end{aligned}$$

$$= k_i\tilde{\theta}_i q_i[1 - F(\tilde{\theta}_i)] + \sum_{n=i+1}^{g-1} k_n\theta_{n-1}[q_n - q_{n-1}][1 - F(\theta_{n-1})]$$
$$+ k_g\theta_{g-1}[q_{g+1} - q_{g-1}][1 - F(\theta_{g-1})] + \sum_{n=g+2}^{h} k_n\theta_{n-1}[q_n - q_{n-1}][1 - F(\theta_{n-1})].$$

Hence, profits decrease when group g is offered the same version as group $g-1$. Thus the monopolist must set $q_g > q_{g-1}$, which means that a version is customized for group g.

Combining the above three cases completes the proof. □