The Zero-Day DLC Strategy: A Case for Versioning to Facilitate Product Sampling*

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Abstract

Out of the recent popularity of downloadable contents (DLC) among video game manufacturers has resurfaced the issue of versioning of information goods. The central idea behind the zero-day DLC strategy is that consumers who find the base version of a game to be sufficiently attractive would pay a premium to upgrade by purchasing such a DLC. In this work, we combine the literature on versioning with that on product sampling to model the impact of consumer learning on the product-line strategy of a game manufacturer. In doing so, we demonstrate that a manufacturer's desire to vertically differentiate could actually stem from a horizontal separation among consumers. When consumers differ in their perception of the fit between their tastes and the features of the product, horizontal differentiation seems a natural choice. However, if the manufacturer is unable to classify potential consumers into groups with distinct tastes, horizontal differentiation becomes impractical. We find that, interestingly, this inability to differentiate horizontally does not limit the manufacturer from vertically positioning its product line. We characterize the conditions under which the DLC strategy is effective and discuss how it affects consumer and social welfare. Our results also have obvious implications in markets for other digital experience goods.

Keywords: Video game, downloadable content (DLC), information good, experience good, vertical differentiation, versioning, consumer learning, product sampling.

1 Introduction

As a result of rapid technological innovations and consumers embracing video games as an integral part of their entertainment, the gaming industry—including gaming software, hardware, and services—has become one of the most prominent technology markets. Over the last few years, the gaming market has grown substantially, from \$20 billion in 2001 to \$62.7 billion in 2010. Gartner (2011) estimates that it has exceeded \$74 billion in 2011 and will reach a whopping \$112 billion by 2015; see Figure 1. According to PricewaterhouseCoopers, the global video game market is "more than twice the size of the recorded-music industry, nearly a quarter more than the magazine business and about three-fifths the size of the film industry" (Cross 2011).

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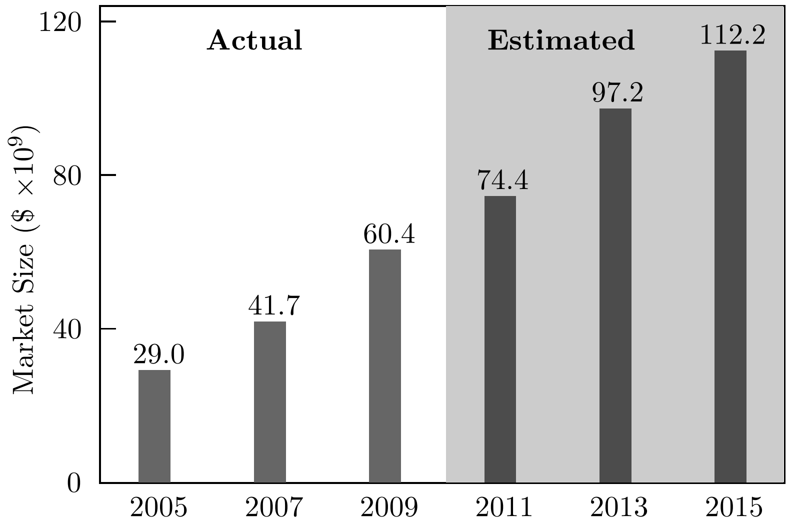


Figure 1: Growth of Global Video Gaming Industry (Source: Gartner Group)

Along with this tremendous growth have come innovations in marketing and product placement. One of these innovative strategies has taken the form of downloadable content, or DLC as it is more popularly known—instead of including the complete set of features in the retail version of the game, a manufacturer offers only a subset of features initially, and the rest as DLCs at additional prices. Consider, for example, the case of *Mass Effect*, currently the highest rated Xbox game in the market (McCaffrey and Dyer 2012). DLCs have been offered for every generation of the game—two for *Mass Effect* and sixteen each for *Mass Effect 2* and *Mass Effect 3*. Of the sixteen DLCs for the latest generation, three popular ones are shown in Table 1. It is clear from the table that *Mass Effect* is not alone in offering DLC packs; almost all games offer varying amounts of DLCs. At the same time, more and more gamers have started acquiring DLC packs in recent years, resulting in significant additional revenues for game publishers. According to Brightman (2011), 51% of console owners purchased at least one DLC in 2011, up from 40% in 2010 and 34% in 2009. In absolute terms, this translates to more than 20 million gamers in the North America having purchased DLCs in 2011. Similar trends have also been observed in Asia and Europe (Peterson 2011).

To be sure, the concept of a DLC (or an expansion pack) is not new. In the past, they have been used to provide security patches or, at times, free new features and upgrades, perhaps to keep the interest in a game alive in the market for a longer time (Fang 2011). However, in recent years, a specific type of DLCs has become very popular among game manufacturers (Thier 2012);

Table 1: A Few Recent Games and Their Popular DLC Packs

Game	Publisher	DLCs	Price
Mass Effect 3	Electronic Arts	From Ashes*	$9.99
		Leviathan	$9.99
		Omega	$14.99
Battlefield 3	Electronic Arts	Back to Karkand*	$14.99
		Armored Kill	$14.99
Dragon Age 2	Electronic Arts	Exiled Prince*	$6.99
		Legacy	$9.99
		Mark of the Assassin	$9.99
Borderlands 2	2K Games	Mechromancer*	$9.99
		Pirate's Booty	$9.99
Call of Duty: Modern Warfare 3	DVG Activision	Collection 3 (Chaos)	$14.99
		Collection 4	$14.99
Saints Row: The Third	THQ	Season Pass	$9.99
		Maximum Pleassure	$3.49
		Saints Purple Ops	$3.49
Halo 4	Microsoft	Crimson Map	$9.99
		Majestic Map	$9.99
		Castle Map	$9.99

NOTE: Zero-day DLCs are identified by the asterisk mark next to the name.

they take the forms of a "zero-day" DLC or an "on-disk" DLC. A zero-day DLC (also known as a "day-one" DLC) is one that becomes available to download on the very day the game is released; all one has to do is pay for it, download it, and install it. On-disk DLCs are also zero-day DLCs; they ship with the retail game itself, requiring the consumer to pay for and download an "unlock code" to enjoy the full range of features (Senior 2012). For example, the DLC "From Ashes" was included in the original disc of *Mass Effect 3*, and its unlock code became available on the very day the game was released (March 6, 2012).

Clearly, the features included in a zero-day DLC are all ready for use at the time of product release. Yet, the manufacturer holds them back just to sell them separately. Furthermore, although a manufacturer would want to sell as many copies of its zero-day DLC as possible, it certainly does not expect every consumer to buy the DLC. Had the manufacturer expected so, it would not have offered the DLC separately in the first place. It appears that versioning of information goods—a much debated issue in the information systems and economics literature—has reemerged as a strategy of choice among manufacturers of video games. Prior research would, however, predict that such versioning is not optimal for information goods as all versions essentially have the same zero marginal cost (Bhargava and Choudhary 2001, Jones and Mendelson 2011).

Central to the zero-day DLC strategy is, in fact, the notion that a lower version at a lower price might induce people to sample the good and to eventually get "hooked" or "sold" on the "goodness" of the good (Thier 2012). When that happens, the "hooked" consumers—those who had a positive *experience* with the base version—would choose to pay a premium to acquire additional content, allowing the manufacturer to make a higher profit. Current literature on versioning of information goods does not take into account this *experience* aspect—a personal experience with the product that may result in a change in the willingness-to-pay (WTP), up or down. This is why the current literature, which finds versioning to be suboptimal for a monopolist, does not extend immediately to this broader context. Naturally, the following questions arise:

- Can versioning using a zero-day DLC be an effective tool for market penetration? Can a manufacturer induce a significant portion of the population to buy such a DLC?
- If so, under what conditions, is it optimal to offer the DLC? What impacts do the characteristics of the product or consumers have on the efficacy of this DLC strategy?
- What are the implications for a manufacturer's product-line decisions? Does the DLC strategy lead to higher prices or an expansion in the market coverage?
- What, if any, are the welfare implications?

This paper seeks to answer these questions using a parsimonious economic model. Answering them is indeed important. Given the size and rapid growth trajectory of the gaming industry, it is of much practical relevance to understand whether versioning through DLCs is a viable strategy for a vendor in this market and, if so, how such a strategy would shape its product-line decisions. Furthermore, recent times have witnessed a considerable level of outrage against such zero-day DLCs (Kain 2012). Many consumers demand that all features be included in the base version itself; according to them, these DLCs simply harm consumers while enriching the manufacturer. In fact, some are so opposed to it that they even call the DLC strategy "horror pricing" (Meer 2012). Thus, the question concerning the welfare implications is also of particular interest.

Although motivated by zero-day DLCs, our research can also shed light on the immense popularity of versioning among manufacturers of other types of information goods. Consider, for example,

Table 2 which lists some popular software products along with the different versions available for each. As can be seen from this table, *Dragon*, a leading speech recognition software, offers two different versions, both of which are capable of converting speech to text and both allow users to, say, compose an email by simply speaking to the computer. Additionally, the premium version supports features such as simple voice shortcuts (or commands) and voice control for desktop applications and peripherals.

Table 2: A Few Software Products and Their Versions

Software	**Manufacturer**	**Versions and List Prices**[a]
PhotoShop CS5	Adobe	PhotoShop: \$699 PhotoShop Extended: \$999
Quicken	Intuit	Deluxe \$59.99 Premier: \$89.99 Home and Business: \$99.99 Rental Property Manager: \$149.99
Windows 7	Microsoft	Home Premium: ≈ \$180 Professional: ≈ \$250 Ultimate: ≈ \$275 (Prices vary across retailers)
Oracle 11g	Oracle	Express Edition: Free Standard Edition One: \$180 per user Standard Edition: \$350 per user Enterprise Edition: >\$950 per user
Dragon	Nuance	Home: \$99.99 Premium: \$199.99
Creator	Roxio	Creator: \$99.99 Creator Pro: \$129.99
Sales Cloud	SalesForce	Contact Manager: \$2 per user-month Group: \$15 per user-month Professional: \$65 per user-month Enterprise: \$125 per user-month Unlimited: \$250 per user-month

[a]Unless otherwise specified, all prices are as listed at manufacturer's website.

Evidently, such popularity of versioning cannot be fully understood without acknowledging that information goods are also *experience* goods—consumers are often unable to understand their true value before using them (Shapiro and Varian 1999, Varian 1998). According to Varian (1998), there are three main characteristics of information goods: (i) they are experience goods, (ii) they have a negligible marginal cost of reproduction, and (iii) they are public goods in the sense that they are both non-rival and nonexcludable. Apparently, it is the second characteristic that has been the primary focus of the versioning literature, while the first one has rarely been discussed. We take an important step in this work towards filling this particular void in the literature.

In order to capture the experience aspect of an information good, we take cues from prior work on product sampling, which argues that consumers, in some cases, overestimate an experience good and underestimate it in others (Goering 1985, Shapiro 1983). Specifically, we consider a scenario in which consumers *ex ante* have the same perception regarding the quality of an information good, and, *ex post*, they reach different conclusions—upon using the good and learning about it directly through personal experience, some find it to be better than originally perceived, and some worse (Chellappa and Shivendu 2005). Thus, when consumers use a lower version of an information product, they revise their prior perceptions about its quality, which, in turn, causes their valuations for the higher version to change. This prompts some consumers to upgrade to the higher version, that is, to purchase the DLC. In other words, the base version plays the role of a product sample of the higher version. In addition, versioning may also expand the market coverage, inducing an even greater level of product sampling and consumer learning. At the same time, however, our monopolist faces the risk of cannibalization, because some consumers may remain adequately satisfied with the base version and not feel the need to purchase a DLC. Facing a trade-off between the benefits from DLC and cannibalization, the monopolist chooses the prices of the two versions, as well as the relative quality level of the base version, in a way that maximizes its total profit.

An important finding of this work is that, even when the marginal cost is zero, versioning can indeed be a preferred strategy. This result is new, and it has important implications for manufacturers of information goods searching for newer market penetration tools. Surprisingly, we also find that there is a significant portion of the parameter space, where, despite an overall positive influence of learning on consumers' WTP, versioning remains suboptimal. Our analyses indicate that a critical factor influencing the optimal product-line strategy is the uncertainty around consumers' prior perception of the product's usefulness. On one hand, when this uncertainty is low, versioning expands the market and induces additional product sampling without overwhelmingly cannibalizing the full version. On the other, when the uncertainty is high, the manufacturer can no longer expand the market but it can charge a hefty price premium to those seeking to upgrade, which also makes versioning desirable. However, when the uncertainty is moderate, the manufacturer can find itself in a situation where it can neither expand the market nor charge a premium large enough, which renders versioning ineffective. Our study thus indicates that established manufacturers selling well-known titles about which consumers have little uncertainty in their minds, as well as new entrants launching new games with large amounts of associated uncertainty, can gain from the DLC strategy. However, for the rest in the middle, deploying a zero-day DLC is not necessarily attractive; as we demonstrate both analytically and numerically, doing so is effective only when the marginal impact of learning on consumers' WTP is larger than a threshold.

There are important theoretical implications, too. First, by incorporating learning from personal experience, our model provides a possible explanation as to why versioning—through DLC or otherwise—may be attractive to manufacturers of information goods. Second, we contribute to the literature on vertical differentiation by establishing that such differentiation has impacts above and beyond market segmentation—in the case of an experience good, it can also be used as a facilitator of product sampling. Third, we show that consumers' opposition to DLC is not well founded, as the opportunity to learn eventually contributes to their welfare, even though the monopolist is able to extract a part of the gain through higher prices.

2 The Economics of Versioning

Versioning of information goods can take the form of *horizontal* or *vertical* differentiation. Horizontal versioning, in essence, amounts to creating different versions of the same product, where certain features in one version act as substitutes for a set of features in another (Wei and Nault 2013). A case in point is *MacSpeech Dictate* by Nuance; it comes in two versions, *legal* and *medical*. Based on the description of the two versions by its manufacturer, it appears that the two versions offer exactly the same set of functionalities and a common *vocabulary*, except that the specialized (or domain) vocabularies of the two versions are different. Similar horizontal versioning is also observed with video games as well. For example, the different DLC map packs for *Halo 4* shown in Table 1 could perhaps be viewed as a case of horizontal differentiation, as the game can be played with only one map pack at a time, thereby making the map packs substitutes for each other. Viewed differently, there is no universally acceptable preference ordering between the specialized vocabularies in *MacSpeech Dictate* or the map packs in *Halo 4*, and the preference for one version over the other is related to the fit between consumers' tastes and the features of the product.

The other—and also the more common—form of versioning is vertical, where there exists a universally accepted quality ordering among the versions (Bhargava and Choudhary 2001). A good example is *Dragon*, another speech recognition software from Nuance (the same manufacturer as *MacSpeech Dictate*). *Dragon* comes in two versions, *home* and *premium* (see Table 2). The home version contains only a subset of the features available in the premium version. The additional features in the premium version makes it a "superior" product, as they complement the features in the home version. It turns out that, in the context of video games, a large majority of DLCs—especially the zero-day DLCs—do not have horizontal substitutes and can only be viewed as a case of vertical differentiation. Consider, for example, the case of *Mass Effect 3* from Electronic Arts. As mentioned earlier, one of its DLCs, "From Ashes," was actually included in the retail pack, and its unlock code could be purchased on the release day itself. Among the several new features that this DLC adds to the base game are two notable ones: (i) a permanent squad member named *Javik*, the last surviving *Prothean*, and (ii) a new weapon, the Prothean *particle rifle*. From a description of how these new features enhance the base game, it is clear that none of them actually substitute for other similar features; they only complement what was already included in the base version (Schwarz 2012). Therefore, "From Ashes" can only be viewed as a part of a vertical versioning strategy. That this DLC is another form of vertical versioning is further evidenced by the "Collector's Edition" of the game—a version in which this DLC was included for free—offered to interested gamers, of course, at a higher price.

The case of versioning to facilitate product sampling and consumer learning is, however, a curious one. To be sure, it is indeed a case of vertical differentiation, but, here, the manufacturer's desire to differentiate actually originates from a horizontal separation of consumers. The difference in the perceived fit—why some gamers like a game and others do not—is surely horizontal, as gamers are playing the same game with exactly the same feature set. Viewed another way, although the real quality of an information good is a vertical issue, consumers' perception of quality (or fit) is really a horizontal one. Therefore, our consumers are heterogeneous not only in their taste for quality but also in their perception of it—consumers like more features, but they do not necessarily value a feature the same way.

Since a video game is very much an experience good, a perception of fit cannot be formed before playing the game. Irrespective of the amount of investment in product design, market survey, and user testing, the personal aspect of consumer learning simply means that it is difficult to predict who will end up liking what features, making it impossible to classify gamers accordingly. Of course, had the manufacturer known consumers' perceptions up front, as in the case of *MacSpeech Dictate*, it would surely have resorted to horizontal differentiation, making both the groups happy and extracting a portion of that satisfaction in the form of a higher price. However, when consumers' affinity towards features cannot be predicted, such horizontal versioning does not make much practical sense.

What is fascinating is that this inability to version a product horizontally does not stop the manufacturer to cleverly position its product line vertically. In essence, not knowing where a product should horizontally be placed, the manufacturer chooses two vertically differentiated versions, with the idea of luring more consumers to try the base product at a lower price. When they do, consumers would also want to upgrade if they like the base product. This, in turn, allows the manufacturer to identify one end of the market and effectively extract its surplus. The base version thus serves two purposes. First, it induces a larger segment of the market to try the product, helping consumers eliminate the uncertainty about the fit—the horizontal separation between the product and a consumer. Second, it also allows the manufacturer to charge a handsome premium for an upgrade to the higher version. The demand to upgrade mainly comes from those who have discovered themselves to be horizontally close to the product and happy with the experience. The resulting increase in their WTP can be leveraged by the manufacturer to its advantage. Therefore, as long as it can induce a significant portion of the market to like the base version, the manufacturer would choose to version vertically. To the best of our knowledge, no prior work has viewed versioning of information goods in this light.

Is vertical differentiation the only way to facilitate product sampling when the manufacturer cannot predict the horizontal location of an experience good? The answer is an obvious no. Software manufacturers often resort to free trial versions for exactly the same reason (Dey et al. 2013). A software trial can be time-locked or feature-limited, or both. For example, a 30-day free trial version of Adobe Creative Suite 6.0—a well-known suite of media authoring and publishing tools—is available on Adobe's website for users to download and use before they decide to purchase the unlimited version. MediaMonkey from Ventis Media, Inc., on the other hand, provides a perpetual free trial, but with only a limited feature set, and allows consumers to pay for and upgrade to the Gold version that contains all the features. Even though trial versions are quite common for software products, their use is rare in the gaming industry, especially for console games. There are two main reasons. First, piracy of games is a serious issue for game manufacturers (Lahiri and Dey 2013); they are often worried about time-locked trials getting hacked for perpetual use.[1] Second, feature-limited trials also do not work well for video games. If the trial version contains only a few features, it would not afford the gamer sufficient experience and learning that is necessary to obtain a full perception of fit. If, on the other hand, the trial version is feature-rich, it may cannibalize a significant portion of sales. Therefore, having no other means to reduce consumers' uncertainty, the manufacturer finally resorts to versioning.

Interestingly, the substitutability between the strategies of offering free trials and versioning is also borne out by real-world observations. There are few products that offer free trials and versions at the same time. In a sense, the base version in this work serves the role of a trial version, although it is not free. Hence, the problem of designing free trials can also be considered a special case of the problem we are studying in this paper.

3 Literature Review

Over the last couple of decades, along with the tremendous growth of the internet and e-business, the market for information goods, such as software, video games, and digital movies or music, has grown at a rapid pace. Although this market is structurally different from the market for physical goods (Jones and Mendelson 2011), there is one common thread that connects the two—vertical differentiation is widely used in both the markets. Economists have long recognized vertical differentiation as a profitable way of "smoking out" consumers differing in their preferences for quality (Mussa and Rosen 1978).

Earlier research on vertical differentiation by a monopolist focused primarily on the optimal design of a price-quality menu that contains one item aimed at each consumer type (Maskin and Riley 1984, Mussa and Rosen 1978). In those models, two consumers differing in their preferences for quality typically buy two different items. The general finding is that the lowest type pays its valuation for the item aimed at it while higher types walk away with some surplus. This is because

[1] See, for example, `http://tag.wonderhowto.com/hack-time-trial/` for information on how to hack time-locked trials of different games.

the manufacturer must concede some surplus in order to ensure that higher types buy the items aimed at them instead of switching to the ones meant for lower types (Moorthy 1984, Mussa and Rosen 1978). Therefore, even though vertical differentiation expands the market coverage to lower valuation consumers, it also reduces the manufacturer's ability to profit from higher valuation ones. Moorthy (1988) examines a variation of this problem involving a continuum of consumer types, where the manufacturer sells only a limited number of quality levels. In particular, he shows that the manufacturer, when offering two quality levels instead of only one, faces the threat of *cannibalization*—a few consumers who would have originally purchased the higher quality product would now switch to the lower quality one. He finds that, for physical products whose marginal costs increase rapidly with quality, the manufacturer makes more profits with two quality levels than with one, that is, the expansion in the market coverage is sufficient to overcome the cannibalization of the higher quality good. This result, in our opinion, reflects the reality in markets for many physical goods, where manufacturers indeed go beyond offering just one quality level.

Information systems researchers have, however, reached a different conclusion about the efficacy of vertical differentiation. Bhargava and Choudhary (2001, 2008), as well as Jones and Mendelson (2011), have concluded that vertical differentiation—often called *versioning* in this literature—is not optimal for a monopolist when all versions have the same marginal cost. Their main finding is that, when a monopolist targets a continuum of consumer types with a finite number of versions, the benefits of market segmentation are completely offset by the resulting cannibalization of the highest quality version. They argue that, unless the marginal cost of a lower version is sufficiently less than that of the highest one, vertical differentiation cannot be effective. Since information goods typically have a zero marginal cost irrespective of quality (Varian 1997, 1998), an immediate implication is that versioning is not useful for information goods. Although this line of thinking is solidly rooted in theory, and echoes findings in economics and marketing (e.g., Anderson and Dana 2009, Salant 1989), it does not explain many real-world observations, including the prevalence of DLCs in the video game market.

Nonetheless, some information systems researchers have sought to explain why software products often come in different versions. Jing (2007) and Sun et al. (2004) have found that versioning can, in fact, be effective for information goods if they exhibit a positive network effect that is independent of the consumer type. The main insight is as follows: the network effect resulting from an expansion in the market coverage through versioning drives up every consumer's WTP, eventually leading to a larger profit. In another related stream, piracy is cited as a possible factor that can make versioning desirable: Cho and Ahn (2010), Lahiri and Dey (2013), and Wu and Chen (2008) have all shown that the seller of an information good can reduce piracy by offering price-sensitive consumers cheaper stripped-down versions of its product while continuing to sell the highest quality version to those with very high valuations for quality. Finally, Hui et al. (2008) argue that versioning is useful when the marginal value of consuming an additional feature is diminishing; this argument is relevant in the context of quantity-based bundling (e.g., a collection of songs or movies) discussed there, though it does not capture issues of our interest. Our work is at the intersection of versioning and product sampling, which sets it apart from all these studies.

The literature above does not consider the issue of consumer learning from experience. However, there is another line of work that does. There is ample evidence in the latter that, when consumers have incomplete information about a product initially, it could be optimal for the manufacturer to first offer it at a promotional price (e.g., Goering 1985, Shapiro 1983) or as a free sample (e.g., Bawa and Shoemaker 2004), though either strategy leads to some lost sales. A low introductory price, or a free product sample, entices more consumers to use the product in order to discover its true value. When they come back to purchase the product again at a later time, the seller can charge them a higher price. Indeed, examples of such intertemporal price discrimination abound in markets for fast-moving consumer products such as cosmetics and toiletry. However, this line of work in marketing and economics is not directly applicable to our context, mainly because many information goods, including software products, are best described as consumer durables, with little need for repeat purchases.

Product sampling and other market penetration strategies have received some attention from information systems researchers as well. Chellappa and Shivendu (2005), for example, show that a pirated version of an information good can serve as its product sample. Cheng and Liu (2012) find that offering a free trial can lead to a greater profit when product sampling is capable of improving consumers' perception of an information good. Niculescu and Wu (2010) explain how different types of "freemium" strategies may be employed by an information goods manufacturer for achieving higher market penetration. In a similar vein, Dou et al. (2013) explain why and when seeding—offering the product for free to a segment of the market—is effective. However, none of these papers has explored how versioning of information goods facilitates product sampling, an important issue that we address in this work. In another interesting work, Wei et al. (2007) examine the problem of versioning an information good whose true worth is not known initially. Their work assumes that, upon personal experience, all consumers reach the same conclusion about the value of the good. Hence, their model, too, is not suitable for our context, as it does not capture the horizontal element of consumer experience that can be different for different consumers. Understanding the implication of this horizontal element on the vertical versioning strategy is central to our work.

4 Model Preliminaries

Our setting mirrors the one modeled in (Moorthy 1988), where a monopolist offers only a finite number of quality levels to a continuum of consumer types. Specifically, our manufacturer, also a monopolist, considers offering two versions, V1 and V2, where V2 is the base version and V1 is the full version that includes the DLC. We assume that V2 can be developed in a costless manner by "turning off" some features of V1 (Jones and Mendelson 2011, Shapiro and Varian 1999). Accordingly, we normalize the *intrinsic* quality of V1 to 1 and denote that of V2 by $\theta \in (0, 1)$. Thus, θ is essentially a measure of the features included in V2, relative to those in V1, and consumers can observe its value from product descriptions made available by the manufacturer. Finally, following research on information goods, we consider the marginal cost of each version to be negligible (Shapiro and Varian 1999, Varian 1998).

How do consumers, heterogeneous in their preferences for quality, react to the above product offerings from the monopolist? To answer this, we index consumers by a parameter v representing their preference for quality. The WTP of a consumer depends on his v as well as the quality of the product as *perceived* by him:

Assumption 1 *Consumer v has a WTP of $v\varphi$ for a product with perceived quality φ, where v is uniformly distributed over* $[0, 1]$*; every consumer knows his v, but the manufacturer only knows the distribution.*

The assumption related to the uniform distribution of v is fairly standard in the literature, as is the multiplicative form of the WTP (e.g., Shapiro 1983, Moorthy 1988). We show in Section 8 that our results remain qualitatively similar for other distributional forms as well.

A consumer's perception of quality (or fit) depends on two aspects: (i) his need for certain functionalities, and (ii) his belief of how well the features of the information good, taken together, meet that need. Although a consumer may know the former, the latter is unlikely to be obvious to him, unless he himself gets to use the product for a period of time. When he does, his realized fit may turn out to be different from that of another consumer. It is in this sense that our consumers are also horizontally separated. We capture this separation by representing his perception of quality, for a product of intrinsic quality $\vartheta \in \{\theta, 1\}$, as $\varphi = \vartheta\kappa$, where $\kappa > 0$ denotes his perception about how well his need is fulfilled by the product as a whole. Thus, the parameter κ essentially represents the "experience part" of the good and is indeed analogous to the concept of "fit" discussed by Chellappa and Shivendu (2005). When κ is small, the consumer is willing to pay little because of a lack of fit with his need; conversely, when it is large, he is willing to pay substantially more.

Prior to using the product, consumers lack information about κ and, therefore, have the same initial perception of quality (Chellappa and Shivendu 2005). This prior, in our case, is the same as the intrinsic quality, meaning that all consumers initially have the same $\kappa = 1$. This κ gets revised up or down later—differently for different consumers—based on their personal experiences with the product:

Assumption 2 *Upon using an information good, if a consumer gets a positive personal experience, he revises κ from 1 to $(1 + \delta)$; otherwise, he revises it down to $(1 - \delta)$, where $\delta \in (0, 1)$ is common knowledge.*

Assumption 2 is fairly straightforward. When a consumer gets a *positive experience*—that is, he finds the game to be a good fit for his needs—he simply revises up his WTP for quality $\vartheta \in \{\theta, 1\}$ from $v\vartheta$ to $v\vartheta(1 + \delta)$; in the case of a *negative experience*—that is, when he discovers a poor fit—he revises it down to $v\vartheta(1 - \delta)$. This binary nature of the revision process is in line with prior literature (Chellappa and Shivendu 2005, Lewis and Sappington 1994); it is also consistent with the idea of a *uniform prior*—in the absence of learning from personal experience, a consumer treats both possibilities, positive and negative experiences, to be equally likely (Lewis and Sappington

1994).[2] Viewed differently, δ here represents the "premium" a consumer is willing to pay upon positive experience; at the same time, it represents the "discount" that the consumer would want otherwise. It is thus possible to interpret δ as the amount of uncertainty associated with the prior valuation. If the manufacturer is relatively unknown, or if the product is new to the market, this uncertainty would be higher. In this sense, the parameter δ reflects the commonly held belief about the brand;[3] hence, it is common knowledge in our setting.

In contrast, if δ were zero, there would be no uncertainty and consumers' valuations would originally be based on complete information. In that case, there can be no revision based on personal experience and, as shown by Bhargava and Choudhary (2001, 2008) and Jones and Mendelson (2011), there would be no benefit to versioning; we restate their result in our context:

Lemma 1 *When consumers' perceptions of quality do not change following their personal experiences with the good, offering two versions leads to a profit identical to that obtained from offering the higher version alone.*

Let p and r denote the prices of versions V1 and V2, respectively; alternatively, $(p-r)$ is the upgrade price or the price of the DLC. In order to ensure that there is a market for V2, these prices must satisfy $p > \frac{r}{\theta}$. All consumers, for whom the following individual rationality constraint is satisfied, will buy at least the base version:

$$v\theta \geq r \Rightarrow v \geq \frac{r}{\theta}. \tag{IR}$$

Among these consumers, some may have a v so large that, even after a negative experience, they would prefer V1 to V2; these consumers will surely buy the DLC. For them, the following incentive

[2]A discerning reader may note that it is indeed possible to construct an alternative model where κ becomes $(1+\delta_1)$ upon positive experience, and $(1-\delta_2)$, upon negative. In that case, however, the prior κ will no longer be 1; instead, for a uniform prior, it will be $\bar{\kappa} = \frac{(1+\delta_1)+(1-\delta_2)}{2}$. Denote $u = v\bar{\kappa}$ and $\bar{\delta} = \frac{\delta_1+\delta_2}{2\bar{\kappa}}$. Now, we can rewrite consumer v's prior valuation for quality ϑ as $u\vartheta$ and the possible posterior valuations as $u\vartheta(1+\bar{\delta})$ and $u\vartheta(1-\bar{\delta})$. In doing so, we essentially end up with a scaled version of our model, where u, the effective consumer preference for perceived quality, is still uniformly distributed, but over $[0,\bar{\kappa}]$ instead of $[0,1]$.

[3]This connection between δ and brand equity is echoed by empirical research on consumer learning (van Osselaer and Alba 2000), which argues that brand cues may partially "block" cues from the actual attributes of the product, thereby limiting the extent to which a consumer may revise his prior perception and resulting in a smaller δ for a well-known brand.

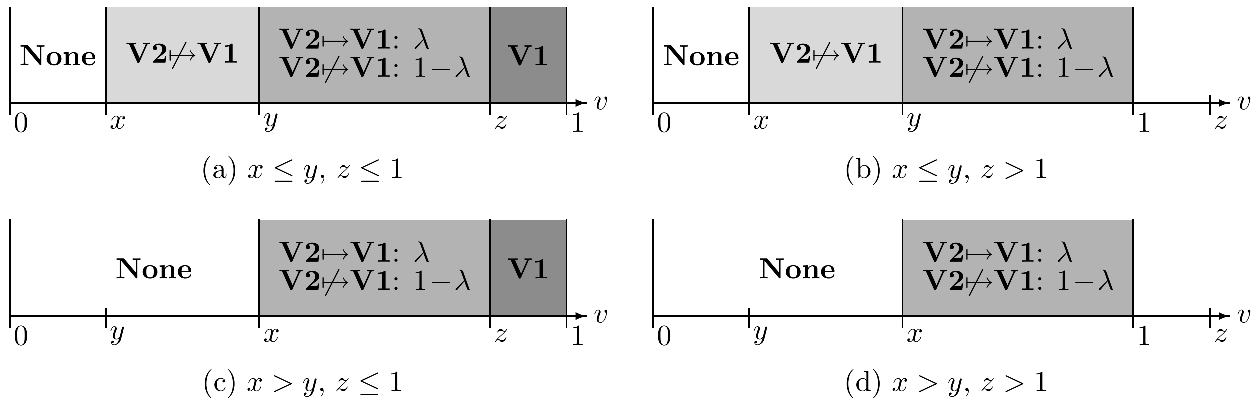


Figure 2: Consumers Self-Select Based on Their Relative Benefit

compatibility constraint holds:

$$v(1-\delta) - (p-r) \geq v(1-\delta)\theta \Rightarrow v \geq \frac{p-r}{(1-\delta)(1-\theta)}. \tag{IC1}$$

The rest of the consumers—those who satisfy (IR) but not (IC1)—will first try V2; they have no incentive to buy the DLC up front. Among these consumers, those who get a negative experience will continue to use V2, but those with a positive experience will upgrade if the following incentive compatibility constraint is satisfied:

$$v(1+\delta) - (p-r) \geq v(1+\delta)\theta \Rightarrow v \geq \frac{p-r}{(1+\delta)(1-\theta)}. \tag{IC2}$$

Let λ denote the fraction of consumers who would have a positive experience upon using V2; it can also be viewed as the probability of a randomly selected consumer getting a positive experience from V2. Four configurations are possible; Figure 2 shows them with the following shorthand notations:

$$x = \frac{r}{\theta}, \quad y = \frac{p-r}{(1+\delta)(1-\theta)}, \text{ and } z = \frac{p-r}{(1-\delta)(1-\theta)} = \frac{1+\delta}{1-\delta}y.$$

Since $p > \frac{r}{\theta}$ and $z > \frac{p-r}{1-\theta}$, it is easy to see that $x, y < z$. As shown in panels (a) and (c) of this figure, if $z \leq 1$, consumers with $v \geq z$ purchase the DLC irrespective of their experience, and product sampling is not relevant for them. However, in panels (b) and (d), where $z > 1$, there are no such consumers who upgrade up front, implying that product sampling is critical to eventually selling the DLC. In (a) and (b), those satisfying $x \le v < y$ purchase V2, but never upgrade, whereas those satisfying $y \le v < \min\{1, z\}$ upgrade in the event of a positive experience, which happens with a probability of λ. Similarly, in (c) and (d), consumers satisfying $x \le v < \min\{1, z\}$ upgrade in the event of a positive experience. Finally, if $v < x$ for a consumer, he will not purchase at all—based on his incomplete information about the product, he prefers forgoing use completely. Thus, despite the assumption that consumers revise their valuations in a binary manner (Assumption 2), our model is quite comprehensive in the sense that it allows all possible market segments one could imagine in this context:

- a fraction x of consumers who do not buy at all,
- a fraction $(\max\{x, y\} - x) + (1 - \lambda)(\min\{1, z\} - \max\{x, y\})$ of consumers who buy V2 and stick with it throughout,
- a fraction $\lambda(\min\{1, z\} - \max\{x, y\})$ of consumers who buy V2 initially and then upgrade to V1, and
- the remaining $(1 - \min\{1, z\})$ fraction of consumers who buy the full version, V1, including the DLC, regardless of their experience.

Therefore, the total revenue for the manufacturer becomes:

$$R = r(1 - x) + (p - r)(\lambda(1 - \max\{x, y\}) + (1 - \lambda)(1 - \min\{1, z\})), \tag{1}$$

where the first term is the revenue from the base version and the second from the DLC. Note that R is also the profit since the marginal cost is zero. The monopolist's optimal profit from versioning can then be expressed as:

$$R^* = \max_{p,r,\theta} R, \text{ subject to: } p > \tfrac{r}{\theta},\ r \ge 0,\ \theta \in (0, 1).$$

In contrast, when a monopolist offers only one version, its optimal profit is $\frac{1}{4}$. Therefore, versioning would be optimal if and only if $R^* > \frac{1}{4}$. If it turns out that versioning is not an optimal strategy after all, then R is maximized at $\theta = 1$ and $p = r = \frac{1}{2}$; otherwise, the monopolist would offer V2 with a θ strictly less than one.

5 Pricing Decision

The order in which the monopolist chooses p, r, and θ is irrelevant (Boyd and Vandenberghe 2004, p. 133). For ease of exposition, we let the monopolist choose θ first and then p and r, implying that θ is known at the time of the pricing decision, which we discuss now.

Proposition 1 *If versioning is optimal, the manufacturer chooses p and r such that $x = y$, i.e., $\frac{r}{\theta} = \frac{p-r}{(1+\delta)(1-\theta)}$.*

Proposition 1 provides us with insights into the pricing strategy of a manufacturer seeking to use vertical differentiation to facilitate product sampling. We know from Lemma 1 that there is no benefit to versioning in our context if there is no consumer learning. In other words, if our monopolist offers a base version to anyone, it would do so solely to entice him to buy the DLC. It has nothing to gain from serving V2 to the market segment which will not upgrade under any circumstances, even including that of a positive experience. Proposition 1, on one hand, ensures that this market segment, which is of size $(y - x)$ in Figures 2(a) and (b), disappears completely. On the other, when offering two versions is optimal, the monopolist sets $x = y$ to also guarantee that no consumer is priced out of the market as long as he has any chance of upgrading. Indeed, only by eliminating the situation where $x > y$, as in Figures 2(c) and (d), can the monopolist enjoy the full benefits of product sampling and consumer learning.

Another implication of Proposition 1 is that the ratio of the prices of the two versions is independent of λ and depends only on δ and θ:

$$\frac{p}{r} = \frac{1 + \delta(1-\theta)}{\theta},$$

even though the individual prices may vary with λ. It is interesting to note that, if $\delta = 0$, $\frac{p}{r}$ becomes $\frac{1}{\theta}$, mimicking the result from prior research, as stated in Lemma 1.

When $x = y$ is substituted into (1), the manufacturer's profit can be written as a function of only r and θ:

$$R = (\theta + \lambda(1+\delta)(1-\theta))x(1-x) + (1+\delta)(1-\theta)(1-\lambda)x\left(1 - \min\{1, z\}\right), \tag{2}$$

where $z = \frac{1+\delta}{1-\delta}x$. For ease of exposition, we break this into two separate cases:

Case 1: $z \leq 1$; $R = R_1 = (\theta + \lambda(1+\delta)(1-\theta))x(1-x) + (1+\delta)(1-\lambda)(1-\theta)x\left(1 - \frac{1+\delta}{1-\delta}x\right)$, and

Case 2: $z > 1$; $R = R_2 = (\theta + \lambda(1+\delta)(1-\theta))x(1-x)$.

Analyzing these two cases separately, we obtain the following result:

Proposition 2 *If a manufacturer offers two versions with quality levels of* 1 *and* $\theta \in (0,1)$*, then the optimal prices are given by:*

$$p(\theta) = \begin{cases} \frac{(1-\delta)(1+\delta(1-\theta))^2}{2(1-\delta+\delta(1-\theta)(2+(1+\delta)(1-2\lambda)))}, & \textit{in Case 1,} \\ \frac{1+\delta(1-\theta)}{2}, & \textit{in Case 2.} \end{cases}$$

$$r(\theta) = \begin{cases} \frac{\theta(1-\delta)(1+\delta(1-\theta))}{2(1-\delta+\delta(1-\theta)(2+(1+\delta)(1-2\lambda)))}, & \textit{in Case 1,} \\ \frac{\theta}{2}, & \textit{in Case 2.} \end{cases}$$

Proposition 2 provides us with additional insights about the manufacturer's overall strategy. To see it more clearly, note that the total size of the market is $(1 - \frac{r}{\theta})$ when two versions are offered, but is equal to $\frac{1}{2}$ in the no-versioning case. It is easy to verify that $\frac{r}{\theta} < \frac{1}{2}$ in Case 1. Therefore, Proposition 2 simply tells us that the monopolist adopts a market expansion strategy in Case 1. In this case, the monopolist serves two different segments of consumers: (i) those who surely upgrade, and (ii) those who buy the base version first and then, with probability λ, upgrade. It can be easily shown that the demand from the first segment is more elastic, which creates an opportunity for the profit-maximizing monopolist to expand this segment by keeping $\frac{r}{\theta}$ below $\frac{1}{2}$.

In contrast, in Case 2, where $\frac{r}{\theta} = \frac{1}{2}$, the monopolist desists from expanding the overall market. This can be explained by the market configuration for Case 2, where the monopolist serves only one segment of consumers—all consumers in this segment first buy V2 and then, with a probability of λ, upgrade to V1. With no other consumer segment in play, the monopolist chooses the same level of market coverage as it would under no versioning. To see this more clearly, note that the profit in this case, R_2, can be written as a constant times $x(1-x)$, resulting in a situation similar to a single-version monopoly.

6 Versioning Decision

It is clear that the manufacturer would prefer a larger fraction of V2 owners to have positive experience, because it is this segment of consumers that presents the manufacturer with an opportunity to upsell. In order to understand how the manufacturer can increase this fraction, λ, we need to examine how a consumer might actually learn. To this end, we follow van Osselaer and Alba (2000), who show that a higher number of attribute cues experienced by a consumer helps him better ascertain future consumption benefits and more accurately establish the fit with his needs. Thus, when a consumer gets a positive experience, he is more likely to be convinced of the veracity of such an experience if it were based on working with a richer set of features (i.e., a higher number of attribute cues). In contrast, if θ is small, a consumer can try only a few features; consequently, despite a positive experience with those features, he may remain skeptical as to whether this experience indeed reflects reality and may still be unwilling to admit a positive experience. Therefore, similar to (Lewis and Sappington 1994), we assume the following functional form for λ:

Assumption 3 *The probability of a positive experience for a V2 user is given by:* $\lambda = \frac{1+\alpha\theta}{2}$, *where* $\alpha \in (-1, 1)$ *is a constant. This* λ *is known only to the manufacturer.*

According to Assumption 3, the manufacturer can influence λ by choosing θ, where the model parameter α essentially captures the manufacturer's ability to do so. It is important to note that λ is private information to the manufacturer, perhaps acquired from its own market research efforts. A clear implication is that the manufacturer can estimate the overall impact of learning, even though it cannot predict how a particular consumer would eventually react. In other words, akin to (Goering 1985), our manufacturer knows the value of consumer learning from product sampling, although only in a stochastic sense. Finally, since consumers cannot estimate λ, they are unable to use it for their own valuation revision; in spirit, we thus follow prior literature (Goering 1985, Shapiro 1983) where, too, all learning is "personal," and any revision of a consumer's valuation happens only after the consumer uses the good himself. Viewed differently, if the manufacturer is not able to influence λ, and, therefore, λ is always $\frac{1}{2}$ irrespective of θ, there would be no information asymmetry between the manufacturer and consumers, implying no personal learning that one would expect for an experience good. Only if the manufacturer has some private information about the benefit of product sampling, would it be able to weigh that against the downside of cannibalization.

Maximizing R_1 and R_2 over θ, we can now find the optimal quality of V2. At this point, we need to check two conditions to confirm the validity of any interior maximum:

1. In each case, θ must satisfy $0 < \theta < 1$. The extreme cases of $\theta = 0$ and $\theta = 1$ are excluded as they are both equivalent to not versioning.

2. In Case 1, $z = \frac{1+\delta}{1-\delta}x$ is no larger than one, but z exceeds one in Case 2.

If a valid interior maximum is found in both cases, we would need to compare R_1 and R_2 to identify which case occurs in optimality. In contrast, if neither condition is met, or if the revenue is below $\frac{1}{4}$, versioning is not optimal. The above conditions can be analytically verified, and the region in which versioning is optimal can be established.

Theorem 1 *Offering two versions is more profitable than offering one if and only if any of the following three conditions are satisfied: (i)* $\alpha > \frac{1}{2}$*, (ii)* $0 < \alpha \leq \frac{1}{2}$ *and* $\delta > \frac{1-\alpha}{1+\alpha}$*, or (iii)* $0 < \alpha \leq \frac{1}{2}$ *and* $\delta < \frac{\alpha}{2-\alpha}$.

The result in Theorem 1 is better depicted in Figure 3, which partitions the entire (α, δ) space and shows three different regions. As expected, when $\alpha \leq 0$, the manufacturer cannot influence λ favorably, and versioning is not optimal.[4] Surprisingly, however, we find that versioning may not be optimal even when $\alpha > 0$, though a positive α implies that more than half the consumers would have a positive experience after using the base version. Viewed differently, an overall positive experience from learning is, by itself, not sufficient to make versioning optimal for a monopolist. Thus, in a way, Theorem 1 extends the result in prior research (Bhargava and Choudhary 2001, Jones and Mendelson 2011), which has essentially examined a special case of $\delta = 0$ (the horizontal axis in Figure 3) and has found versioning to be suboptimal for an information good; see Lemma 1. We find that this result is not only valid for $\delta = 0$, but it actually extends to a larger region; see Figure 3. At the same time, however, there is a significant portion of the parameter space where the prior result does not extend; versioning is indeed optimal there. This versioning region is further separated into two subregions by a dashed curve, AB: Regions 1 and 2 represent the subregions where versioning is optimal under Cases 1 and 2, respectively.

It is interesting to observe that, if α is between 0 and $\frac{1}{2}$, versioning is optimal only when δ is either small or large; for moderate values of δ, versioning is not optimal. This is instructive.

[4] In subsequent figures, we show only the interesting part of the parameter space where $\alpha > 0$.

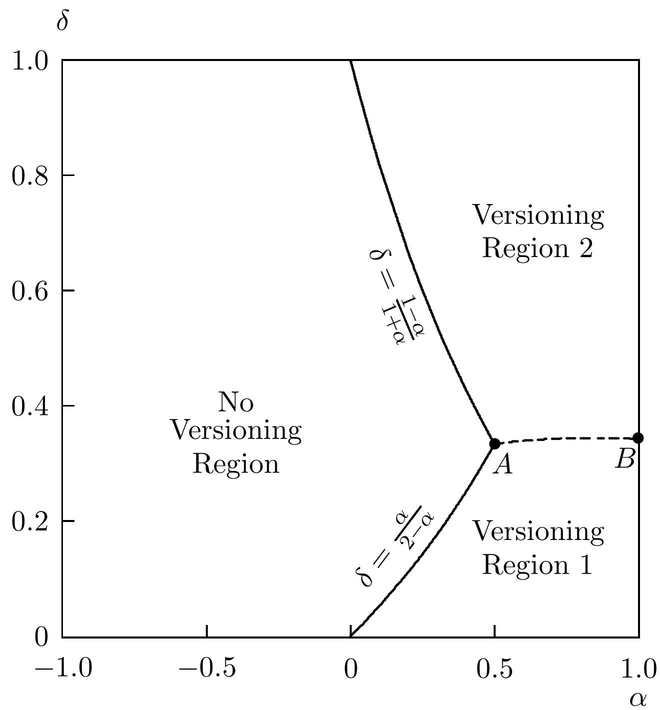


Figure 3: Regions of Versioning as Partitions of the (α, δ) Space

Recall that δ indicates the extent to which a user's valuation can be revised. At low values of δ, the potential positive impact of learning on a user's valuation is small, as is its negative impact. Therefore, notwithstanding the negative impact, a significant portion of the market opts to upgrade. Further, as explained in the previous section, the manufacturer also induces more consumers to sample its product. Then, by upselling to a fraction of them, it finds a way to overcome the adverse effect of cannibalization. In terms of its decision problem, the manufacturer finds the optimal solution in Region 1, where $z < 1$ and $x = y < \frac{1}{2}$.

As δ starts increasing, however, there comes a time when z becomes close to one, and few upgrade after negative experience. When that happens, versioning ceases being optimal. However, when δ increases further, beyond a threshold, the decision problem finds its optimality in Region 2, where the manufacturer completely stops worrying about market expansion and simply increases the price of the DLC, in order to extract a higher profit from the positive-experience users. Therefore, versioning becomes optimal once again. It is in this region where vertical differentiation is surprisingly optimal despite a lack of market expansion. This insight is new. Prior research has shown that vertical differentiation leads to an increase in social welfare through market expansion, and the manufacturer's strategy essentially involves extracting a part of that surplus through second-degree discrimination (Anderson and Dana 2009, Moorthy 1988, Mussa and Rosen 1978). What we find here is that market expansion is, in fact, not necessary for vertical differentiation to be effective. When consumers face a significant level of uncertainty about the fit, a manufacturer can use vertical differentiation with the sole objective of inducing product sampling. Note that, in Region 2, the optimal price for V1 is more than the monopoly price of $\frac{1}{2}$ and that it is also increasing in δ. The implication is obvious. The manufacturer does make higher profits by charging a handsome premium to those seeking to upgrade than by offering one version at a flat price to all buyers.

As α increases towards $\frac{1}{2}$, the effect of learning from product sampling becomes more and more powerful, leading to a shrinkage of the region of no versioning. This is because higher learning makes both tactics—those of market expansion and price increase—more desirable than no versioning. Beyond $\alpha = \frac{1}{2}$, the no-versioning region completely disappears, making versioning preferable irrespective of δ. The choice of tactics, however, still depends on δ.

A few words are in order about the dashed curve *AB* in Figure 3 that separates the two regions of versioning. In order to see more clearly how these two regions are divided, in Figure 4, we zoom into only the relevant portion of the (α, δ) space. In this figure, the line *AC*, given by $\delta = \frac{1}{3}$, represents the threshold above which Case 2 is valid; it is derived from the fact that a valid solution in Case 2 must abide by $z > 1$. Similarly, any valid solution in Case 1 must satisfy $z \leq 1$, which results in a different threshold represented by the curve *AD*; a valid Case 1 solution must be below this curve. Therefore, the region *ACDA* represents a set of (α, δ) values for which both cases provide a valid maximum, and the resulting profit in either case is better than the monopoly profit under no versioning. In order to verify which case is actually optimal, we compare R_1 and R_2. Setting $R_1 = R_2$, we get a polynomial equation in δ of order 5, which has exactly one unique root in the region *ACDA*. This root provides the desired threshold and is represented by the curve *AB* in Figures 3 and 4. Case 1 is optimal below *AB*, and Case 2, above. In Figure 4, as well as for the subsequent discussion, we write *AB* as $\delta = \eta(\alpha)$; a closed-form expression for $\eta(\alpha)$ does not exist, but a good approximation is provided by $\eta(\alpha) \approx \frac{\alpha(0.3807+0.2732\alpha)}{(0.3807+\alpha)^2}$.

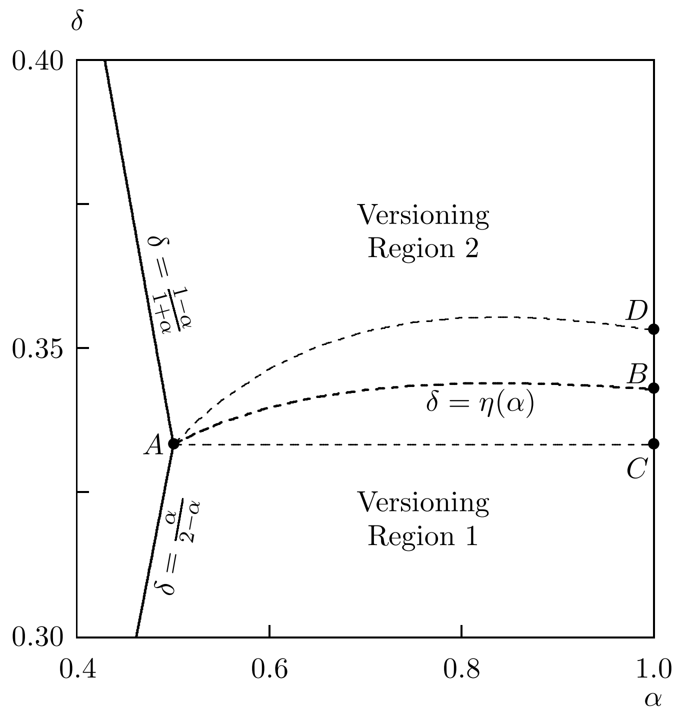


Figure 4: Zoomed Portion of the (α, δ) Space

Theorem 2 *The optimal quality level for the base version can be found from:*

- **Versioning Region 1:** *When $\delta < \frac{\alpha}{2-\alpha}$ and $\delta \leq \eta(\alpha)$, the manufacturer uses a strategy of market expansion and sets:*

$$\theta^* = \frac{\alpha(1+\delta)^2}{\alpha(1+\delta)(2+\delta) - 2\delta}.$$

  In this region, θ^* is decreasing in α but increasing in δ.

- **Versioning Region 2:** *When $\delta > \frac{1-\alpha}{1+\alpha}$ and $\delta > \eta(\alpha)$, the manufacturer uses a strategy of charging users with a positive experience a substantial price premium and sets:*

$$\theta^* = \frac{1+\alpha-\delta(1-\alpha)}{2\alpha(1+\delta)}.$$

  In this region, θ^* is decreasing in both α and δ.

- **No-Versioning Region:** *In all other cases, versioning is suboptimal, which is equivalent to setting $\theta^* = 1$.*

The result in Theorem 2 is better visualized in Figure 5, which shows how θ^* changes with α and δ.[5] As can be seen from this figure, θ^* does not change monotonically with δ. In Region 1, where

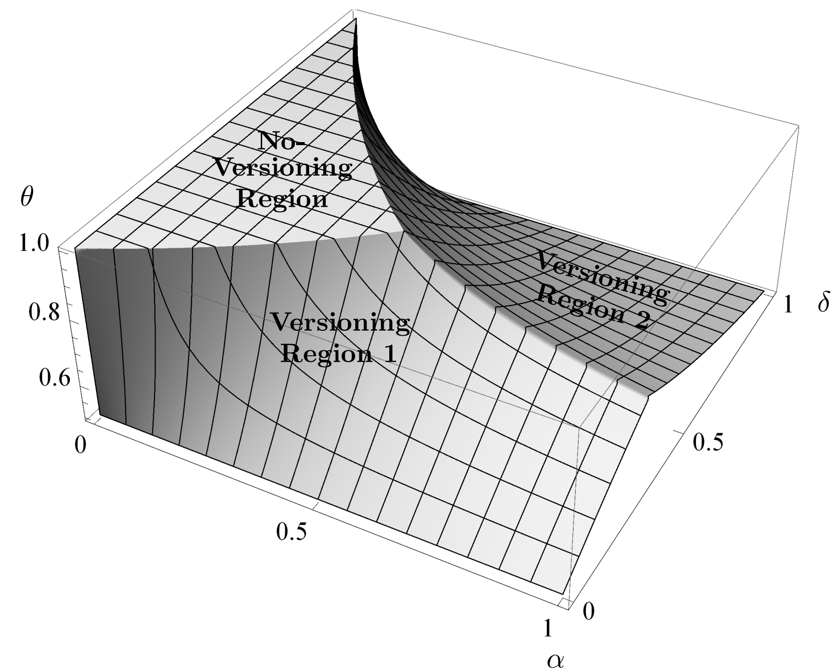


Figure 5: Optimal Quality, θ^*, as a Function of α and δ

the manufacturer adopts a market expansion strategy, θ^* increases with δ. In contrast, in Region 2, where the upgrade price increases but the market coverage does not, θ^* decreases with δ. Recall that, in Region 1, a segment of the market always upgrades; as δ increases, this segment shrinks, and the monopolist responds to this shrinkage in two ways: First, it starts increasing θ with the aim of providing a better learning experience, which now becomes necessary to increase the fraction of those upgrading and, therefore, to sustain the overall level of sales for the DLC. Second, as δ increases, the monopolist also increases r along with θ in such a way that the quality adjusted price, $\frac{r}{\theta}$, decreases, thereby expanding the overall market. This higher coverage not only increases the profit directly, but also contributes to the profit in terms of a higher number of consumers who might upgrade.

[5] Based on our extensive numerical analyses, we would like to note here that all the insights remain qualitatively applicable over a wide variety of distributions of consumers' valuation; please see Section 8.

As δ increases beyond Region 1, the uncertainty about the fit becomes so high that no consumer is ready to buy the DLC until a positive experience with the base version. Two possibilities arise. If α is small, so is λ; unable to influence a sufficient number of consumers to upgrade, the monopolist decides against versioning altogether, and we move into the no-versioning region. For example, in Figure 5, when $\alpha = \frac{1}{4}$, we move into the no-versioning region when δ crosses $\frac{1}{7}$. The manufacturer offers only one version as long as $\frac{1}{7} \leq \delta \leq \frac{3}{5}$, and beyond $\delta = \frac{3}{5}$, we move into Region 2 of versioning. In contrast, when α is large, the manufacturer realizes that it can positively influence a sufficiently large number of consumers, and we cross over directly to Region 2; such is the case with $\alpha = \frac{3}{4}$ in Figure 5.

In Region 2, the manufacturers strategy becomes quite different. Here, the manufacturer finds that the posterior valuation of the positive-experience consumers is quite high and concentrates on extracting as much surplus out of them as possible. To that end, as δ increases, the manufacturer starts increasing the price premium, $(p-r)$, very rapidly by increasing p and reducing both r and θ at the same time, while maintaining $\frac{r}{\theta}$ at $\frac{1}{2}$. Thus, in this region, the market does not expand, but a larger horizontal separation between the positive- and negative-experience groups leads directly to a wider gap between the quality levels offered.

7 Welfare Analysis

We start with an analysis of the manufacturer's profit. As mentioned earlier, the monopolist would resort to this strategy only if the overall profit from this strategy is higher than that in the no-versioning case. We now state this more formally:

Proposition 3 *The manufacturer's profit, R^*, can be found from:*

- **Versioning Region 1:** *When $\delta < \frac{\alpha}{2-\alpha}$ and $\delta \leq \eta(\alpha)$, the manufacturer's profit is:*

$$R^* = \frac{\left(1-\delta^2\right)\left(\alpha - \delta(1-\alpha)\right)}{\alpha(1+\delta)(4-\alpha\delta(1+\delta)) - 4\delta}.$$

In this region, R^* is greater than the no-versioning profit of $\frac{1}{4}$.

- **Versioning Region 2:** *When $\delta > \frac{1-\alpha}{1+\alpha}$ and $\delta > \eta(\alpha)$, the manufacturer's profit is:*

$$R^* = \frac{4\alpha(1+\delta)^2 + (1+\alpha-\delta(1-\alpha))^2}{32\alpha(1+\delta)}.$$

  In this region as well, R^* is greater than the no-versioning profit of $\frac{1}{4}$.

- **No-Versioning Region:** *In all other cases, versioning is suboptimal, and the manufacturer's profit is $R^* = \frac{1}{4}$.*

Proposition 3 is illustrated in Figure 6, which plots R^* as a function of α and δ. Evidently, the

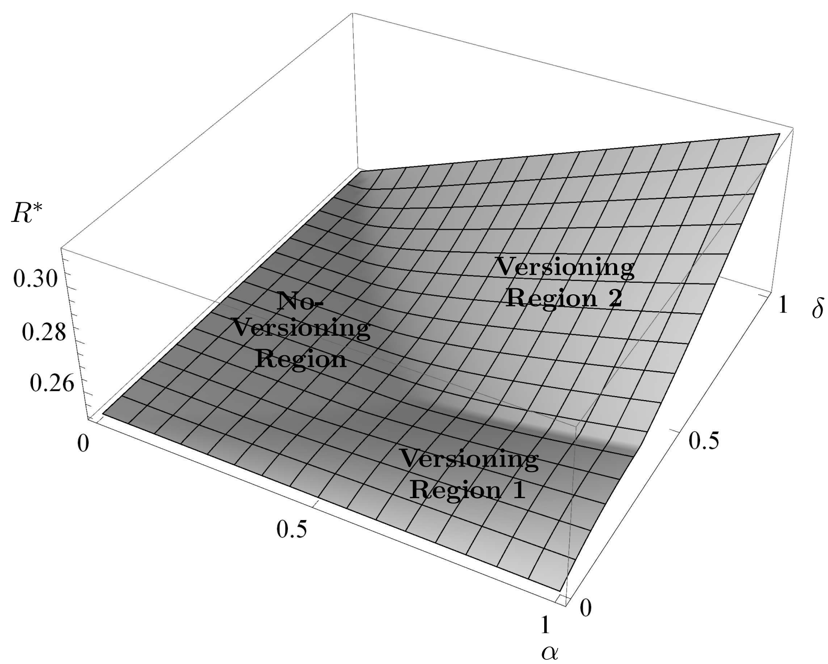


Figure 6: Profit, R^*, as a Function of α and δ

optimal profit is an increasing function of α. This is intuitive—a higher α simply means that more consumers are likely to have a positive experience and upgrade. However, the optimal profit is not monotonic in δ in Region 1, where the profit increases with δ for very small values of δ and starts decreasing beyond a certain point. When δ is small, the manufacturer increases both θ and r as δ increases, which results in an increased profit initially, even though a rising δ means fewer consumers are now willing to upgrade after a negative experience. However, beyond a threshold, the increase in revenue from a higher r is no longer sufficient to compensate for this decline in upgrades. Consequently, the overall profit decreases. In contrast, in Region 2, where δ is large and no one buys the DLC after a negative experience, the manufacturer's profit increases monotonically with δ. In this region, as δ increases, the manufacturer simply ignores the possibility that a consumer would upgrade after a negative experience; therefore, it only concentrates on the consumers with a positive experience and raises the price premium for the DLC, while, at the same time, reducing the quality and price of the base version. This increase in the premium readily translates to a rapid increase in the profit, as shown in Figure 6.

We now turn our attention to an analysis of consumer welfare when a manufacturer employs the DLC strategy.

Theorem 3 *The aggregate consumer surplus, CS, can be found from:*

- **Versioning Region 1:** *When* $\delta < \frac{\alpha}{2-\alpha}$ *and* $\delta \leq \eta(\alpha)$*:*

$$CS = \frac{\nu(\beta,\delta)}{2(\beta(2+\delta)-2\delta)(4\delta-\beta(4-\beta\delta))^2},$$

where $\beta = \alpha(1+\delta)$ *and*

$$\begin{aligned}\nu(\beta,\delta) \quad &= \quad \beta^6\delta^3 - \beta^5\delta^2(6-\delta) + \beta^4\delta\left(1+\delta^2\right)(4-\delta(4+\delta)) + \beta^3\left(2+\delta+\delta^2\right)\left(4+5\delta^2(1+\delta)\right) \\ &\quad -2\beta^2\delta(12+\delta(4+3\delta(11+\delta(4+\delta)))) + 4\beta\delta^2(6+\delta)\left(1+3\delta^2\right) - 8\delta^3\left(1+3\delta^2\right).\end{aligned}$$

In this region, CS is greater than the no-versioning consumer surplus of $\frac{1}{8}$*.*

- **Versioning Region 2:** *When* $\delta > \frac{1-\alpha}{1+\alpha}$ *and* $\delta > \eta(\alpha)$*:*

$$CS = \frac{(1+7\delta)\left((1-\delta)^2+\alpha^2(1+\delta)^2\right)+2\alpha(3+\delta(13+5(1-\delta)\delta))}{64\alpha(1+\delta)^2}.$$

In this region as well, CS is greater than the no-versioning consumer surplus of $\frac{1}{8}$*.*

- **No-Versioning Region:** *In all other cases, versioning is suboptimal, and the consumer surplus is* $CS = \frac{1}{8}$*.*

Figure 7 plots the consumer surplus as a function of α and δ. It can be clearly seen from the plot

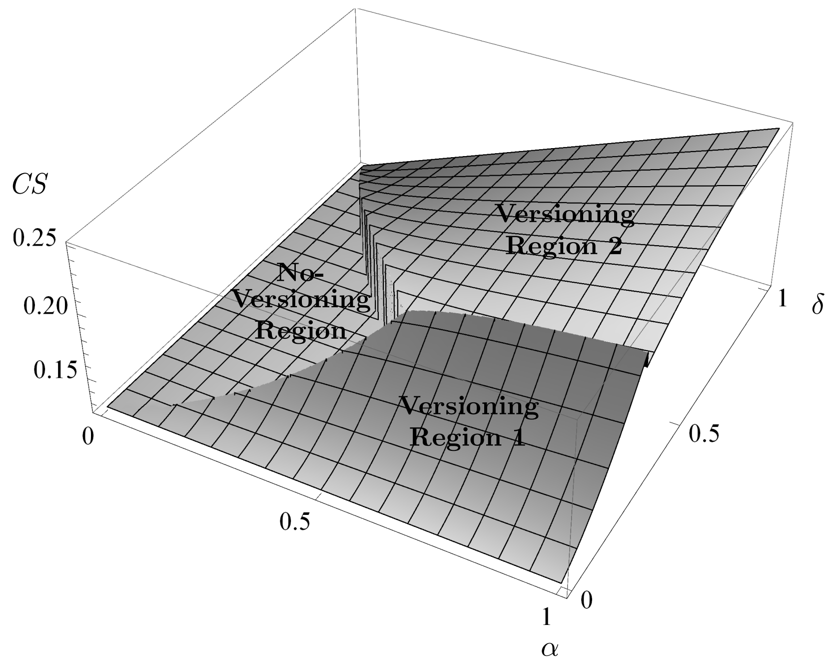


Figure 7: Consumer Surplus, CS, as a Function of α and δ

that, as stated in Theorem 3, the consumer surplus increases when the manufacturer uses the DLC strategy. In essence, versioning allows the consumer to reduce his uncertainty about the product, resulting in an increase in the social surplus. Even though a portion of this surplus is extracted by the manufacturer, it cannot be extracted fully, which results in an overall increase in the consumer surplus. Therefore, it seems that the claim by certain consumer groups—the DLC strategy is unfair to the gamers (Meer 2012)—is not necessarily correct. The DLC strategy may actually benefit the consumers in an overall sense, even though a few may be impacted negatively.

Since both the manufacturer's profit and the overall consumer surplus increase with the DLC strategy, it is clear that the total social welfare would, too. For the sake of completeness, in Figure 8, we plot the total surplus for the manufacturer and consumers combined. The trends are as expected.

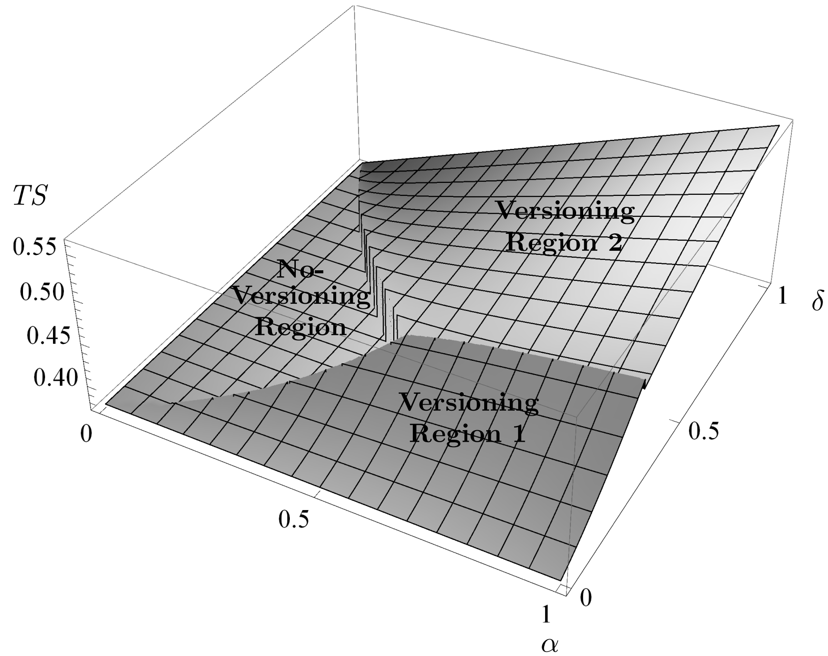


Figure 8: Total Surplus, TS, as a Function of α and δ

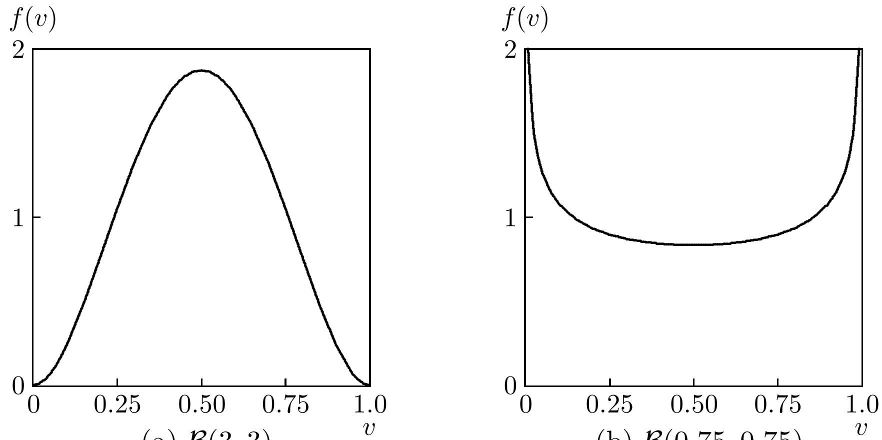
8 Some Technical Remarks

All our analyses are based on the assumption that v is uniformly distributed. Such an assumption is fairly standard. However, given the newness of our problem context, it is important to ascertain that our results are not driven by this assumption itself. To that end, we have performed extensive numerical analyses with many other distributional forms. In order to create these different forms, we use the Beta distribution, $\mathcal{B}(s,t)$, the shape of which can be varied at will by suitable choices of its parameters s and t.[6]

Although we have tested with a wide variety of s and t values, we first report our results with two different sets shown in Figure 9; both cases result in a symmetric distribution, the first one has most of its mass near the mean and the second, near the two ends. This way, we are able to test the robustness of our findings for a range of symmetric distributions.

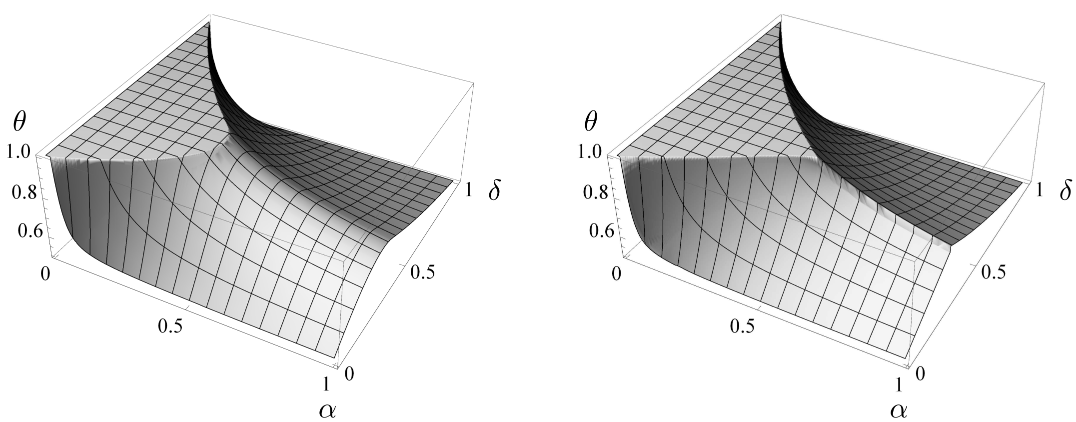
[6] As a special case, we have also considered the situation where consumers are homogeneous with respect to their taste for quality, that is, v is a constant. In such a situation, it can be shown that versioning is optimal as long as $\delta > \frac{1-\alpha}{1+\alpha}$, and the optimal quality is given by: $\theta^* = \frac{1+\alpha-\delta(1-\alpha)}{2\alpha(1+\delta)}$. This illustrates that our result—the inability to horizontally differentiate leads the manufacturer towards vertical differentiation—is not driven by any vertical separation among consumers.

Figure 10 shows how the optimal quality changes with α and δ for these two distributions. Comparing this figure with Figure 5, we can see that the results are qualitatively similar, though the actual boundaries of the three regions described in Theorem 2 change somewhat. As expected, all other insights, including those related to welfare, extend to these settings.



(a) $\mathcal{B}(3, 3)$ (b) $\mathcal{B}(0.75, 0.75)$

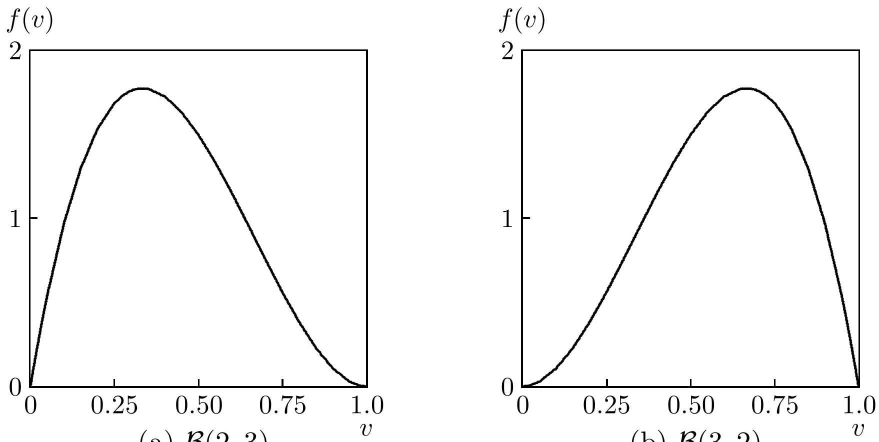
Figure 9: Probability Density Function for the Beta Distribution



(a) $\mathcal{B}(3, 3)$ (b) $\mathcal{B}(0.75, 0.75)$

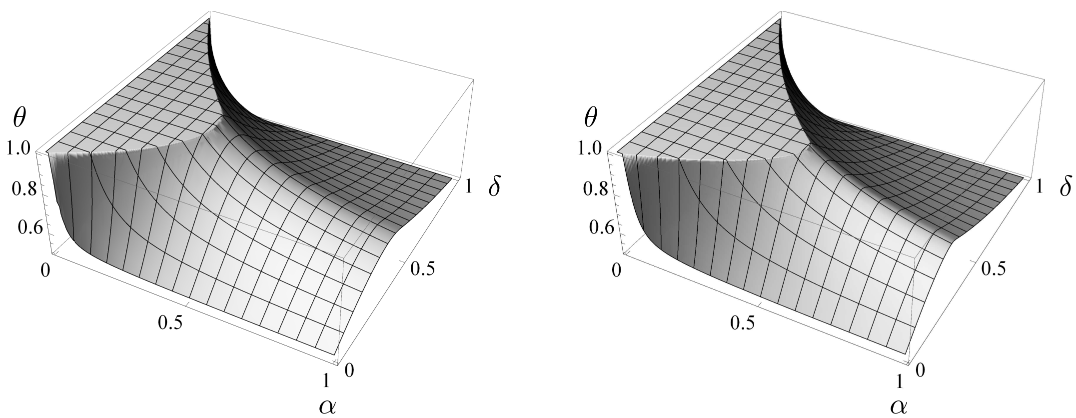
Figure 10: Optimal Quality, θ^*, as a Function of α and δ

Having established the robustness with respect to symmetric distributions, we now consider asymmetric ones as a final check. Here we report two cases, one right skewed and the other, left; see Figure 11. The plots of the corresponding optimal quality levels are shown in Figure 12. Once again, comparing Figures 5, 10, and 12, we can see that our analysis is quite robust to the choice of the valuation distribution.



(a) $\mathcal{B}(2,3)$ (b) $\mathcal{B}(3,2)$

Figure 11: Probability Density Function for the Beta Distribution



(a) $\mathcal{B}(2,3)$ (b) $\mathcal{B}(3,2)$

Figure 12: Optimal Quality, θ^*, as a Function of α and δ

9 Conclusion

The video game industry, which is already more than double the size of the music industry, is on a rapid growth trajectory and is projected to gross well over $100 billion a year by 2015. Almost every manufacturer in this market offers premium contents as DLCs, and tens of millions of consumers purchase them. One of the recent trends in this industry has been the emergence of versioning in the form of zero-day DLCs. Prompted by this trend, and the surrounding controversy (Kain 2012, Meer 2012), we examine the efficacy and welfare implications of such a versioning strategy.

Prior research on physical goods has observed that, when a monopolist serves a continuum of consumer types with a finite number of quality levels, the cannibalization of the highest quality product can be overcome through market expansion, provided the marginal cost increases sufficiently with quality (Moorthy 1988). However, when the marginal cost is the same regardless of quality, as in the case of information goods, vertical differentiation ceases being optimal (Bhargava and Choudhary 2001, Jones and Mendelson 2011). We, too, consider a monopolist serving a continuum of consumer types with a zero marginal cost good. Our monopolist also decides whether to offer a base version of inferior quality, in addition to the full version. Unlike prior research, however, we incorporate consumer learning from personal experience. We do so because the DLC strategy in the video game market cannot be fully understood without recognizing that games are actually experience goods. After a consumer experiences the base version of a game, he gathers valuable private information regarding the fit between his needs and the game's features, and revises his valuations accordingly. Then, if he had a positive experience with the game, he would seek more of it. This notion of "I'd rather have more game when I want it" is, in essence, "the crux of the argument for day-one and on-disc DLC" (Thier 2012). It is also central to our work. In summary, the base version in our model plays the role of a product sample, just as it plays its traditional role as an imperfect substitute. It is this dual role that allows us to capture the trade-off between the benefits of product sampling and the adverse effects of cannibalization, an interesting connection not made before.

Our model, despite its rather simple nature, reveals some valuable insights. We find that versioning can indeed be optimal for information goods with zero marginal costs. In fact, versioning turns out to be optimal over a reasonably large part of the (α, δ) space. Recall that the parameter $\alpha \in (0, 1)$ represents the marginal impact of product sampling, whereas $\delta \in (0, 1)$ represents the uncertainty associated with a consumer's prior perception. We find that, when $\alpha > \frac{1}{2}$, the benefits of product sampling (and the resulting consumer learning) are sufficiently large to offset all adverse effects of cannibalization, making versioning the preferred strategy for our monopolist. On the other hand, when $\alpha \leq \frac{1}{2}$, versioning is optimal only when δ is close to 0 or 1; surprisingly though, it is not so at moderate values of δ. At low δ, versioning is effective because it allows the manufacturer to expand the market, which leads to increased product sampling. Eventually, this results in many consumers upgrading to the higher version. However, as δ increases, the fraction of consumers willing to upgrade after a negative experience starts to drop. As a result, versioning ceases being optimal after a point. Finally, when δ becomes sufficiently high, even though a market expansion is no longer viable, the manufacturer is able to charge a handsome premium to those seeking to upgrade following a positive experience, making versioning an effective strategy again.

As we illustrate numerically, our results are fairly robust in the sense that they hold irrespective of the distribution of consumers' taste parameter. Thus, there are important practical implications applicable in a variety of situations. For manufacturers or products that are relatively new in the marketplace, the valuation uncertainty (δ) is likely substantial. For them, upselling at a substantial price premium is critical. On the other hand, for established brands with relatively small valuation uncertainty, the focus needs to be on expanding the market coverage and inducing additional product sampling without significantly cannibalizing the market for the full version. Interestingly, our results also imply that, for manufacturers or products in the middle, versioning could be futile unless the marginal benefit of product sampling (α) is sufficiently high. Finally, in terms of welfare implications, we show that learning from experience actually increases the social surplus. Although the manufacturer captures a part of this increase through higher prices, consumers end up with a share as well. In other words, despite the claims to the contrary, overall, the DLC strategy can also be beneficial to the consumers of video games.

There is a notable contribution to theory as well. To the best of our knowledge, this is the first work that examines versioning in a context where consumers are heterogeneous in their taste for quality as well as in their perception of it. And, because it is also not possible to identify different groups of gamers with distinct tastes, the manufacturer is unable to practise horizontal differentiation. What is really interesting is that this inability to horizontally place the product line does not stop the manufacturer from vertically positioning it. With an aim to induce product sampling and promote consumer learning, the manufacturer offers vertically differentiated versions. In fact, when the uncertainty around consumers' initial perceptions is high, we show why a monopolist should use vertical differentiation solely for this purpose—notwithstanding a lack of market expansion, it can benefit by charging a substantial price premium to those willing to upgrade. On the other hand, when the uncertainty is low, product sampling does not lead to high price premiums, but the manufacturer is still able to induce a greater number consumers to try the product, which again makes such versioning effective. This insight—that a manufacturer can indeed version vertically to leverage what is essentially a horizontal separation among consumers—is new, and it does provide an interesting way to look at the issue of versioning information goods.

Of course, our work is not without a few limitations. We leave out factors such as network effects, piracy, and competition. If prior research is an indication (e.g., Chellappa and Shivendu 2005, Sun et al. 2004, Wu and Chen 2008), incorporating network effects or piracy is likely to make versioning even more attractive to the manufacturer; however, no clear inferences can still be made regarding how incorporating such issues will influence our analyses. Likewise, it is also not clear how our findings would extend to a competitive setting. Despite such limitations, we believe that our work provides a path forward for researchers interested in understanding the subtle interplay between vertical differentiation and product sampling.

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Appendix: Proofs

Proof of Lemma 1

When consumers have full information about quality all along, the monopolist's profit is:

$$r\left(\frac{p-r}{1-\theta}-\frac{r}{\theta}\right)+p\left(1-\frac{p-r}{1-\theta}\right).$$

The first order conditions with respect to r leads to:

$$2\left(\frac{p-r}{1-\theta}-\frac{r}{\theta}\right)=0,$$

simplifying which we obtain $p=\frac{r}{\theta}$. However, when $p=\frac{r}{\theta}$, there is no incentive for any consumer to use V2, implying that versioning cannot be optimal. ■

Proof of Proposition 1

Suppose, there is an optimal solution with $y > x$. In that case, the revenue is:

$$R = r(1-x)+(p-r)(\lambda(1-y)+(1-\lambda)(1-\min\{1,z\})).$$

If $z < 1$, then

$$\frac{\partial R}{\partial r} = 1-2x-(\lambda(1-y)+(1-\lambda)(1-z))+\lambda y+(1-\lambda)z = 2(\lambda y+(1-\lambda)z-x) > 0,$$

which is also a violation of the optimality condition. Note that the last inequality above follows from $y, z > x$. If, on the other hand, $z \geq 1$, then the optimality conditions are:

$$\begin{aligned}\frac{\partial R}{\partial p} &= \lambda(1-y) - \lambda y = 0, \text{ and}\\ \frac{\partial R}{\partial r} &= 1 - 2x - \lambda(1-y) + \lambda y = 0,\end{aligned}$$

solving which we get $x = y = \frac{1}{2}$. Therefore, an optimal solution with $y > x$ is not possible.

We now consider an optimal solution with $y < x$. The total revenue in this case is given by:

$$R = r(1-x) + (p-r)(\lambda(1-x) + (1-\lambda)(1-\min\{1,z\})).$$

When $z \geq 1$, then

$$\frac{\partial R}{\partial p} = \lambda(1-x) > 0,$$

which is again a violation of the optimality condition. We now consider scenarios where $z < 1$; the proof now becomes a little trickier. Here, we first show that, when the optimality conditions are met and versioning is optimal, the resulting solution implies $y > x$, a violation of the assumption that $y < x$ in optimality. The optimality conditions in this case are given by:

$$\begin{aligned}\frac{\partial R}{\partial p} &= \lambda(1-x) + (1-\lambda)(1-2z) = 0, \text{ and}\\ \frac{\partial R}{\partial r} &= 2(1-\lambda)z - 2x + \lambda x - \lambda\frac{p-r}{r}x = 0.\end{aligned}$$

The above can be solved to obtain:

$$x = \frac{2\theta(1-\lambda) - \lambda(1-\delta)(1-\theta)}{4\theta(1-\lambda) - \lambda^2(1-\delta)(1-\theta)}, \text{ and } \quad z = \frac{\theta(2-\lambda)}{4\theta(1-\lambda) - \lambda^2(1-\delta)(1-\theta)}.$$

Note that for this solution to be meaningful, z must be positive, which, in turn, implies that:

$$4\theta(1-\lambda) - \lambda^2(1-\delta)(1-\theta) > 0. \tag{A1}$$

The resulting revenue must also be greater than the revenue from offering a single version, for versioning to be more profitable. In other words, we must have $R > \frac{1}{4}$. By substituting x and z from above, we find:

$$4\left(R - \frac{1}{4}\right) = \frac{(1-\theta)\left(\lambda^2(1-\delta) - 4\delta\theta(1-\lambda))\right)}{4\theta(1-\lambda) - \lambda^2(1-\delta)(1-\theta)}.$$

Since the denominator is positive from (A1), versioning would be optimal if and only if the numerator is also positive. Since $\theta \leq 1$, this results in:

$$4\delta\theta(1-\lambda) < \lambda^2(1-\delta). \tag{A2}$$

Now, we are ready to compare y with x:

$$x - y \;=\; x - \frac{1-\delta}{1+\delta}z \;=\; \frac{\delta^2\lambda(1-\theta) - \lambda + \delta\theta(4-3\lambda)}{(1+\delta)(4\theta(1-\lambda) - \lambda^2(1-\delta)(1-\theta))}.$$

From (A1), we conclude that the denominator in the above expression is positive. We now analyze the numerator (denoted w):

$$\begin{aligned} w &= \delta^2\lambda(1-\theta) - \lambda + \delta\theta(4-3\lambda) = \delta^2\lambda(1-\theta) - \lambda + 4\delta\theta(1-\lambda) + \delta\theta\lambda \\ &< \delta^2\lambda(1-\theta) - \lambda + \lambda^2(1-\delta) + \delta\theta\lambda \qquad \text{[from (A2)]} \\ &= -\lambda(1-\delta^2) + \lambda^2(1-\delta) + \delta\theta\lambda(1-\delta) \\ &= (1-\delta)(-\lambda(1+\delta) + \lambda^2 + \delta\theta\lambda) \\ &= -(1-\delta)(\lambda(1-\lambda) + \lambda\delta(1-\theta)) \leq 0. \end{aligned}$$

Since $w < 0$, it follows that $x < y$, which is the desired contradiction. ■

Proof of Proposition 2

We can rewrite R_i, $i = 1, 2$, as:

$$R_i = Ax(1-x) + B_i x(1-\mu x),$$

where $A = (\theta + \lambda(1+\delta)(1-\theta))$, $B_1 = (1+\delta)(1-\lambda)(1-\theta)$, $B_2 = 0$ and $\mu = \frac{1+\delta}{1-\delta}$. Setting $\frac{\partial R_i}{\partial r} = 0$ leads to:

$$r = \frac{\theta(A + B_i)}{2(A + \mu B_i))},$$

which can be simplified to get the desired solution. Finally, since $\frac{\partial^2 R_i}{\partial r^2} = -\frac{2}{\theta}(A + \mu B_i) < 0$, the second order condition is also satisfied. ■

Proof of Theorem 1

It is clear from the proof of Theorem 2 below that, in the regions specified by the conditions (i), (ii), and (iii) in the theorem statement, there is a valid solution that satisfies $0 < \theta < 1$. ■

Proof of Theorem 2

Substituting the value of r from Proposition 2 into (2), we get:

$$R = \begin{cases} \frac{(1-\delta)(1+\delta(1-\theta))^2}{4((1+\delta)(1-\alpha\delta\theta(1-\theta))-2\delta\theta)}, & \text{in Case 1,} \\ \frac{(1+\delta)\left(1+\alpha\theta-\alpha\theta^2\right)+\theta(1-\delta)}{8}, & \text{in Case 2.} \end{cases}$$

The first order condition with respect to θ yields:

$$\theta^* = \begin{cases} \theta_1 = \frac{\alpha(1+\delta)^2}{\alpha(1+\delta)(2+\delta)-2\delta}, & \text{in Case 1,} \\ \theta_2 = \frac{1+\alpha-\delta(1-\alpha)}{2\alpha(1+\delta)}, & \text{in Case 2.} \end{cases}$$

It can be easily verified that this θ^* corresponds to a minimum when $\alpha < 0$, implying versioning is not optimal then. Furthermore, there is no interior solution for $\alpha = 0$. We, therefore, turn our attention to the interesting situation in which $\alpha > 0$.

Using Proposition 2, we can compute the corresponding optimal prices easily:

$$r^* = \begin{cases} r_1 = \frac{\alpha(1-\delta)(1+\delta)^2}{\alpha(1+\delta)(4-\alpha\delta(1+\delta))-4\delta}, & \text{in Case 1,} \\ r_2 = \frac{1-\delta+\alpha(1+\delta)}{4\alpha(1+\delta)}, & \text{in Case 2.} \end{cases}$$

$$p^* = \begin{cases} p_1 &= \frac{2(\alpha-(1-\alpha)\delta)\left(1-\delta^2\right)}{\alpha(1+\delta)(4-\alpha\delta(1+\delta))-4\delta}, & \text{in Case 1,} \\ p_2 &= \frac{\alpha(1+\delta)(2+\delta)-\delta(1-\delta)}{4\alpha(1+\delta)}, & \text{in Case 2.} \end{cases}$$

Let us now identify the regions where the solutions above are valid. We start with Case 1:

1. For Case 1 to occur at optimality, θ_1 must satisfy $0 < \theta_1 < 1$. Now, $\theta_1 < 1$ leads to

$$\delta < \frac{\alpha}{2-\alpha}, \tag{A3}$$

   which automatically guarantees that $\theta_1 > 0$.

2. In Case 1, $z = \frac{p_1 - r_1}{(1-\delta)(1-\theta_1)}$ must be no larger than one. First, it can be easily verified that this is indeed true if $\alpha \le \frac{1}{2}$ and $\delta < \frac{\alpha}{2-\alpha}$. Second, if $\alpha > \frac{1}{2}$, this requires that δ be no larger than the unique real root of the following cubic equation in δ.

$$(1+\delta)(\alpha(1+\delta)(2+\delta) - 2\delta) = \alpha(1+\delta)(4 - \alpha\delta(1+\delta)) - 4\delta.$$

   The uniqueness of this real root can be ascertained by verifying that the *discriminant* of the cubic equation, $4\left(4 - 36\alpha + 109\alpha^2 - 186\alpha^3 - 207\alpha^4 - 16\alpha^5\right)$, is indeed negative when $\alpha > \frac{1}{2}$. This root appears as the curve AD in Figure 4, which zooms in on a portion of the (α, δ) space in Figure 3.

3. The second order condition with respect to θ must be satisfied. Since

$$\left.\frac{d^2 R_1}{d\theta^2}\right|_{\theta=\theta_1} = \frac{-(1-\delta)\delta(\alpha(1+\delta)(2+\delta)-2\delta)^4}{2(1+\delta)(\alpha-(1-\alpha)\delta)(4\delta+\alpha(1+\delta)(\alpha\delta(1+\delta)-4))^2},$$

   for the second order condition to be satisfied, we require that $\delta < \frac{\alpha}{1-\alpha}$. However, this is trivially satisfied whenever (A3) holds.

We now move on to Case 2:

1. For Case 2 to occur at optimality, θ_2 must satisfy $0 < \theta_2 < 1$. Here, $\theta_2 < 1$ leads to $\delta > \frac{1-\alpha}{1+\alpha}$. Also, $\theta_2 > 0$ trivially holds.

2. In Case 2, $z = \frac{p_2 - r_2}{(1-\delta)(1-\theta_2)}$ must be larger than one. This is indeed true if $\alpha \le \frac{1}{2}$. If, on the other hand, $\alpha > \frac{1}{2}$, this requires that $\delta > \frac{1}{3}$. The curve $\delta = \frac{1}{3}$ appears as the horizontal line AC in Figure 4.

3. The second order condition with respect to θ must also be satisfied. It turns out that this condition is always satisfied, because

$$\left.\frac{d^2 R_2}{d\theta^2}\right|_{\theta=\theta_2} = \frac{-\alpha}{4(1+\delta)} < 0.$$

Finally, we consider the region $ACDA$ in Figure 4. It is apparent from the discussion above that, for $\alpha > \frac{1}{2}$, Case 1 is valid only below the curve AD, and Case 2 only above AC, meaning that both cases are feasible in the region $ACDA$. In order to examine which case actually results in the optimal solution, we need to compare the values of R_1 (at p_1, r_1, and θ_1) and R_2 (at p_2, r_2, and θ_2). Equating the two, we obtain the curve AB in Figures 3 and 4, which represents the root $\delta = \eta(\alpha)$ of the following equation:

$$4(1-\delta)^2\delta + \alpha^4\delta(1+\delta)^4 - 4\alpha(1+\delta)\left(1 - \delta^2 - 8\delta^3\right) \\ - 2\alpha^3(1+\delta)^3(2 - \delta(3+\delta)) + \alpha^2(1+\delta)^2(8 - \delta(3 + (34-\delta)\delta)) = 0.$$

Although the above equation has multiple roots, it turns out that $(R_2 - R_1)$ is increasing in δ in *ACDA*, implying that there exists a unique root in this region and the curve *AB* is unambiguously determined. ■

Proof of Proposition 3

Substituting the values of p, r and θ from Proposition 2 and Theorem 2 into the expression of R, we get the desired result. That the optimal profit is greater than $\frac{1}{4}$ in the two versioning regions follows directly from the existence of an interior maximum. ■

Proof of Theorem 3

Versioning Region 1

In Region 1, all consumers with $v \geq x$ buy the base version. Of them a λ fraction gets a positive experience and upgrade by purchasing the DLC. Of the remaining $(1-\lambda)$ fraction, those with $v < z$ do not purchase the DLC whereas those with $v \geq z$ do. Therefore the aggregate consumer surplus can be expressed as:

$$\text{CS} = \lambda \int_x^1 ((1+\delta)v - p)\, dv + (1-\lambda) \int_z^1 ((1-\delta)v - p)\, dv + (1-\lambda) \int_x^z ((1-\delta)\theta v - r)\, dv.$$

The expression for the surplus in the theorem statement follows after some algebra. Proving that this surplus is at least $\frac{1}{8}$ involves a number of steps. For the sake of brevity, we provide only a sketch. Note:

$$\text{CS} - \frac{1}{8} = \frac{\phi(\alpha,\delta)}{8\left(2\alpha - 2\delta + 3\alpha\delta + \alpha\delta^2\right)\left(4\delta - 4\alpha(1+\delta) + \alpha^2\delta + 2\alpha^2\delta^2 + \alpha^2\delta^3\right)^2},$$

where

$$\phi(\alpha,\delta) = 4\,\nu(\beta,\delta) - (\beta(2+\delta) - 2\delta)(4\delta - \beta(4-\beta\delta))^2,$$

$\beta = \alpha(1+\delta)$, and $\nu(\beta,\delta)$ is as defined in the theorem statement. Since the denominator of the fraction on the right hand side is clearly positive in Region 1 (as $\alpha \geq \frac{2\delta}{1+\delta}$), all we need to show is that $\phi(\alpha,\delta) \geq 0$. Further, since $\alpha \geq \frac{2\delta}{1+\delta}$ in the region of interest and

$$\phi\left(\frac{2\delta}{1+\delta}, \delta\right) = 192\delta^5\left(1-\delta^2\right)^2 \geq 0,$$

it is sufficient to show that $\frac{\partial\phi(\alpha,\delta)}{\partial\alpha} \geq 0$. It turns out that

$$\left.\frac{\partial\phi\left(\alpha,\delta\right)}{\partial\alpha}\right|_{\alpha=\frac{2\delta}{1+\delta}} = 32\delta^4(19+20\delta)(1-\delta^2)^2,$$

which is again positive. Therefore, it is sufficient to show that $\frac{\partial^2\phi(\alpha,\delta)}{\partial\alpha^2} \geq 0$. Now,

$$\left.\frac{\partial^2\phi\left(\alpha,\delta\right)}{\partial^2\alpha}\right|_{\alpha=\frac{2\delta}{1+\delta}} = 16\delta^3(1-\delta)(1+\delta)^3(83 - 3\delta(36\delta-1)),$$

which is also positive in Region 1 because $\delta \leq 0.35$ there. Therefore, it is sufficient to show that $\frac{\partial^3\phi(\alpha,\delta)}{\partial\alpha^3} \geq 0$. It can be easily verified that $\frac{\partial^3\phi(\alpha,\delta)}{\partial\alpha^3}$ is concave in α whenever $\delta \leq 0.35$. Therefore, it attains its minimum either at $\alpha = 0$ or $\alpha = 1$. At $\alpha = 0$, it is $24\delta^2(1+\delta)^3(6+\delta(13+5\delta(2+\delta)))$, which is positive. At $\alpha = 1$, it is $12\delta(1-\delta)(1+\delta)^3(64-\delta(6+\delta(173+\delta(137+32\delta))))$, which is also positive for $\delta \leq 0.35$. Therefore, $\frac{\partial^3\phi(\alpha,\delta)}{\partial\alpha^3} \geq 0$ in the region of interest, implying that $\phi(\alpha,\delta) \geq 0$.

Versioning Region 2

In this region, $x = \frac{1}{2}$, and $v \ngeq z$. Therefore, we get:

$$\begin{aligned} \text{CS} &= \lambda \int_{\frac{1}{2}}^{1} ((1+\delta)v - p)\,dv + (1-\lambda)\int_{\frac{1}{2}}^{1} ((1-\delta)\theta v - r)\,dv. \\ &= \frac{(1+7\delta)\left((1-\delta)^2 + \alpha^2(1+\delta)^2\right) + 2\alpha(3+\delta(13+5(1-\delta)\delta))}{64\alpha(1+\delta)^2}. \end{aligned}$$

To see that this is also greater than $\frac{1}{8}$, we note:

$$\text{CS} - \frac{1}{8} = \frac{\psi(\alpha,\delta)}{64\alpha(1+\delta)^2},$$

where $\psi(\alpha,\delta) = 1 - 2\alpha + \alpha^2 + 5\delta + 10\alpha\delta + 9\alpha^2\delta - 13\delta^2 + 2\alpha\delta^2 + 15\alpha^2\delta^2 + 7\delta^3 - 10\alpha\delta^3 + 7\alpha^2\delta^3$. Clearly, to complete the proof, we need to show that $\psi(\alpha,\delta) \geq 0$. To that end, we first observe that $\psi(\alpha,\delta)$ is a convex function of α since:

$$\frac{\partial^2\psi(\alpha,\delta)}{\partial\alpha^2} = 2 + 18\delta + 30\delta^2 + 14\delta^3 > 0.$$

Next, solving $\frac{\partial\psi(\alpha,\delta)}{\partial\alpha} = 0$, we find that $\psi(\alpha,\delta)$ is minimized at $\alpha = \frac{1-6\delta+5\delta^2}{1+8\delta+7\delta^2}$. Finally, substituting this α we find the minimum value of $\psi(\alpha,\delta)$ as $\frac{24\delta(1+\delta)(1-\delta)^2}{1+7\delta} \geq 0$. ■