Bloatware and Jailbreaking: How Consumer-Initiated Modification Interacts with Product Pricing

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Abstract

Today, many firms in consumer electronics market sell their devices bundled with unwanted applications – called *bloatware*, which provide additional revenue stream to firms, but deteriorate the value of purchased devices for consumers. Consumers, in response, find technical means to modify purchased devices – called *jailbreaking*– to remove those applications, thereby reducing the anticipated bloatware revenue for firms. From the perspective of a monopolistic firm, we investigate whether bloatware inclusion is a viable strategy and how the firm should price its product with bloatware given that consumers can get rid of bloatware from the product after the purchase. We show that it is not always optimal for the firm to sell a bloatware-included product. Even when the firm benefits from bundling its product with bloatware, discouraging every buying customer from jailbreaking by pricing the bloatware-included product strategically is not necessarily in the best interest of the firm. Furthermore, we show that even if the firm can make it harder for consumers to jailbreak, the firm is not always better off by doing so. Surprisingly, consumers do not necessarily benefit from the reduced cost of jailbreaking either. Finally, we show the firm passes part of the bloatware revenue to consumers in the form of a lower product price and, thus, higher revenue from the bloatware leads to a win-win situation for the firm and consumers.

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1. Introduction

The last decade has witnessed an explosive growth in the variety of personal devices in the consumer electronics market. Notable examples include smartphones, tablets, laptops, and wearable gadgets. Consumers of all kinds enjoy various forms of these devices as part of their daily routine. Firms – including manufacturers and service providers – often pre-install software applications (apps in short) onto these devices before consumers purchase them. Such pre-installed apps are highly valuable to firms because they bring additional revenue[1]. Oftentimes firms do not carefully assess the usefulness of these apps for consumers[2]. Hence, consumers consider many pre-installed apps a hindrance rather than an added value. As Time Magazine put it, "Pre-loaded, junky Android apps … keep finding more ways to annoy" (Newman 2014). Consumers refer to such pre-installed yet unrewarding apps on smart phones and other devices as *bloatware*, or sometimes in a more negative tone, *crapware* or *junkware*[3] (Pinola 2012, Newman 2014). Although the sales of PCs have long been subsidized by third-party apps, bloatware is becoming a more pervasive and prevalent issue for consumers in the era of smart phones (McDaniel 2012, McMillan 2015). Today, many handheld devices are loaded with apps that consumers "did not ask for, do not want, and can't get rid of" (McDaniel 2012). Bloatware deteriorates consumer value in several ways. Many bloatware apps occupy precious screen space and clutter app drawers and yet are seldom used by consumers (Dent 2014). Bloatware also takes up storage space and runs in the background often without users' knowledge. In case of Samsung Galaxy S4, one of the best-selling phones in 2013, "unwanted 'bloatware' and system files take up 45% of the handset's internal storage" (Woollaston 2013). Bloatware can also result in excessive battery drain, unnecessary data usage and performance reduction (Triggs 2014). The last, but not the least, bloatware can expose consumers to security and privacy risks (McDaniel 2012).

While forcing products onto consumers (such as through bundling) is a phenomenon observed in a wide range of industries and bloatware inclusion can be viewed as bundling, this paper recognizes a counter-bloatware dynamic that is unique to information technology products: *consumer-initiated*

[1] For example, third-party software companies typically pay between $2 to $10 per installation to personal computer manufacturers, bringing up to $30 additional revenue from each computer (Richtel 2008).

[2] http://www.howtogeek.com/163303/how-computer-manufacturers-are-paid-to-make-your-laptop-worse/

[3] Not all pre-installed apps are categorized as bloatware. Bloatware refers to unwanted apps only. Hence, programs, which are perceived to be valuable by users, like Adobe Reader, are not considered as bloatware.

modification of product's software with the purpose of removing bloatware, as commonly referred to as *jailbreaking* or *rooting* in popular press (Dachis 2011, Cogen 2013). Broadly speaking, jailbreaking refers to actions taken by consumers to override the software constraints imposed by firms (often by gaining root-level access to an operating system), so that consumers can have control over what apps to have on their devices. In this research, we focus on jailbreaking by consumers (Cogen 2013), and use the terms *jailbreaking* and *bloatware-removal* interchangeably.

Jailbreaking helps consumers avoid the aforementioned detriments of bloatware, thus can result in better consumer value. Yet, device manufacturers and service providers are often on the losing end of jailbreaking: bloatware suppliers would be discouraged to pay for pre-installation of their apps if there was a large-scale removal of bloatware by customers (Yegulalp 2012). As a result, firms would not be able to earn critical revenue from bloatware suppliers. Bloatware removal is a serious threat to device manufacturers where the economics of business is characterized as "precarious" (Richtel 2008). In markets with shrinking margins like in smart phone and PC markets, the extra revenue from bloatware often makes a difference between profit and loss (McDaniel 2012, Spence 2015), thereby putting even more pressure on manufacturers to rely on ancillary means to extract revenue. While there exists rich information on the technology side of jailbreaking, little research exists that explores the economic consequences of bloatware removal on the firm strategy. Understanding the implications of prevalent bloatware removal practices by consumers is a matter of utmost importance for firms that are bundling or considering bundling bloatware onto their product. Therefore, as our first research question, we study *how consumer-initiated jailbreaking affects a firm's bloatware inclusion and product pricing strategies*.

Because a direct economic consequence of jailbreaking is the loss of bloatware revenue for the firm, intuitively a higher cost of jailbreaking for consumers is seemingly beneficial for firms that implement a bloatware strategy. Anecdotal evidence in practice, nevertheless, does not paint a consistent picture. Some firms in the smartphone industry adopt measures that artificially increase the technical difficulty of bloatware removal. For example, in the recent releases of the popular Galaxy S series, Samsung famously designated most of its pre-installed apps as non-removable (Limer 2015). Verizon further encrypted *bootloader*, a low-level software program that loads the operating system, on many phones it carries, thereby significantly increased the difficulty of rooting (Whitwam 2012). Some other firms, however, appeared more lenient (or even accommodative) to jailbreaking. HTC is publically committed to unlocked bootloader for its recent phones.[4] The Nexus series phones and tablets, designed by Google and manufactured by various firms, often either directly offer root access to consumers, or require only simple

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[4] http://www.htcdev.com/bootloader

steps for jailbreaking.[5] In light of inconsistent practices by firms adopting a bloatware strategy, it becomes crucial to study the relationship between difficulty in jailbreaking and firm profits. Thus, our second research question asks *whether a firm that adopts a bloatware strategy benefits from an increased cost of jailbreaking for consumers.*

Consumers also have an influence on the cost of jailbreaking. In practice, consumers with technical expertise are likely to discover various methods of jailbreaking. These methods are frequently shared in forums or social media such as XDA Developers and YouTube and further simplified by consumers. There are also service companies, like Best Buy Geek Squad, that can help consumers eliminate bloatware from their personal computers for a fee (Richtel 2008). Given consumer resentment at bloatware, it is understandable that consumer effort and market solutions are geared toward reducing jailbreaking costs. Nevertheless, given the strategic actions of the firm that is aware of jailbreaking and has a pricing lever, *is it true that a lower cost of jailbreaking always results in a higher consumer surplus?* This is our third research question.

While more revenue from bloatware is intuitively desirable for the firm, it is less clear whether consumers actually benefit from an increase in bloatware revenue in the form of a reduced product price and/or purchase of the product by more consumers. Hence, the implication of more revenue for the firm from the bloatware on consumer surplus deserves further investigation. Thus, as our last question, we, ask *which stakeholder (firm or consumers) benefits from higher bloatware revenue* and *whether there can be a win-win situation.*

We develop a game-theoretical model to study the four research questions mentioned above. We first analyze a case, called the *baseline case*, in which the firm sells a bloatware-free product. We next consider a case, called the *bloatware case*, where the firm sells a bloatware-included product. Comparing the findings in these two cases, we seek answers to our research questions. Regarding the firm's bloatware inclusion decision, we find that adding bloatware and selling a product with bloatware can be *worse* than selling a bloatware-free product. Hence, it is *not* always in the best interest of the firm to use the bloatware strategy. Specifically, the firm is better off with bloatware if the revenue that the firm generates from bloatware is *large enough*, irrespective of the magnitude of the bloatware removal cost. Although jailbreaking can put downward pressure on the price of the bloatware-included product, the firm earns more profit than the baseline case because the firm not only makes money from product sales but also significant money from bloatware. However, for low values of bloatware revenue, the firm is better off with bloatware *only if* the cost of bloatware removal is either sufficiently low or sufficiently high. When the removal cost is low enough, the firm capitalizes on both a larger market and higher revenue

[5] http://unrevoked.com/rootwiki/doku.php/public/root_friendly

(product price plus bloatware revenue) from each product sold. When the removal cost is high enough, a greater demand from a lower product price more than compensates the drop in revenue per product.

Regarding the impact of bloatware removal cost on the firm's profit, we find that even if a firm is able to make it harder for consumers to jailbreak the product, surprisingly, it is *not* always in the interest of the firm to do so. In particular, we show that the firm actually benefits from lowering the cost of jailbreaking when this cost is relatively low. Intuitively, a reduction in jailbreaking cost increases the willingness-to-pay of consumers who jailbreak, which in turn allows the firm to strategically raise the price. Furthermore, the reduction in jailbreaking cost also increases the market demand. Consequently, the firm earns more profit.

We next investigated the relationship between the cost of jailbreaking and consumer surplus. Since a reduction in the cost of jailbreaking can have a *direct effect* of lowering a consumer's total cost of ownership, this reduction would seemingly benefit consumer surplus. Our analysis, nevertheless, shows that a reduction in jailbreaking cost may also have a *strategic effect* of increasing the firm's equilibrium price. We further show conditions under which the strategic effect dominates the direct effect, and consequently a reduction in jailbreaking cost surprisingly hurts consumer surplus. This finding contributes to the literature in IS research by showing, from the consumer surplus perspective, the strategic detriments of a lowered jailbreaking cost can dominate the direct cost savings it generates.

We finally considered the impact of bloatware revenue on the firm profit and consumer surplus. Interestingly, our analysis reveals that higher bloatware revenue benefits both the firm and consumers: it benefits the former because bloatware directly brings additional revenue, and it benefits the latter because the firm passes part of this revenue to the consumers in order to serve to a larger market.

The rest of the paper proceeds as follows. We briefly review the relevant literature in Section 2. We present our model and solve for the equilibrium in Section 3. In Sections 4 and 5 we analyze the impact of the cost of jailbreaking, then the bloatware revenue, on the firm and consumers. In Section 6 we conclude the paper with a discussion of implications and future research directions.

2. Literature Review

Our paper adds to the literature on pricing of information goods. Research in this literature addresses a diverse set of topics including congestion pricing (Dewan and Mendelson 1990, Westland 1992, Gupta et al. 1997), usage-based pricing versus fixed pricing (Sundararajan 2004, Masuda and Whang 2006), horizontal product differentiation (Dewan et al. 2003, Choudhary 2009), and vertical product differentiation (Choudhary et al. 2005, Bhargava and Choudhary 2008). Our paper is closely related to the research stream on vertical product differentiation. In this stream, Choudhary et al. (2005) consider the competition between firms of heterogeneous qualities, and find that personalized pricing can lower the profit of the higher-quality firm. Bhargava and Choudhary (2008) study versioning – one firm offering multiple quality levels to consumers – and find the conditions for versioning to be optimal for a firm under a setup more general than the often-used setup where each consumer has a constant marginal valuation of quality. While we also look at the quality dimension in this research, our paper differs from the prior work in that we study *jailbreaking*, i.e., consumer-initiated product modification, through which consumers can remove bloatware and thus improve product quality. To our knowledge, this is the first paper that studies the impact of consumer-side product quality modification on the provisioning and pricing of IT products.

Bloatware differs from most information goods in that it *negatively* affects consumer value. As a result, a firm's action of including bloatware into its product reduces its product quality. In this regard, our paper is related to the literature on damaged goods. The seminal work by Deneckere and McAfee (1996) shows that it can be profitable for a firm to intentionally reduce the quality of some of its products even if such reduction does not bring any cost savings (or even leads to more wasteful costs). Further, they show that consumers can also benefit. Hahn (2006) extends the analysis to the case of durable products. Anderson and Dana (2009) further extend the model to a generalized price discrimination setup. Our paper differs from this stream of research in that bloatware, while damaging to consumer value, directly benefits the firm. Consumers in our paper can also remove the bloatware and hence reverse the damage imposed by the firm through jailbreaking, which is not considered in prior work.

Including bloatware in the product is a form of bundling in that consumers have to buy the hardware device and the pre-installed bloatware together. There is a rich literature on monopolistic bundling in business and economics research (Adams and Yellen 1976, Schamelensee 1984, Geng et al. 2005, Basu and Vitharana 2009, Prasad et al. 2010, Bhargava 2012). To isolate the strategic effects of jailbreaking on firm strategy and consumer surplus, in this paper we consider a scenario where the ranking of consumer valuation of the product is consistent with or without the bloatware. As a result, in this paper the profitability of the firm that adopts a bloatware strategy cannot be explained by the stylized bundling argument that bundling decreases heterogeneity among consumers in valuation and thus allows more effective surplus extraction by the firm (Geng et al. 2006).

3. Models and Analyses

In our model, a monopolistic firm that sells a particular product with software and hardware components decides whether to adopt a bloatware inclusion strategy (i.e., whether to include bloatware apps in its product or not) in the face of a threat of jailbreaking by consumers. By bloatware, we refer to software apps that their inclusion reduces consumer valuation of the product.[6] Since bloatware reduces consumer value, we treat bloatware inclusion as a quality reduction from the consumer perspective. Consumers are heterogeneous in their sensitivity to quality, where $\theta \sim U[0,1]$ represents the valuation type of a customer. Each customer decides whether to purchase the product or not. If the product comes with bloatware apps, the customer also decides whether to jailbreak the product or not by trading off the cost of bloatware removal against the disutility of using the product with bloatware.

3.1. Baseline Case: No Bloatware

We first analyze a case where the firm sells its product without including any bloatware. In this scenario, the firm knows that a customer of θ type earns a utility of $\theta U - p_{base}$ if the customer purchases the product, where U captures the maximum utility and p_{base} denotes the price of the bloatware-free product. Hence, only customers with $\theta > \frac{p_{base}}{U}$ purchase the product. Knowing that, the firm maximizes the following profit expression in which c represents the marginal cost of production.

$$\Pi_{base} = (1 - \frac{p_{base}}{U})(p_{base} - c) \tag{1}$$

Solving the profit expression for the price gives the equilibrium price presented in Lemma 1.

Lemma 1: *When the firm sells a bloatware-free product, it charges the equilibrium price of* $p^*_{base} = \frac{U+c}{2}$.

It is easy to see that the firm charges a monopolistic price to extract the largest surplus from customers. Using the equilibrium price, we can calculate the firm's optimum profit as follows:

$$\Pi^*_{base} = \frac{(U-c)^2}{4U} \tag{2}$$

3.2. Bloatware Case

In this scenario, the firm sells its product with bloatware. From the customer perspective, the product with bloatware is inferior in quality to product without bloatware. A customer who purchases the bloatware-included product gains a utility of $\theta(U-V) - p_{bl}$, where p_{bl} indicates the price of the bloatware-included

[6] Not all pre-installed apps are regarded as bloatware. We also acknowledge that consumers may differ in their views on what constitutes bloatware. In this paper, we focus on the scenario where consumer opinions are homogeneous regarding bloatware.

product and V denotes the reduction in consumer utility due to bloatware. It is clear from the formulation that a customer who values the product more also incurs more disutility from the bloatware. This is reasonable because a customer who either uses a larger set of functions of the product and/or uses the product more frequently is expected to experience more inconvenience from the bloatware[7]. In addition to degradation of performance and annoyance (Keane 2015), the disutility also accounts for potential damages from security and privacy risks[8]. However, different from the baseline case, a customer has now an ability to remove the bloatware after the purchase. If that is the case, the customer earns a utility of $\theta U - p_{bl} - e$, where e is the cost of effort to remove the bloatware[9]. We assume that the removal cost is same across all types of customers[10]. Therefore, a prospective customer decides on whether to purchase the product, and whether to keep or remove the bloatware, if purchased. For a given price, we present the best response of customers in the following corollary.

Corollary 1: *When* $p_{bl} < \frac{e(U-V)}{V}$, *(i) customers with valuation* $\theta \in (\frac{e}{V}, 1]$ *buy the product and remove its bloatware, (ii) customers with valuation* $\theta \in (\frac{p_{bl}}{U-V}, \frac{e}{V}]$ *buy the product and keep its bloatware. Other customers do not buy the product. When* $p_{bl} \geq \frac{e(U-V)}{V}$ *(iii) customers with valuation* $\theta \in (\frac{p_{bl}+e}{U}, 1]$ *buy the product and remove its bloatware. Other customers do not buy the product.*

Removing the bloatware after purchasing the product is a viable option only for customers with high valuation. These customers suffer the most from the bloatware, and therefore, they are willing to incur the removal cost to increase the utility from their purchase. On the contrary, customers with low valuation are affected less negatively by bloatware and they are fine with purchasing the product and using it with

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[7] Modeling constant disutility for each type of customer results in a trivial case: Every customer either removes the bloatware or keeps it depending on the magnitudes of removal cost and disutility, irrespective of the type of customer.

[8] For instance, preloaded software named Superfish in Lenova laptops revealed consumers' confidential communications including passwords and financial transactions to attackers (Rosenblatt 2015). Devices on the Android platform are vulnerable to privacy violations (McDaniel 2012).

[9] In addition to do-it-yourself tutorials available online, consumers can use paid services, like the Best Buy optimization service from the Geek Squad, to get rid of unwanted software cluttering their computers for a fee of $30 (Richtel 2008). Consumers can also use tools like 'PC Decrapifier' to scan and remove bloatware from their computers (Keane 2015).

[10] The removal cost may also depend on the technical savviness of the customer. It is possible that highly technical customers can remove the bloatware by themselves and therefore incur a lower cost than non-technical customers, who may have to get an outside help to do the same thing. Modeling two types of users in terms of technical skills does not change the qualitative nature of results but complicates the analyses.

bloatware as long as it is not priced high so that they have a positive utility. Hence, there can be two groups of buyers in equilibrium. If the firm charges a lower price, while users with higher valuation buy the product and remove the bloatware, users with lower valuation buy the product and keep the bloatware. However, when the firm charges a higher price, all users who purchase the product choose to remove the bloatware.

We assume that the firm earns additional revenue of σ if the bloatware is not removed, and $\beta\sigma$ if the bloatware is removed, where $\beta < 1$. We call σ as (full) bloatware revenue and $\beta\sigma$ as partial bloatware revenue. This is a reasonable assumption given that some bloatware suppliers (like those with utility apps) pay an upfront fixed fee for inclusion of their apps while some other suppliers (like those with trialware) have a revenue sharing deal with manufacturers if the user upgrades[11]. Hence, we can argue that the manufacturer makes money from bloatware regardless of whether a consumer removes it after purchase. The manufacturer makes more money, on average, from each user who does not remove the bloatware. We also make three technical assumptions: (i) $e < V$, otherwise no one prefers to remove the bloatware at any price, and (ii) $c < U - V$, otherwise no one buys the product and keeps the bloatware even if the product is offered at the marginal cost *c*, (iii) $\sigma < U - V + c \equiv \sigma_{\max}$, otherwise giving away the bloatware-included product free is possible.

Knowing how customers will respond to a price, we can write the firm's profit function as follows:

$$\Pi_{bl} = \begin{cases} (1-\frac{e}{V})(p_{bl}+\beta\sigma-c)+(\frac{e}{V}-\frac{p_{bl}}{U-V})(p_{bl}+\sigma-c) & \text{if} \quad p_{bl} < \frac{e(U-V)}{V} \\ (1-\frac{p_{bl}+e}{U})(p_{bl}+\beta\sigma-c) & \text{if} \quad p_{bl} \geq \frac{e(U-V)}{V} \end{cases} \tag{3}$$

The firm maximizes its piecewise concave profit function with respect to price. The next lemma shows the pricing equilibrium in the bloatware case.

Lemma 2: *When the firm sells its product with bloatware, it charges the equilibrium price of*

$$p_{bl}^{*} = \begin{cases} p_{bl}^{1} \equiv \frac{U+c}{2} - \frac{V}{2} - \frac{\sigma}{2} & \text{if } \Omega(\sigma) < e < V \\ p_{bl}^{2} \equiv \frac{U+c}{2} - \frac{e}{2} - \frac{\beta\sigma}{2} & \text{if } e \leq \Omega(\sigma) \end{cases}$$

[11] Reason Software, a firm specializing in removing pre-installed yet unwanted programs, states that "PC manufacturers (and other OEMs) are paid by trialware creators and receive a portion of the revenue from any user upgrades" (see http://www.shouldiremoveit.com/oems-bloatware.aspx).

where $\Omega(\sigma) \equiv (V+(1-\beta)\sigma)\sqrt{\frac{U}{U-V}} - (U + \frac{2(1-\beta)\sigma U}{V} + \beta\sigma - c)(\sqrt{\frac{U}{U-V}} - 1)$.

As can be seen from the lemma, there are two types of pricing equilibriums: p_{bl}^{1} and p_{bl}^{2}, where $p_{bl}^{1} < p_{bl}^{2}$. The former equilibrium price leads to two segments of buyers (i.e. those removing the bloatware and those who do not) while the latter results in one segment of buyers (i.e., every purchasing customer removes the bloatware). We can explain the equilibrium pricing decision of the firm by considering bloatware removal cost a customer incurs and bloatware revenue the firm generates. When the bloatware revenue is low and the cost of removing bloatware is cheap, the firm prefers to serve to higher valuations customers only (i.e., customers who would buy and remove the bloatware) by charging a higher price. This can be explained as follows. When the bloatware revenue is small, the difference between full bloatware revenue and partial bloatware revenue (due to removed bloatware) is also small. Hence, the firm does not forgo too much revenue by pushing lower valuation customers out of market. Since the removal cost is not significant, customers who purchase the product also prefer to remove the bloatware. However, the firm extracts more surplus by charging a price premium because of higher willingness-to-pay of these customers. Therefore, the firm sells its product to the higher valuation segment only by setting a higher price. On the contrary, when the bloatware revenue is high and removing bloatware is expensive, the firm's ability to extract surplus from high valuation customers by charging more is limited. At the same time, the firm gives up significant revenue from low valuation customers by charging more because these customers prefer not to purchase the product if its price is high. This is a big loss when bloatware revenue is high. Therefore, the firm sets a lower price, not only to enable customers in the high valuation segment to purchase the product and remove its bloatware, but also to allow customers in the low valuation segment to buy the product and use it with bloatware. When bloatware revenue is large (small) and removing bloatware is cheap (expensive), the firm's pricing decision is driven by whether the firm is better off with more revenue from product sales and less revenue from bloatware or less revenue from product sales and more revenue from bloatware. These tensions determine the equilibrium price and outcome.

We can observe from Lemma 2 that, compared to the baseline case, the firm charges a lower price in equilibrium when the product includes bloatware (i.e., $p_{bl}^{*} < p_{base}^{*}$). This is because the firm can earn additional revenue from bloatware, and therefore, charging as much for the product itself is not needed.

It is useful to see how the equilibrium price changes with model parameters. We report the comparative statics of the equilibrium price in the bloatware case in Table 1.

Table 1. Comparative Statics

$\frac{\partial \text{column}}{\partial \text{row}}$	$p_{bl}^{*} = p_{bl}^{1}$	$p_{bl}^{*} = p_{bl}^{2}$
β	0	-
e	0	-
V	-	0
σ	-	-

We can explain the comparative statics considering the customer who is indifferent between purchasing the product and not purchasing it. When we look at the price from the indifferent customer's perspective, we can see that the firm adjusts the baseline equilibrium price that it would have charged if there had not been any bloatware in the product (first terms in the price expressions in Lemma 2) considering the inconvenience that the indifferent customer incurs due to the purchase of the product with bloatware, which is disutility from bloatware if not removed or the bloatware removal cost if removed (second terms in the price expressions in Lemma 2) and the bloatware revenue that the firm generates from the indifferent customer (third terms in the price expressions in Lemma 2). When the firm prefers to serve to both the low and high valuation segments, the indifferent customer chooses not to remove the bloatware. Hence, he incurs a disutility $\underline{\theta}V$ where $\underline{\theta}$ is the quality sensitivity of the indifferent customer and the firm, in turn, generates a revenue of σ from the bloatware. However, when the firm chooses to serve only to the high valuation segment, the indifferent customer chooses to remove the bloatware. Hence, he incurs a removal cost of e and the firm, in turn, generates a revenue of $\beta\sigma$ from the bloatware. Essentially, the firm is sharing a portion of both (i) the inconvenience of the indifferent customer and (ii) the bloatware revenue from the product sold to the indifferent customer, with the indifferent customer. As a result, an increase in the inconvenience to the indifferent customer and/or in the bloatware revenue that the firm generates reduces the equilibrium price.

To summarize, when the firm serves to the high valuation only segment (high and low valuation segments), the bloatware removal cost (disutility from the bloatware) is negatively correlated with the firm's ability to earn price premium from customers. If the removal cost (disutility from the bloatware) is low, the firm can charge a higher price due to a higher willingness-to-pay of customers. If the removal cost (disutility from the bloatware) is high, the firm cannot afford to price its product high because of a lower willingness-to-pay of customers as they have to incur high removal cost to get rid of the bloatware (high disutility while using the product with bloatware) and, subsequently, the price premium decreases with the removal cost (disutility from the bloatware).

After finding the equilibrium price of the product in the bloatware case as well as in the baseline case, we want to see if the firm prefers selling the product with bloatware or without bloatware. We answer this question by comparing the equilibrium profits in both cases.

Proposition 1:

(i) The firm makes more profit with bloatware unless

$$\beta\sigma < e < \Psi(\sigma) \text{ , where } \Psi(\sigma) \equiv \frac{V\left(U\left(V\left(U-V\right)+2\left(U-V\right)\left(1-2\beta\right)\sigma-\sigma^2\right)+2cU\sigma-c^2V\right)}{4U\left(U-V\right)\left(1-\beta\right)\sigma}.$$

(ii) If $\beta > \frac{(U+c)(U-\sqrt{U(U-V)})}{2U(U-V+c)}$, *there exists a* $\sigma_s \in (0,\sigma_{\max})$ *such that the firm always makes more profit with bloatware whenever* $\sigma > \sigma_s$.

Proposition 1(i) indicates that including bloatware in the product can result in a profit lower than the baseline profit. Hence, it is not always optimal for the firm to add bloatware to its product offering. We can show that while the lower bound of the condition on *e* is increasing in σ, the upper bound of the condition on *e* is decreasing in σ. Hence, assuming that β is larger than a threshold value, there exists a $\sigma_s < \sigma_{\max}$ such that the condition in the proposition 1(i) is never satisfied. That is, the firm is always better off with bloatware so long as the bloatware revenue is large enough (i.e., $\sigma > \sigma_s$) irrespective of the magnitude of the removal cost. This finding can be explained as follows. When bloatware is a significant source of revenue even after removal, for low values of the removal cost, the firm charges a high price and sells its product to the high valuation segment only. For high values of the removal cost, the firm sells its product to both segments by charging a lower price. In either equilibrium outcome, the firm earns more than the baseline case because the firm not only makes money from product sales but also significant money from bloatware. The revenue in the baseline case is limited to product sales only.

We can observe that, for low values of bloatware revenue (i.e., $\sigma \le \sigma_s$), the firm is better off with bloatware only if the cost of jailbreaking is either very low or very high. This result is quite interesting. Why does the firm benefit from bloatware unless the removal cost is in the medium range? The intuition behind this seemingly unintuitive result is the following. When the removal cost is low, every purchasing customer prefers to remove the bloatware. The firm charges a price lower than the baseline price, but not much lower because of the higher willingness-to-pay of customers. A lower price also results in more demand for the product as more customers find it worthwhile to pay for the product and incur some cost to remove its bloatware. As a result, the firm not only appeals to a larger market, but also earns more revenue (sales+bloatware) from each product sold, compared to the baseline case. However, as the removal cost increases, the firm has to reduce the price to make it possible for high valuation customers to still buy the product and remove its bloatware (i.e., $\partial p_{bl}^{2} / \partial e < 0$). Yet, reducing the price in response to the increasing cost of bloatware removal also reduces the demand as well as the revenue from sales. After the cost of jailbreaking exceeds a threshold ($e > \beta\sigma$), the firm starts serving to not only a smaller market but also earning less revenue (sales+bloatware) from each product sold, relative to the baseline case. Further increase in the removal cost subsequently causes the firm to change its strategy from serving to the high valuation segment only to serving to both high and low valuation segments by offering an even lower price. In this equilibrium, while customers in the low valuation segment choose to keep the bloatware, customers in the high valuation segment prefer to remove the bloatware. The firm continues to be worse off with an increase in bloatware removal cost even though it now serves both high and low valuation segments. Further increase in the cost of jailbreaking changes neither the overall demand nor the equilibrium price. Yet, an increase in the cost of jailbreaking increases (decreases) the fraction of customers who chooses to keep (remove) the bloatware. However, once the removal cost gets high enough (i.e., $e > \Psi(\sigma)$), the bloatware case again starts performing better than the baseline case because customers who keep the bloatware bring more bloatware revenue (compared to customers who prefer to remove the bloatware) and an increase in the fraction of those customers results in higher total revenue from bloatware. Higher total revenue from bloatware, in turn, compensates the reduction in sales revenue.

Proposition 1 indicates that the firm may not prefer selling the product with bloatware. Lemma 2 reveals that if bloatware is to be included in the product, there are two kinds of equilibriums depending on the types of customer segments the firm prefers to sell. By integrating Proposition 1 with Lemma 2, we can characterize the optimal strategy of the firm as follows:

Corollary 2:

*(i) When $\beta\sigma < e < \Psi(\sigma)$, the firm adopts the **bloatware-free strategy**.*

*(ii) When $\max\{\Psi(\sigma), \Omega(\sigma)\} < e < V$, the firm adopts the bloatware strategy that targets both high valuation customers and low valuation customers (hereafter, **high-and-low bloatware strategy**).*

*(iii) When $e \leq \min\{\beta\sigma, \Omega(\sigma)\}$, the firm adopts the bloatware strategy that targets high valuation customers only (hereafter, **high-only bloatware strategy**).*

Corollary 2 indicates that the firm's optimal strategy can be of three types. The parameter space over which each strategy becomes optimal is depicted in Figure 1. The bloatware-free strategy refers to the case where the firm does not include any bloatware in the product. When bundling the product with bloatware is more profitable than selling a bloatware-free product, the firm's optimal strategy is either high-and-low bloatware strategy or high-only bloatware strategy. When the condition (ii) in the corollary holds, the firm charges a lower price (i.e., p_{bl}^{1}) for its product to attract low valuation customers who will use the product without removing its bloatware. The high valuation customers will remove the bloatware by incurring an additional cost. Therefore, the firm caters to both segments of customers. When the condition (iii) in the corollary holds, the firm charges a higher price (i.e., p_{bl}^{2}) for its product. The low valuation customers will not afford to buy the product at this price. Only high valuation customers will afford the product. And those customers will remove the bloatware.

4. The Impact of the Cost of Jailbreaking on the Firm and Consumers

In this section, we assess the effect of a change in the bloatware removal cost on the firm and consumers. Specially, we quantify the impact of the jailbreaking cost on (i) the firm's bottom line and (ii) consumer surplus.

4.1. On the Relationship between the Cost of Jailbreaking and Firm Profit

While we treat the cost of jailbreaking, e, as an exogenous parameter in our model, in practice firms often have some influence – either technological or economic – over the magnitude of this cost. For example, some leading smart phone manufacturers such as Apple and Samsung do not offer customers root access to their devices, which is a striking departure from the common practice in the PC industry where consumers always have root access. As a result, it is harder, for consumers to remove bloatware from root-locked smart phones than from PCs. Furthermore, some manufacturers even void their product warranties once the firmware in the product is tampered with (which is often necessary for jailbreaking). Hence, firms are using a variety of mechanisms to increase the cost of jailbreaking, and thereby to deter bloatware removal. Is it true that firms are always better off with a higher cost of jailbreaking? In this subsection we seek answer to this question.

From Lemma 2, we know that the firm's optimal profit under the high-and-low bloatware strategy (i.e., when $\max\{\Psi(\sigma),\Omega(\sigma)\} < e < V$), is

$$\Pi_{bl}^{1} = \frac{V(U-V-c)^2 + V\sigma^2 - 2(cV + (U-V)(V-2e(1-\beta)-2\beta V))\sigma}{4V(U-V)},$$

and under the high-only bloatware strategy (i.e., when $e \leq \min\{\beta\sigma,\Omega(\sigma)\}$), is

$$\Pi_{bl}^{2} = \frac{(U+\beta\sigma-c-e)^{2}}{4U}.$$

By considering the behavior of the equilibrium profit expressions with respect to *e*, we characterize the impact of the removal cost on the firm's bottom line in the next proposition.

Proposition 2: *Assuming that bloatware is profitable for the firm (i.e., $e<\beta\sigma$ or $e>\Psi(\sigma)$), then,*

i) The firm profit decreases in the jailbreaking cost e if $e<\Omega(\sigma)$.

ii) The firm profit increases in the jailbreaking cost e if $e>\Omega(\sigma)$.

Proposition 2(i) shows that, surprisingly, the firm can indeed benefit from a reduction in the cost of jailbreaking as long as the removal cost is not too high (i.e., bounded above by $\min\{\beta\sigma,\Omega(\sigma)\}$). To see the intuition, recall that when $e\le\min\{\beta\sigma,\Omega(\sigma)\}$, the firm adopts the high-only bloatware strategy in which all of the purchasing consumers jailbreak. Under this strategy, the profit margin for the firm is $p_{bl}^{2}+\beta\sigma-c=(U-c-e+\beta\sigma)/2$ and the demand is $1-(p_{bl}^{2}+e)/U=(U-c-e+\beta\sigma)/(2U)$, both are decreasing in *e*. Intuitively, a reduction in *e* improves the profit margin because the reduction increases the willingness-to-pay of consumers who jailbreak, which enables the firm to charge a higher price for its product. Furthermore, the reduction in *e* also expands the market demand under the firm's equilibrium price. Consequently, the firm benefits from the reduction. In other words, while a lower cost of jailbreaking directly benefits consumer welfare, the firm is able to extract part of this welfare gain by strategically increasing price and expanding its demand.

When the removal cost is already high (i.e., higher than $\max\{\Psi(\sigma),\Omega(\sigma)\}$), nevertheless, Proposition 2(ii) shows that the firm is hurt by a reduction in the cost of jailbreaking. Recall that in this case the firm adopts the high-and-low bloatware strategy where only a proportion of the purchasing consumers jailbreak. Now a lower jailbreaking cost starts causing more purchasing consumers to jailbreak, resulting in a bloatware revenue loss of $(1-\beta)\sigma$ from each such consumer. At the same time, a lower jailbreaking cost neither increases the equilibrium price nor expands the market because the price is independent of the jailbreaking cost (refer to Table 1). Thus a reduction in jailbreaking cost hurts the firm profit.

Overall, the increase in the cost of jailbreaking does not necessarily improve the firm's profit, as one would expect. Hence, firms adopting a bloatware strategy should carefully assess implication of their decision before making the removal of bloatware increasingly difficult.

4.2. On the Relationship between the Cost of Jailbreaking and Consumer Surplus

We now shift our attention to the relationship between the cost of jailbreaking and consumer surplus. While we treat the cost of jailbreaking e as an exogenous parameter in our model, like the firm, consumers collectively also have some influence over the jailbreaking cost. Popular jailbreaking/rooting tools and methods are often initiated at the consumer end of the market (either by tech-savvy individuals or by third-party businesses such as CyanogenMod[12] that are more aligned with consumer interests than with manufacturer interests). A common objective of these tools is to ease the effort consumers exert in removing bloatware – in other words, to reduce the jailbreaking cost. However, does a reduction in jailbreaking cost always result in a higher consumer surplus? We answer this question in this subsection.

We first need to calculate consumer surplus under each of the firm's three possible optimal strategies. Under the bloatware-free strategy, from Lemma 1, consumer surplus can be calculated as:

$$CS_{base}^{*} = \int_{(U+c)/2U}^{1} (\theta U - \frac{c+U}{2})\, d\theta = \frac{(U-c)^2}{8U}.$$

Under the high-and-low bloatware strategy, from Lemma 2, consumer surplus is

$$CS_{bl}^{1} = \int_{p_{bl}^{1}/(U-V)}^{e/V} (\theta(U-V) - p_{bl}^{1}) d\theta + \int_{e/V}^{1} (\theta U - p_{bl}^{1} - e) d\theta$$

$$= \frac{c^2 V + (U-V)(4e^2 - 8eV + V(U+3V-2c)) + 2V(U-V-c)\sigma + \sigma^2 V}{8(U-V)V}.$$

Under the high-only bloatware strategy, from Lemma 2, consumer surplus is

$$CS_{bl}^{2} = \int_{(p_{bl}^{2}+e)/U}^{1} (\theta U - p_{bl}^{2} - e) d\theta = \frac{(U+\beta\sigma - c - e)^2}{8U}.$$

To facilitate the discussion, hereafter we differentiate between two types of reductions in jailbreaking cost. If a reduction does not change the firm's pricing strategy, we call it a *within-strategy reduction* in jailbreaking cost. For example, given σ and suppose that the jailbreaking cost is reduced from e_1 to e_2 where $e_1 > e_2$, if both $e_1 > \max\{\Psi(\sigma), \Omega(\sigma)\}$ and $e_2 > \max\{\Psi(\sigma), \Omega(\sigma)\}$, then this is a within-strategy reduction because both values of e are in the same parameter space corresponding to the same equilibrium strategy (that is the high-and-low bloatware strategy). If a reduction changes the firm's pricing strategy, we call it a *cross-strategy reduction* in jailbreaking cost. Continuing the above example,

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[12] http://www.cyanogenmod.org/about.

if $e_1 > \max\{\Psi(\sigma), \Omega(\sigma)\}$ but $\beta\sigma < e_2 < \Psi(\sigma)$, this is a cross-strategy reduction because the firm adopts the high-and-low bloatware strategy under e_1 but adopts the bloatware-free strategy under e_2.

We first consider a within-strategy reduction in the cost of jailbreaking. The following position characterizes the impact of such a reduction on consumer surplus.

Proposition 3: *Assuming that bloatware is profitable for the firm (i.e., $e < \beta\sigma$ or $e > \Psi(\sigma)$), a within-strategy reduction in the jailbreaking cost always increases the consumer surplus.*

Proposition 3 is consistent with anecdotal evidence that consumers seem to favor reduction in the removal cost. We next explain the intuition under each bloatware strategy. Under the high-and-low bloatware strategy, because the firm's price is independent of jailbreaking cost, a reduction in removal cost strictly benefits consumers who remove the bloatware and does not affect consumers who keep the bloatware. Under the high-only bloatware strategy where all purchasing consumers remove the bloatware, the savings consumers gain from the reduction in jailbreaking cost dominates the increase in the firm's equilibrium price. Therefore, a within-strategy reduction in jailbreaking cost is always beneficial to consumers. We did not discuss the bloatware-free strategy in Proposition 3. Since the cost of jailbreaking is irrelevant to consumer surplus, a within-strategy reduction in jailbreaking cost does not affect consumer surplus under the bloatware-free strategy.

One key insight from our results in Lemma 2 and Proposition 1 is that jailbreaking cost affects not only the firm's equilibrium price, but also its choice of strategy regarding bloatware (i.e., include or exclude bloatware, target high valuation consumers only or target both high and low valuation consumers). The firm's choice of strategy, in turn, affects the consumer surplus. We next consider a cross-strategy reduction in the cost of jailbreaking, where the firm's choice of pricing strategy turns out to play a critical role in determining the consumer surplus.

Note that there are only two possible scenarios for a cross-strategy reduction in the cost of jailbreaking when bloatware is included in the product: (i) from the high-and-low bloatware strategy to the bloatware-free strategy or (ii) from the high-and-low bloatware strategy to the high-only bloatware strategy. For each scenario, we compare consumer surplus before and after the reduction in jailbreaking cost, the findings of which are summarized in the next proposition. To simplify the exposition, define $S_2(\sigma; e_1)$ as:

$$S_2(\sigma; e_1) \equiv U + \beta\sigma - c - \frac{\sqrt{U(U-V)V(c^2V + (U-V)(4e_1^2 - 8e_1V + V(U+3V-2c)) + 2V(U-V-c)\sigma + V\sigma^2)}}{V(U-V)}.$$

Proposition 4: *Given σ, consider a cross-strategy reduction in jailbreaking cost from e_1 to e_2 where $e_1 > e_2$.*

i) *If $e_1 > \max\{\Psi(\sigma), \Omega(\sigma)\}$ and $\beta\sigma < e_2 < \Psi(\sigma)$, this cross-strategy reduction in jailbreaking cost always decreases consumer surplus.*

ii) *If $e_1 > \max\{\Psi(\sigma), \Omega(\sigma)\}$ and $e_2 \le \min\{\beta\sigma, \Omega(\sigma)\}$, this cross-strategy reduction in jailbreaking cost decreases consumer surplus if and only if $e_2 > S_2(\sigma; e_1)$.*

Note that when conditions in (i) hold, the firm adopts the high-and-low bloatware strategy under e_1 and the bloatware-free strategy under e_2, as illustrated with the arrow on the left in Figure 1, and when conditions in (ii) hold, the firm adopts the high-and-low bloatware strategy under e_1 and the high-only bloatware strategy under e_2, as illustrated with the arrow on the right in Figure 1. Proposition 4 identifies conditions in which a reduction in the jailbreaking cost surprisingly hurts consumer surplus. To understand the reason, let us first focus on the case in Proposition 4 (i) in which the reduction in jailbreaking cost is significant enough to trigger the firm to switch its pricing strategy from the high-and-low bloatware strategy under e_1 to the bloatware-free strategy under e_2. This switch has both a direct effect and an indirect (strategic) effect. First, the firm's decision of not bundling the bloatware with its product *directly and positively* affects consumer surplus because of the savings on the jailbreaking cost *e* and gains because of the quality improvement V. Second, however, this switch also causes an *indirect and strategic effect* on firm pricing in which the firm responds to the reduction by increasing the product price. Note that under the high-and-low bloatware strategy with e_1, the firm charges an equilibrium price of $p_{bl}^1 = (U + c - V - \sigma)/2$; under the bloatware-free strategy with e_2, the firm equilibrium price is $p_{base}^* = (U + c)/2$. Therefore, by switching from the high-and-low bloatware strategy to bloatware-free strategy, the firm increases its price by an amount of $(V + \sigma)/2$. The increase in price thus *negatively* affects the consumer surplus. Proposition 4 (i) shows that, if the reduction in jailbreaking cost triggers the firm to switch from the high-and-low bloatware strategy to the bloatware-free strategy, the strategic price effect always dominates the direct effect. Consequently, such a reduction always decreases consumer surplus.

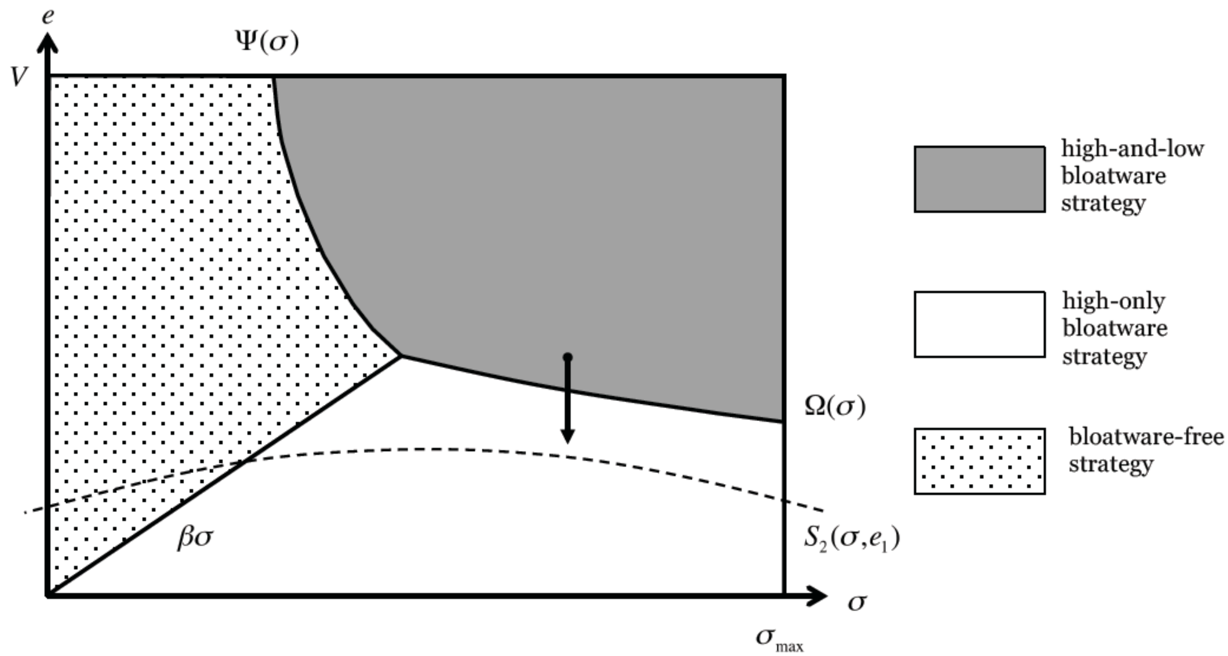

Figure 1. Equilibrium Strategies and Jailbreaking Cost Reduction

To our knowledge, Proposition 4 (i) is the first in IS research that highlights the strategic and negative consequence of lowering the cost of bloatware removal. While existing coverage of jailbreaking tools and methods often focus on their value in easing bloatware removal, this research cautions consumers that a lowered removal cost may trigger a higher product price that can overwhelm any cost savings that consumers enjoy.

In Proposition 4 (i), the reduction in jailbreaking cost triggers the firm to give up bloatware. Nevertheless, given up the bloatware is not a necessary condition for the surprising finding that consumers are not better off as a result of the reduction in bloatware removal cost. In Proposition 4 (ii), we show that a cross-strategy reduction in jailbreaking cost may hurt consumer surplus even if the firm continues to bundle bloatware with its product.

The intuition for Proposition 4 (ii) is best illustrated on curve $\Omega(\sigma)$ in Figure 1, where the firm is indifferent between the high-and-low bloatware strategy and the high-only bloatware strategy. While the firm is indifferent between these two bloatware strategies on curve $\Omega(\sigma)$, it turns out that *consumers face a surplus shock on the two sides of this curve*. To see this, first consider a consumer who purchases and removes the bloatware on curve $\Omega(\sigma)$ under the high-and-low bloatware strategy, where $p_{bl}^1 = (U + c - V - \sigma)/2$ (i.e., a customer with $\theta \in (\frac{e}{V}, 1]$). If the firm switches to the high-only bloatware strategy, the price increases to $p_{bl}^{2}=(U+c-e-\beta\sigma)/2$. Therefore this consumer's surplus decreases by an amount of $(V+(1-\beta)\sigma-e)/2$ on curve $\Omega(\sigma)$. Next consider a purchasing consumer on curve $\Omega(\sigma)$ who does not remove bloatware under the high-and-low bloatware strategy (i.e., a customer with $\theta < e/V$). This customer would either purchase the product or not when the firm switches to the high-only bloatware strategy. If she still purchases, her surplus also decreases (i.e., $[\theta U - p_{bl}^{2} - e] - [\theta(U-V) - p_{bl}^{1}] < 0$). If the consumer quits the market (i.e., $\theta < (U+e+c-\beta\sigma)/(2U)$), this results in an apparent surplus reduction.

It turns out that the surplus shock on curve $\Omega(\sigma)$ is strong enough that, even if $e_1 = V$ (i.e., the lowest consumer surplus case under the high-and-low bloatware strategy), we still have $S_2(\sigma;V) < \Omega(\sigma)$. In other words, even if consumers can enjoy a significant jailbreaking-cost saving of $V-e_2$ for any $e_2 \in (S_2(\sigma;V),\Omega(\sigma))$, this cost saving cannot triumph over the damage done to surplus due to the discrete price jump on curve $\Omega(\sigma)$.

To summarize, Propositions 3 and 4 together show that a reduction in jailbreaking cost does not necessarily benefit consumers. A reduction may hurt consumer surplus when the firm switches from including bloatware to abandoning bloatware, or when the firm sticks with bloatware strategy yet switches from catering to both high and low valuation consumers to catering to high valuation consumers only given that the reduction is not sufficiently large.

5. The Impact of the Bloatware Revenue on the Firm and Consumers

Recall that, from each purchasing consumer, the firm earns full bloatware revenue of σ if the bloatware is not removed, and partial bloatware revenue of $\beta\sigma$ if the bloatware is removed. The latter is possible because the firm can charge the bloatware provider an upfront fee to bundle the bloatware with its product, hence even if the bloatware will not be used by the customers, the firm can still generate some revenue from the bloatware. In this subsection we examine how the firm profit and the consumer surplus change with respect to σ and β.

Proposition 5: *Assuming that bloatware strategy is profitable for the firm (i.e., $e < \beta\sigma$ or $e > \Psi(\sigma)$),*

i). firm profit always increases in σ and β,

ii). consumer surplus always increases in σ,

iii). consumer surplus increases in β if $e \le \Omega(\sigma)$, and is independent of β if $e > \Omega(\sigma)$.

Parts (i) and (ii) of Proposition 5 show a positive impact of bloatware revenue both on the firm profit and, surprisingly, on the consumer surplus. The intuition is best illustrated when the firm adopts the high-only bloatware strategy (i.e., when $e \le \min\{\beta\sigma, \Omega(\sigma)\}$), where two dynamics play key roles. The first dynamic is the direct impact of the bloatware on firm margin: the bloatware, though removed in equilibrium (recall part iii of Corollary 1), directly contributes additional revenue of $\beta\sigma$ to the firm through each purchasing consumer. The second dynamic is the firm's strategic reduction of price in exchange for market expansion: in equilibrium the firm transfers a portion of this partial bloatware revenue, $\beta\sigma/2$, in the form of a reduced price to consumers (recall Lemma 2). Consequently, when σ increases, under the high-only bloatware strategy the firm enjoys a higher margin (due to the first dynamic) and a higher demand (due to the second dynamic), thus the overall firm profit increases. At the same time, the second dynamic (of strategic price cut by the firm in face of a higher bloatware revenue to expand the demand) also explains the increase in consumer surplus.

When the firm adopts the high-and-low bloatware strategy, the above intuition still holds, albeit the average per-consumer revenue contribution from bloatware is between $\beta\sigma$ and σ due to the fact that some purchasing consumers will not remove the bloatware. Still, when σ increases, the firm profit increases due to both a higher average margin and a higher market demand, and consumers benefit from a lower product price. In summary, a key message from parts (i) and (ii) of Proposition 5 is that higher revenue to the firm from the bloatware leads to a *win-win* situation for the firm and consumers.

Part (iii) of Proposition 5 is directly driven by the facts that the equilibrium price is decreasing in β under the high-only bloatware strategy and it is independent of β under the high-and-low bloatware strategy (recall Lemma 2). Intuitively, when e is small enough (i.e., $e < \Omega(\sigma)$), the firm only captures the partial bloatware revenue, $\beta\sigma$, from every purchasing consumer, and it strategically passes half of this revenue, $\beta\sigma/2$, to consumers to induce more sales. The higher β is, the higher this benefit to consumers ($\beta\sigma/2$) is. When e is large enough (i.e., $e > \Omega(\sigma)$), on the other hand, the firm will find it optimal to adopt the high-and-low bloatware strategy, under which the total market size is solely determined by the behavior of consumers who do not remove the bloatware – in other words, the market size is determined by the consumer who is indifferent between purchasing (and not-removing-the-bloatware) and not purchasing. Recall that the additional revenue the bloatware contributes to the firm from the purchasing consumers who do not remove the bloatware is σ rather than $\beta\sigma$. Therefore, the firm's strategic decision on how much margin to pass on to consumers is affected by σ but not by β. Consequently β does not affect consumer surplus if $e > \Omega(\sigma)$.

6. Conclusion

Whether to include bloatware in products is a crucial question to answer for many firms in the consumer electronics market. Some firms sell bloatware-included products while others sell bloatware-free products. From the vantage point of a monopolistic firm, this paper investigates bloatware inclusion and pricing strategies of the firm. Motivated by an increasing phenomenon of jailbreaking of electronic devices to remove unwanted applications bundled with the devices, our game-theoretic model incorporates the ability of consumers to eliminate the bloatware after the purchase by incurring additional cost. This is novel in that a consumer is treated not only as a passive entity deciding whether to purchase the product, but also a strategic actor deciding whether to remove the bloatware, if included in the product purchased. In response, in our model, the firm anticipates the possibility of jailbreaking by some purchasing consumers when deciding its bloatware inclusion and product pricing strategies.

When a bloatware-included product is sold, we find that jailbreaking decision is contingent on the product price and how each consumer values the product quality. When the price is high, all purchasing consumers prefer to remove the bloatware from the product. On the other hand, when the price is low, only high valuation purchasing consumers remove the bloatware while low valuation purchasing consumers keep the bloatware. We show that there can be two types of prices in equilibrium and these prices are both lower than the equilibrium price the firm charges when it sells a bloatware-free product. We find that the optimal pricing strategy for the firm with bloatware is to serve to (i) the higher valuation segment only by charging a higher equilibrium price when the bloatware revenue is low and the cost of removing bloatware is cheap, and (ii) the high and low valuation segments by charging a lower equilibrium price when the bloatware revenue is high and the cost of removing bloatware is expensive. In other cases (i.e., either bloatware revenue or removal cost is low), the firm's pricing decision is driven by whether the firm is better off with more revenue from product sales and less revenue from bloatware or less revenue from product sales and more revenue from bloatware. These tensions determine the equilibrium price and the market segment(s) from which consumers buy the bloatware-included product.

Despite the appeal of the bloatware strategy due to the additional revenue it generates for the firm, it is not clear if the firm always benefits from bundling its product with the bloatware, especially when consumers can initiate post-purchase actions to remove the bloatware, thereby reducing the addition revenue to the firm. Our analysis reveals that selling a bloatware-included product can indeed be worse than selling a bloatware-free product. Specifically, when the bloatware revenue is not high enough and the bloatware removal cost is moderate (i.e., neither very high, nor very low), the firm's best bet is to sell a bloatware-free product. Hence, it is not always in the best financial interest of the firm to sell a bloatware-included product.

We next turn our attention to the question of whether the firm should make jailbreaking harder for customers as the basic intuition would suggest when that the firm prefers the bloatware strategy. We show, interestingly, that the firm does not necessarily favor a higher cost of jailbreaking. In particular, when the bloatware removal cost is sufficiently low, the firm prefers even a lower cost of jailbreaking. This is because a lower cost enables the firm to extract the welfare gain by strategically increasing its price and expanding its demand. However, if the bloatware removal cost is sufficiently high, the firm prefers even a higher cost of jailbreaking. This is due to the fact that a lower cost does allow the firm to increase neither its price nor its demand as before, but cause more purchasing consumers to jailbreak, resulting in a clear revenue loss.

We next address how the cost of jailbreaking influences the consumer surplus. The basic intuition suggests that a reduction in the jailbreaking cost always results in a higher consumer surplus because a lower cost makes it possible for more customers to remove the bloatware. Consistent with the basic intuition, we show that the reduction in the jailbreaking cost improves the consumer surplus if it does not lead to a change in the bloatware inclusion strategy of the firm. However, if the reduction in the bloatware removal cost causes the firm to switch from bloatware to bloatware-free strategy, consumers can indeed suffer from such a reduction. This is because the direct positive effect of the savings from jailbreaking cost and quality improvement is washed away by the indirect negative effect due to a higher equilibrium price. Furthermore, we show that reduction in jailbreaking cost may hurt consumer surplus even when the firm continues to bundle its product with bloatware. Hence, giving up the bloatware is not a necessary condition for this surprising finding.

Lastly, we show that regardless of whether a purchasing consumer removes the bloatware or not, under the bloatware strategy the firm always passes part of the bloatware revenue to consumers in the form of a lower equilibrium price in order to balance the margin with the demand. As a result, higher revenue from the bloatware always leads to a win-win situation for the firm and the consumers.

To conclude, there is no consensus among firms on whether to include bloatware in their product, and if so, whether to make jailbreaking increasingly difficult. Our results provide normative guidance to firms in the consumer electronics markets on these crucial questions. Despite the attraction of the supplementary revenue that bloatware brings, our results suggest that bundling products with bloatware is not necessarily a right strategy for every firm. The magnitude of the bloatware revenue and that of jailbreaking cost should be carefully assessed before embarking on the seemingly beneficial bloatware strategy. Although jailbreaking reduces the bloatware revenue, our findings reveal that it is not always advisable for firms to make their products harder to jailbreak. Increasing the cost of jailbreaking can be especially costly because the firm may end up losing demand even if the firm cuts the price of its product.

Although consumers are naturally considered on the winning side of easier jailbreaking, our results caution against this common belief as well. We show that consumers can actually be worse off because they end up paying a higher price for the product in some cases.

Our study is not without limitations. We studied a monopolistic firm to provide insight into bloatware inclusion strategy. Future research can expand our model to a situation where there is competition between firms for consumers in the market. Our model assumed that the firm sells one kind of product and that it is only concerned about whether it should be a bloatware-free product or a bloatware-included product. For instance, Apple always offered computers with no pre-installed bloatware by third parties. Even Microsoft, which is mostly blamed for the existence of bloatware (Horowitz 2015), now sells bloatware-free laptops marketed as the signature edition in its store. Future research can investigate how offering both kinds of products together can impact the firm's pricing strategy and the resulting profit in addition to the impact on the consumer surplus. Finally, our model treated bloatware owners whose applications are included in devices exogenous to the model. Future research can also account for bloatware owners' decisions in the model.

In our model we did not differentiate between firms that are device manufacturers and firms that are retailers or service providers. We assumed that the firm selling devices to customers is in a position to decide on whether to place apps into them or not. This is a reasonable assumption given that many electronics devices are sold directly from manufacturers or through their authorized retailers. However, for smart phones, more and more carriers, especially for Android-based smart phones, are using the bloatware strategy as a service to generate additional revenue from their consumers (Spence 2015). Therefore, our findings are still applicable in a setup where a carrier customizes the handset firmware to force bloatware onto consumers. However, it would be interesting to see how manufacturers can contemplate the idea of bloatware given that a service company can subsequently incorporate its own set of apps into devices.

Due to large potential of bloatware business we have recently witnessed an emergence of intermediaries, who act as a bridge between manufacturers and bloatware suppliers. Notable ones include US-based Sweetlabs and Taiwan-based GMobi (Horwitz 2014, Horwitz 2015). These companies follow a business model similar to that of mobile Ad networks to bring two sides of the market together. They negotiate deals with device manufacturers on behalf of bloatware suppliers. Not only they facilitate targeted bloatware (e.g., cricket bloatware stamped on devices to-be-purchased in India), they also provide analytics tools for the bloatware ecosystem to measure engagement with each piece of bloatware (Horwitz 2014). We can speculate that these companies can bring efficiency - thus higher bloatware revenue -to current bloatware practices and reduce the inconvenience felt by consumers. Hence, based on our model we predict that consumers are likely to pay less for the product itself. We leave a more thorough derivation of this setup to future research.

We believe that bloatware would be even a more controversial and important topic in the future as consumers increasingly adopt wearable technologies and connected devices, and their manufacturers can push for more bloatware. We hope that this work, with its limitations, will pave the way for more research on this topic.

Appendix

Proof of Lemma 1: Taking the derivative of (1) with respect to p_{base}, equating it to zero and solving for p_{base} gives the price expression in lemma 1. Since $\partial^2\Pi_{base} / \partial p_{base}^2 < 0$, this price is the profit maximizing equilibrium price.

Proof of Corollary 1: A customer with type θ earns a positive utility from a purchase (i) if $\theta > p_{bl} / (U-V)$ assuming that the customer does not remove the bloatware, and (ii) if $\theta > (p_{bl} + e) / U$ assuming that the customer removes the bloatware. A purchasing customer prefers to remove the bloatware if $\theta > e / V$. Therefore, when $p_{bl} < \dfrac{e(U-V)}{V}$, customers with $\theta > e / V$ buy the product and remove its bloatware, customers with $e / V \geq \theta > p_{bl} / (U-V)$ buy the product and keep its bloatware. When $p_{bl} \geq \dfrac{e(U-V)}{V}$, customers with $\theta > (p_{bl} + e) / U$ buy the product and remove its bloatware.

Proof of Lemma 2: Using the best response of customers, we can write the firm's profit expression as given in (3). This piecewise expression is concave in p_{bl} in each piece. Let's call the profit expression when $p_{bl} < \dfrac{e(U-V)}{V}$ as Π_{bl}^1 and the profit expression when $p_{bl} \geq \dfrac{e(U-V)}{V}$ as Π_{bl}^2. Taking the derivatives of Π_{bl}^1 and Π_{bl}^2 with respect to p_{bl} and solving the expressions for p_{bl} at zero give $p_{bl}^1 \equiv \dfrac{U+c-V-\sigma}{2}$ and $p_{bl}^2 \equiv \dfrac{U+c-e-\beta\sigma}{2}$, respectively. If $p_{bl}^1 < e(U-V)/V$ and $p_{bl}^2 < e(U-V)/V$, then $p_{bl}^* = p_{bl}^1$. If $p_{bl}^1 \geq e(U-V)/V$ and $p_{bl}^2 \geq e(U-V)/V$, then $p_{bl}^* = p_{bl}^2$. Otherwise, we must compare $\Pi_{bl}^1(p_{bl}^1)$ with $\Pi_{bl}^2(p_{bl}^2)$. Solving $\Pi_{bl}^1(p_{bl}^1) = \Pi_{bl}^2(p_{bl}^2)$ for e gives the expression labeled as $\Omega(\sigma)$. After rewriting the condition $p_{bl}^{1} < e(U-V)/V$ as $e > \frac{V(U+c-V-\sigma)}{2(U-V)}$ and the condition $p_{bl}^{2} < e(U-V)/V$ as $e > \frac{V(U+c-\beta\sigma)}{2U-V}$, we can show that the relationship $\frac{V(U+c-\beta\sigma)}{2U-V} > \Omega > \frac{V(U+c-V-\sigma)}{2(U-V)}$ always holds given $c < U-V$. Therefore, we conclude that $p_{bl}^{*} = p_{bl}^{1}$ when $\Omega(\sigma) < e < V$, and $p_{bl}^{*} = p_{bl}^{2}$ when $e \leq \Omega(\sigma)$.

Proof of Proposition 1: (i) Assume that $p_{bl}^{*} = p_{bl}^{1}$. Solving $\Pi_{bl}^{1}(p_{bl}^{1})$ = Π_{base}^{*} for e gives $e = \frac{V(c^2V - 2cU\sigma + U(V(-U+V) + 2(U-V)(-1+2\beta)\sigma + \sigma^2)}{4U(U-V)(-1+\beta)\sigma}$. Therefore, $\Pi_{bl}^{1}(p_{bl}^{1})$ < Π_{base}^{*} if $\Omega < e < \frac{V(c^2V - 2cU\sigma + U(V(-U+V) + 2(U-V)(-1+2\beta)\sigma + \sigma^2)}{4U(U-V)(-1+\beta)\sigma}$ holds. Assume that $p_{bl}^{*} = p_{bl}^{2}$. Solving $\Pi_{bl}^{2}(p_{bl}^{2})$ = Π_{base}^{*} for e gives $e = \beta\sigma$ and $e = 2(U-c) + \beta\sigma$. Since $c < U-V$, $2(U-c) + \beta\sigma > 2V + \beta\sigma$. Thus, since e must be less than V, the second solution is infeasible. Therefore, $\Pi_{bl}^{2}(p_{bl}^{2})$ < Π_{base}^{*} if $\beta\sigma < e \leq \Omega(\sigma)$ holds. Hence, Π_{bl}^{*} < Π_{base}^{*} if and only if $\beta\sigma < e < \frac{V(c^2V - 2cU\sigma + U(V(-U+V) + 2(U-V)(-1+2\beta)\sigma + \sigma^2)}{4U(U-V)(-1+\beta)\sigma}$.

(ii) We know that $\Pi_{bl}^{1}(p_{bl}^{1}) = \Pi_{bl}^{2}(p_{bl}^{2})$ when $e = \Omega(\sigma)$. Therefore, the curves for $\Pi_{bl}^{1}(p_{bl}^{1}) = \Pi_{base}^{*}$ and $\Pi_{bl}^{2}(p_{bl}^{2}) = \Pi_{base}^{*}$ must intersect each other on $e = \Omega$. Let's call the value of σ at this point as σ_s. We observe that $\beta\sigma$ (i.e., lower bound of the condition in (i)) increasing in σ and $\Psi(\sigma)$ (i.e., upper bound of the condition in (i)) decreasing in σ. Thus, σ_s is less than $\sigma_{\max}$ if and only if $\lim_{\sigma \to \sigma_{\max}} \beta\sigma > \lim_{\sigma \to \sigma_{\max}} \Psi(\sigma)$. Since $\lim_{\sigma \to \sigma_{\max}} \beta\sigma = \beta(U-V+c)$ and $\lim_{\sigma \to \sigma_{\max}} \Psi(\sigma) = \frac{(c+U)^2V - 4\beta UV(U-V+c)}{4(1-\beta)U(U-V+c)}$, β has to be greater than $\frac{(U+c)(U-\sqrt{U(U-V)})}{2U(U-V+c)}$.

Proof of Proposition 2:

$\frac{d\Pi_{bl}^1}{de} = \frac{(1-\beta)\sigma}{V} > 0$. $\frac{d\Pi_{bl}^2}{de} = -\frac{U-e-c+\beta\sigma}{2U} < -\frac{U-V-c+\beta\sigma}{2U} < -\frac{\beta\sigma}{2U} < 0$, where we used assumptions $e < V$ and $c < U - V$.

Proof of Proposition 3:

Because $e < V$, $\frac{d(CS_{bl}^1)}{de} = \frac{e}{V} - 1 < 0$. $\frac{d(CS_{bl}^2)}{de} = -\frac{U-e-c+\beta\sigma}{4U} < 0$.

Proof of Proposition 4:

(i) First consider cross-strategy reduction in jailbreaking cost from $e_1 > \max\{\Psi(\sigma), \Omega(\sigma)\}$ (i.e., high-and-low bloatware strategy) to $\beta\sigma < e_2 < \Psi(\sigma)$ (i.e., bloatware-free strategy). For notational convenience, define $S_1(\sigma) \equiv V - \frac{1}{2}\sqrt{\frac{V(V(U(U-V)-c^2)-2U(U-V-c)\sigma - U\sigma^2)}{U(U-V)}}$.

Notice that CS_{base}^* is independent of e_2. Solving $CS_{base}^* = CS_{bl}^1(e_1)$, we get two roots for e_1:

$V - \frac{1}{2}\sqrt{\frac{V(V(U(U-V)-c^2)-2U(U-V-c)\sigma - U\sigma^2)}{U(U-V)}}$ (which is $S_1(\sigma)$ as we defined) and $V + \frac{1}{2}\sqrt{\frac{V(V(U(U-V)-c^2)-2U(U-V-c)\sigma - U\sigma^2)}{U(U-V)}}$. The second root is apparently larger than *V*, thus infeasible. Also recall from Proposition 3 that a reduction in *e* within the region of high-and-low bloatware strategy always increases consumer surplus, we therefore have: $CS_{bl}^1(e_1) > CS_{base}^*$ if and only if $e_1 < S_1(\sigma)$.

We next study the attributes of curve $e = S_1(\sigma)$ in $\sigma - e$ plane (refer to Figure 1 for a visual illustration). $S_1(\sigma)$ is convex and increasing because

$$\frac{d^2 S_1(\sigma)}{d\sigma^2} = \frac{(U-c)^2 V^2}{\sqrt[3/2]{\frac{V(V(U(U-V)-c^2)-2U(U-V-c)\sigma - U\sigma^2)}{U(U-V)}}\,2U(U-V)} > 0 \text{ and}$$

$$\frac{dS_1(\sigma)}{d\sigma} = \frac{V(U-V+\sigma-c)}{2(U-V)\sqrt{\frac{V(V(U(U-V)-c^2)-2U(U-V-c)\sigma - U\sigma^2)}{U(U-V)}}} > 0.$$

We next provide a sketch of the proof that $S_1(\sigma)$ is always larger than $\beta\sigma$ for any β. Given the definition of $S_1(\sigma)$, this is equivalent to proving that the following expression is positive: $Y(\sigma) \equiv 4(V-\sigma)(V-\sigma)U(U-V) - V(V(U(U-V)-c^2) - 2U(U-V-c)\sigma - U\sigma^2)$. It is straightforward to verify that $Y(\sigma)$ is convex and decreasing at $\sigma = 0$. Let $\hat{\sigma}$ be the unconstrained value of σ that minimizes $Y(\sigma)$, then $\hat{\sigma} = (c+3U-3V)V/(4U-3V)$. Also note that σ is bounded above by $\sigma_{\max} = U - V + c$. Simple algebra then proves that $Y(\sigma)$ is positive at both $\sigma = \hat{\sigma}$ and $\sigma = \sigma_{\max}$.

At $\sigma = 0$, $S_1(\sigma)\big|_{\sigma=0} = V - \frac{V}{2}\sqrt{1 - \frac{c^2}{U(U-V)}}$, which is between 0 and V.

Solving $S_1(\sigma) = V$, and discard the negative (and thus infeasible) root, we find that curve $e = S_1(\sigma)$ touches line $e = V$ at point $(\sigma = c + \frac{\sqrt{U(U-c)^2(U-V)}}{U} - U + V, e = V)$. It is straightforward to verify that curve $\Psi(\sigma)$ touches line $e = V$ at the same point. Therefore, for any $e_1 > \max\{\Psi(\sigma), \Omega(\sigma)\}$, $e_1 < S_1(\sigma)$ is always true.

(ii) Next consider cross-strategy reduction in jailbreaking cost from $e_1 > \max\{\Psi(\sigma), \Omega(\sigma)\}$ (i.e., high-and-low bloatware strategy) to $e_2 \le \min\{\beta\sigma, \Omega(\sigma)\}$ (i.e., high-only bloatware strategy). A direct comparison of $CS_{bl}^1(e_1)$ and $CS_{bl}^2(e_2)$ turns out to be complicated, especially on the borderline curve $e = \Omega(\sigma)$. Instead, below we first compare consumer surplus for each consumer θ at any given e and σ.

Given e and σ, under high-and-low bloatware strategy a purchasing consumer of type θ receives a surplus of $(U-V)\theta + \frac{1}{2}(-c-U+V+\sigma)$ if she does not remove the bloatware, and $U\theta + \frac{1}{2}(-c-U+V+\sigma) - e$ if she removes it; under high-only bloatware strategy a purchasing consumer of type θ receives a surplus of $\frac{1}{2}(2U\theta + \beta\sigma - c - e - U)$, which is apparently smaller than both prior surplus numbers. Furthermore, note that, given e and σ, high-and-low bloatware strategy results in more demand than high-only bloatware strategy because $p_1/(U-V) < (p_1+e)/U < (p_2+e)/U$. Therefore, $CS_{bl}^1(e) > CS_{bl}^2(e)$ for any given e and σ. Consequently, there is always a discontinuous downward jump of consumer surplus on curve $e = \Omega(\sigma)$.

Given $e_1 > \max\{\Psi(\sigma),\Omega(\sigma)\}$, we next solve for e_2 (under $\beta\sigma < e_2 < \Psi(\sigma)$) such that $CS_{bl}^1(e_1) = CS_{bl}^2(e_2)$. There are two roots to the above equation, one of which is apparently larger than V, thus infeasible. The only feasible root to $CS_{bl}^1(e_1) = CS_{bl}^2(e_2)$ is $e_2 = S_2(\sigma;e_1)$. Given the prior result that there is a discontinuous downward jump of consumer surplus on curve $e = \Omega(\sigma)$, and recall from Proposition 3 that within-strategy consumer surplus always increases when the jailbreaking cost decreases, we have: $CS_{bl}^1(e_1) > CS_{bl}^2(e_2)$ if and only if $e_2 > S_2(\sigma;e_1)$.

We next study the attributes of curve $e_2 = S_2(\sigma;e_1)$ in $\sigma - e$ plane (refer to Figure 1 for a visual illustration). First consider the special case of $e_1 = V$ (where for any given σ, $CS_{bl}^1(e_1)$ reaches its lowest possible value). $S_2(\sigma;V) = U - c + \beta\sigma - (U - V + \sigma - c)\sqrt{U/(U-V)}$. $S_2(\sigma;V)$ is smaller than $\Omega(\sigma)$ because $\Omega(\sigma) - S_2(\sigma;V) = 2(U - \sqrt{U(U-V)})(1-\beta)\sigma / V > 0$. Therefore, curve $e = S_2(\sigma;e_1)$ is always below curve $e = \Omega(\sigma)$ for any feasible e_1.

$S_2(\sigma;e_1)$ is concave in σ because

$$\frac{d^2 S_2(\sigma;e_1)}{d\sigma^2} = \frac{4U^2(V-e_1)^2(U-V)^2V^2}{(U(U-V)V(c^2V + (U-V)(4e_1^2 - 8e_1V + V(U+3V-2c)) + 2V(U-V-c)\sigma + V\sigma^2))^{3/2}} > 0.$$

Proof of Proposition 5:

First consider $\max\{\Psi(\sigma),\Omega(\sigma)\} < e < V$, under which the firm optimally adopts the high-and-low bloatware strategy. From the expression of Π_{bl}^1, we have

$d\Pi_{bl}^1 / d\sigma = \dfrac{cV + (U-V)(V - 2e(1-\beta) - 2V\beta) - V\sigma}{2v(-U+V)}$. Given $e > \Psi(\sigma)$, the previous expression is larger than $\dfrac{cV + (U-V)(V - 2\Psi(\sigma)(1-\beta) - 2V\beta) - V\sigma}{2v(-U+V)}$, which straightforwardly simplifies to $\dfrac{(U(U-V) - c^2)V + U\sigma^2}{4U(U-V)\sigma}$. The last expression is positive because $U - V > c$. Thus $d\Pi_{bl}^1 / d\sigma > 0$.

$d\Pi_{bl}^1 / d\beta = \sigma(V-e)/V > 0$.

From the expression of CS_{bl}^1, we have $d(CS_{bl}^1)/d\sigma = \dfrac{U - V + \sigma - c}{4(U-V)} > 0$. β does not appear in the expression of CS_{bl}^1.

Next consider $e \le \min\{\beta\sigma, \Omega(\sigma)\}$, under which the firm optimally adopts the high-only bloatware strategy.

From the expression of Π_{bl}^2, it is straightforward that Π_{bl}^2 increases in $U + \beta\sigma - e - c$, thus it increases in both σ and β.

Similarly, from the expression of CS_{bl}^2, it is straightforward that CS_{bl}^2 also increases in $U + \beta\sigma - e - c$, thus it increases in both σ and β.

Lastly, notice that the firm may switch strategy from high-only bloatware strategy to high-and-low bloatware strategy when σ increases. Therefore we also need to compare consumer surplus under these two strategies at $e = \Omega(\sigma)$ (see Figure 1). In the proof of Proposition 4 we have already shown that, for any given σ and e, $CS_{bl}^2 < CS_{bl}^1$. Therefore, an increase in σ that triggers the firm to switch strategy always increases consumer surplus.

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