Should Firms Bundle Bloatware with Consumer Electronics? – Implications for Product Pricing and Consumer Surplus

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Abstract

This paper investigates bloatware bundling and product pricing decisions of a monopolistic firm when consumers can remove the bloatware from their electronic devices after purchase. We show conditions under which it is optimal for the firm not to bundle bloatware with their products. Furthermore, we show that even if the firm can make it harder for consumers to remove bloatware, the firm is not always better off by doing so. Consumers do not necessarily benefit from a reduced cost of bloatware removal either. In particular, if the reduction in the removal cost triggers the firm to change either its bloatware-inclusion strategy or its pricing strategy, the reduced removal cost may hurt consumers.

Keywords: bloatware, consumer electronics, economics of IS, game theory, pricing

Introduction

The last decade has witnessed an explosive growth in the number of devices in the consumer electronics market. Notable examples include smart phones, tablets, 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 valuable to firms because they provide an additional revenue stream. Consumers, however, often view many pre-installed apps a hindrance rather than an added value. As Jared Newman from Time Magazine put it, “Pre-loaded, junky Android apps ... keep finding more ways to annoy” (Newman 2014). Consumers refer to such pre-installed yet unappreciated apps on phones and other devices as bloatware, or sometimes in a more negative tone, crapware or junkware (Pinola 2012, Newman 2014). Bloatware deteriorates consumer value in several ways. Many bloatware apps occupy precious screen space and clutter app drawers yet are seldom used by consumers (Dent 2014). Bloatware also takes up storage space and runs in the background without users’

1 For example, software companies typically pay up to $10 per installation to hardware manufacturers.
knowledge. In the 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 or performance reduction (Triggs 2014).

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 modification of product’s software with the purpose of removing bloatware, or bloatware removal in short (Dachis 2011, Cogen 2013). Broadly speaking, bloatware removal 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 the impact of bloatware removal by consumers on a firm’s strategy and consumer surplus (Cogen 2013).

Bloatware removal 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 bloatware removal: bloatware suppliers would be discouraged to pay for pre-installation of their apps as a result of the wide removal of bloatware by customers (Yegulalp 2012). While there exists rich information on the technology side, little research exists that explores the economic consequences of bloatware removal on the firm strategy. As our first research question, we study how consumer-initiated bloatware removal affects a firm’s bloatware inclusion and product pricing strategies.

Because a direct economic consequence of bloatware removal is the loss of bloatware revenue for the firm, intuitively a higher cost of bloatware removal 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 phone 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). Apple has been following a similar strategy by not offering consumers a convenient way to remove unwanted apps. 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 bloatware removal. HTC is publically committed to unlocked bootloader for its recent phones. 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 steps for bloatware removal. Our second research question thus asks whether a firm that adopts a bloatware strategy benefits from an increased cost of bloatware removal for consumers.

Consumers also have an influence on the cost of bloatware removal. In practice, consumers with technical expertise discover various methods to remove bloatware. These methods are frequently shared in forums or social media such as XDA Developers and YouTube and further simplified by consumers. Given consumer resentment at bloatware, it is understandable that consumer effort is geared toward reducing the cost of removing bloatware. Nevertheless, given the strategic actions of the firm that is aware of the possibility of bloatware removal and has a pricing lever, is it true that a lower cost of bloatware removal always results in a higher consumer surplus? This is our third research question.

We develop a game-theoretical model to address three research questions mentioned above. We first analyze a case, called baseline case, in which the firm sells a bloatware-free product. We next consider a case, called bloatware case, where the firm sells a bloatware-included product. Comparing the findings in these 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 always better off with bloatware if the revenue that the firm generates from bloatware is large enough, irrespective of the magnitude of the removal cost. Although bloatware removal can affect the pricing of the bloatware-included product, the firm earns more profit than the

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2 www.htcdev.com/bootloader

3 unrevoked.com/rootwiki/doku.php/public/root_friendly
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 removal is either sufficiently low or sufficiently high. The intuition behind this interesting 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 but small cost to remove its bloatware. As a result, the firm not only appeals to a larger market, but also earns more revenue for each product sold (product price + bloatware revenue), compared to the baseline case. When the removal cost is high, only a fraction of purchasing customers chooses to remove the bloatware. Therefore, high removal cost does not necessarily force the firm to lower the price aggressively because the willing-to-pay of customers who prefer to use the product with bloatware is not affected by the removal cost. A lower price results in more demand for the bloatware-included product. Although the firm earns less revenue from each product (product price + bloatware revenue) compared to the baseline case, a larger demand more than compensates the reduction 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 bloatware removal when this cost is already low. Intuitively, a reduction in bloatware removal cost increases the willingness-to-pay of consumers who jailbreak, which in turn allows the firm to strategically raise the price. Furthermore, this reduction in bloatware removal cost also increases market demand. Consequently, the firm benefits.

We finally investigated the relationship between the cost of removing bloatware and consumer surplus. Since a reduction in the removal cost 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 the removal cost may also have a strategic effect of increasing the firm’s equilibrium price. Depending on the trade-off between the direct and strategic effects, we identify three scenarios as described below. (i) When the reduction in bloatware removal cost is limited such that it does not change the firm’s bloatware strategy, this strategic effect is dominated by the direct effort savings. Consequently, a lower cost of bloatware removal always benefits consumer surplus. (ii) When the reduction in bloatware removal cost triggers the firm to switch from bundling bloatware with its product to not including bloatware with its product, the firm will also strategically choose a higher price for its bloatware-free product (as compared to its price for bloatware-included product) due to the high consumer valuation of the bloatware-free product. In equilibrium, this strategic effect (i.e., the price increase) dominates the direct effect (i.e., savings in bloatware removal cost) and hence lowering the cost of bloatware removal surprisingly hurts consumer surplus when the reduction in bloatware removal cost is not too large. (iii) When the reduction in bloatware removal cost does not change the firm’s adoption of bloatware, yet triggers the firm to give up trying to prevent some consumers from removing bloatware, the strategic effect (i.e., price increase) may also dominate the direct effect (i.e., savings in bloatware removal cost). Intuitively, the desire to prevent some consumers from removing bloatware puts downward pressure on the product price. This downward pressure no longer applies when the firm expects that all purchasing consumers will jailbreak, thus resulting in a discrete jump in equilibrium price that overwhelms any cost savings from a reduced cost of bloatware removal. Overall, we find that the intuition that a reduction in bloatware removal cost benefits the consumers holds but not always. In particular, if the reduction on bloatware removal cost leads the firm to change its bloatware inclusion and pricing strategies, it is possible that the reduction in bloatware removal cost hurts consumers. This finding is the first result in IS research that shows, from consumer surplus perspective, the strategic detriments of a lowered removal cost can dominate the direct cost savings it generates.

The rest of the paper proceeds as follows. We briefly review the relevant literature in Section 2. We present our model, analysis and findings in Section 3. In Section 4 we conclude the paper with a discussion of implications and future research directions.
Literature Review

Our paper adds to the literature on pricing of information goods. Papers in this literature address 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 bloatware removal, 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 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 bloatware removal, 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 bloatware removal 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 bloatware 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).

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 bloatware removal by consumers. 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 $\theta$ is uniformly distributed on $[0,1]$ represents the valuation type of a customer. Each customer decides whether to purchase the product or not. If the product comes with bloatware apps, a 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.

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 $\theta$ type earns a utility of $\theta U - p_{\text{base}}$ if the customer purchases the product, where $U$ captures the maximum utility and $p_{\text{base}}$ denotes the price of the bloatware-free product.
Hence, only customers with $\theta > \frac{P_{\text{base}}}{U}$ will purchase the product. The firm then maximizes the following profit expression in which $C$ represents the marginal cost of a product.

$$\Pi_{\text{base}} = \left(1 - \frac{P_{\text{base}}}{U}\right)(P_{\text{base}} - C)$$  \hspace{1cm} (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 $P_{\text{base}}^* = \frac{U + C}{2}$.

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

$$\Pi_{\text{base}}^* = \frac{(U - C)^2}{4U}$$  \hspace{1cm} (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 $\theta(U - V) - p_{\text{bl}}$, where $p_{\text{bl}}$ indicates the price of the bloatware-included 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. 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 $\theta U - p_{\text{bl}} - e$, where $e$ is the cost of effort to remove the bloatware. We assume that the removal cost is same across all types of customers\(^4\). 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 $p_{\text{bl}} < \frac{e(U - V)}{V}$, (i) customers with valuation $\theta \in \left(\frac{e}{V}, 1\right]$ buy the product and remove its bloatware, (ii) customers with valuation $\theta \in \left(\frac{p_{\text{bl}}}{U - V}, \frac{e}{V}\right]$ buy the product and keep its bloatware. Other customers do not buy the product. When $p_{\text{bl}} \geq \frac{e(U - V)}{V}$ (iii) customers with valuation $\theta \in \left(\frac{p_{\text{bl}} + e}{U}, 1\right]$ buy the product and remove its bloatware. Other customers do not buy the product.

\(^4\) 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.
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 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 $\sigma$ if the bloatware is not removed, and $\beta \sigma$ if the bloatware is removed, where $\beta < 1$. We call $\sigma$ as (full) bloatware revenue and $\beta \sigma$ as partial bloatware revenue. 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) $\sigma < U - V + c \equiv \sigma_{\text{max}}$, 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

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

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

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

where $\Omega(\sigma) = \frac{(U - V)(-cV + V \beta \sigma + U(V + 2\sigma - 2\beta \sigma) - \sqrt{U(U - V)(cV + V(V + \sigma - 2\beta \sigma) - U(V + 2\sigma - 2\beta \sigma))})}{(U - V)V}$

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 the buyers (i.e. those removing the bloatware and those who do not) while the latter results in one segment of buyers who remove 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 their higher willingness-to-pay of 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...
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It is interesting to note that bloatware removal cost is negatively correlated with the firm’s ability to earn price premium from customers when it serves only to high valuation segment. If the removal cost is low, the firm can charge a higher price due to a higher willingness-to-pay of customers. If the removal cost 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 the high removal cost to get rid of the bloatware) and, subsequently, the price premium decreases with the removal cost.

We can observe from the 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.

**Proposition 1:**

(i) The firm makes more profit with bloatware unless

\[ \beta \sigma < e < \Psi(\sigma), \quad \text{where} \quad \Psi(\sigma) \equiv \frac{V(c^2V - 2cU\sigma + U(V(-U + V) + 2(U - V)(-1 + 2\beta)\sigma + \sigma^2)}{4U(U - V)(-1 + \beta)\sigma} \]

(ii) 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 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 \( \sigma \), the upper bound of the condition on \( e \) is decreasing in \( \sigma \). Hence, assuming that \( \beta \) 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 removal cost, the firm charges a high price and sells its product to high valuation segment only. For high values of 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., \( \sigma \leq \sigma_s \)), the firm is better off with bloatware only if the cost of bloatware removal 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 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) for 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., $\hat{\partial}p^2_{bl} / \hat{\partial}e < 0$). 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 removal cost exceeds a threshold ($e > \beta\sigma$), the firm starts serving only a smaller market and but also earning less revenue (sales+bloatware) for 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 removal cost changes neither the overall demand nor the equilibrium price. Yet, an increase in the removal cost increases (decreases) the fraction of customers who chooses to keep (remove) the bloatware. However, once the removal cost gets high enough, the bloatware case again starts performing better than the baseline case. This is 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.

**How the Cost of Removing Bloatware Impacts Firm Profit**

While we treat the cost of bloatware removal, $e$, as an exogenous parameter in this 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 in 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. For example, some smart phone manufacturers void their product warranties once the firmware in the product is tampered with (which is often necessary for bloatware removal). Do firms prefer a higher or a lower removal cost? In this subsection we conduct a comparative statics analysis of firm profit with respect to the removal cost.

From Lemma 2 and Proposition 1, we know that the firm’s optimal strategy can be categorized into the following three cases. When $\beta\sigma < e < \Psi(\sigma)$, the firm adopts the bloatware-free strategy. 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). 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).

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

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

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

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

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 ($e < \beta\sigma$ or $e > \Psi(\sigma)$), then,

i) The firm profit decreases in the removal cost $e$ if $e < \Omega(\sigma)$.
ii) The firm profit increases in the removal cost \( e \) if \( e \geq \Omega(\sigma) \).

Proposition 2(i) shows that, surprisingly, the firm can benefit from a reduction in the cost of bloatware removal 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 \( e \leq \min\{\beta\sigma,\Omega(\sigma)\} \), the firm adopts the high-only bloatware strategy in which all purchasing consumers jailbreak. Under this strategy, the profit margin for the firm is \( p_{bl}^2 + \beta\sigma - c = \frac{(U - c - e + \beta\sigma)}{2} \) and the demand is \( 1 - \frac{(p_{bl}^2 + e)}{U} = \frac{(U - c - e + \beta\sigma)}{(2U)} \), both are decreasing in \( e \). Intuitively, a reduction in \( e \) improves the profit margin because the reduction increases the willingness-to-pay for consumers who jailbreak, which enables the firm to charge more. Furthermore, the reduction in \( e \) also expands the market demand under the firm’s optimal price. Therefore, the firm benefits. In other words, while a lower removal cost directly benefits consumer welfare, the firm is able to extract part of this welfare gain by strategically increasing price and expanding 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 can no longer benefit from a reduction in the removal cost. 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 removal 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 removal cost neither increases the equilibrium price nor expands market because the price is independent of the removal cost (recall \( p_{bl}^1 \) in Lemma 2). Thus a reduction in removal cost hurts the firm profit.

**How the Cost of Removing Bloatware Impacts Consumer Surplus**

We now shift our attention to the relationship between the cost of bloatware removal and consumer surplus. While the removal cost \( e \) is an exogenous parameter in our model, like the firm, consumers collectively also have some influence over the removal cost. Popular bloatware removal 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 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 removal cost. However, does a reduction in bloatware removal 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 bloatware-free strategy, from Lemma 1, consumer surplus is

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

Under 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 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 bloatware removal cost. If a reduction does not change the firm’s pricing strategy, we call it a *within-strategy*
reduction in bloatware removal cost. For example, given $\sigma$ and suppose that the bloatware removal 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 bloatware removal cost. Continuing the above example, 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 within-strategy reduction in the removal cost. By taking first-order derivatives of $CS^{1}_{hs}$ and $CS^{2}_{hs}$ with respect to $e$, we obtain the following result.

**Proposition 3:** Assuming that bloatware is profitable for the firm ($e < \beta\sigma$ or $e > \Psi(\sigma)$), within-strategy reduction in bloatware removal cost always increases 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 bloatware removal 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 receive from the reduction in removal cost dominates the increment in the firm’s price. Therefore, within-strategy reduction in removal cost is always beneficial to consumers.

We did not discuss the bloatware-free strategy in Proposition 3. Since the cost of bloatware removal is irrelevant to consumer surplus under this strategy, it is apparent and trivial that within-strategy reduction in bloatware removal cost under the bloatware-free strategy does not affect consumer surplus.

One key insight from our results in Lemma 2 and Proposition 1, is that bloatware removal cost affects not only the firm’s optimal 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 pricing strategy in turn can affect consumer surplus. We next consider cross-strategy reduction in the cost of bloatware removal, 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 of cross-strategy reductions in the removal cost when bloatware is included in the product: from high-and-low bloatware strategy to bloatware-free strategy and from high-and-low bloatware strategy to high-only bloatware strategy. For each scenario, we compare consumer surplus before and after the reduction in removal cost, the findings of which are summarized in the next proposition. To simplify the exposition, $S_1(\sigma)$ and $S_2(\sigma;e_1)$ are defined as:

$$S_1(\sigma) \equiv V - \frac{1}{2} \sqrt{\frac{V(V(U-U-V)-c^2)-2U(U-V-c)\sigma-U\sigma^2}{U(U-V)}}$$

and

$$S_2(\sigma;e_1) \equiv U + \beta\sigma - c - \sqrt{\frac{U(U-V)V(c^2V+(U-V)(4c^2-8cV+V(U+3V-2c))+2V(U-V-c)\sigma+V\sigma^2)}{V(U-V)}}.$$
**Proposition 4:** Given \( \sigma \), consider a cross-strategy reduction in bloatware removal 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 bloatware removal cost decreases consumer surplus if and only if \( e_1 < S_1(\sigma) \).

ii) If \( e_1 > \max\{\Psi(\sigma), \Omega(\sigma)\} \) and \( e_2 \leq \min\{\beta \sigma, \Omega(\sigma)\} \), this cross-strategy reduction in bloatware removal 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 high-and-low bloatware strategy under \( e_1 \) and bloatware-free strategy under \( e_2 \) and when conditions in (ii) hold, the firm adopts high-and-low bloatware strategy under \( e_1 \) and high-only bloatware strategy under \( e_2 \). Proposition 4 identifies conditions in which a reduction in the breaking cost hurts consumer surplus. To understand, let’s first focus on the case in Proposition 4 (i) in which the reduction in removal cost which is significant enough to trigger the firm to switch its pricing strategy from high-and-low bloatware strategy under \( e_1 \) to 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 removal 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 high-and-low bloatware strategy with \( e_1 \), the firm charges an equilibrium price of \( p_{bl}^1 = (U + c - V - \sigma) / 2 \); under bloatware-free strategy with \( e_2 \), the firm equilibrium price is \( p_{base}^* = (U + c) / 2 \). Therefore, by switching from 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 consumer surplus. When the reduction in \( e \) is not too large (i.e., \( e_1 < S_1(\sigma) \)), the strategic price effect dominates the direct effect.

To our knowledge, Proposition 4 (i) is the first in IS research that highlights the strategic and negative consequence of lowering the cost of removing bloatware. While existing coverage of bloatware removal 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 bloatware removal 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 cross-strategy reduction in bloatware removal cost may hurt consumer surplus even if the firm continues to bundle bloatware in its product.

The intuition for Proposition 4 (ii) is best illustrated when \( e = \Omega(\sigma) \) (i.e., on curve \( \Omega(\sigma) \)), where the firm is indifferent between high-and-low bloatware strategy and 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 line \( \Omega(\sigma) \) under high-and-low bloatware strategy where \( p_{bl}^1 = (U + c - V - \sigma) / 2 \) (i.e., the customer with \( \theta \in \left( \frac{e}{V}, 1 \right] \)). If the firm switches to high-only bloatware strategy, the price increases to \( p_{bl}^1 = (U + c - e - \beta \sigma) / 2 \). 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 high-and-low bloatware strategy (i.e., the customer with
This customer would either purchase the product or not when the firm switches to 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 high-and-low bloatware strategy), we still have $S_2(\sigma; V) < \Omega(\sigma)$. In other words, even if consumers can enjoy a significant removal-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 removal 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 only catering to high valuation consumers.

**Conclusion**

Whether to include bloatware in products is a crucial question to answer for 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 bloatware removal of electronic devices to remove unwanted applications bundled with products, our game-theoretic model incorporates the ability of consumers to eliminate the bloatware after the purchase by incurring some cost. This is novel in that a consumer is treated not only as a passive entity deciding whether to purchase the product, but also as 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 bloatware removal by some consumers when deciding its bloatware inclusion and product pricing strategies.

When bloatware is bundled with the product sold, we find that bloatware removal 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 do not remove the bloatware. We find that the optimal strategy for the firm is to choose a higher (lower) price when the bloatware removal cost is low (high). Although the equilibrium product price changes depending on the cost of bloatware removal, this price is always lower than the price the firm charges when it sells a bloatware-free product.

Despite the appeal of bloatware strategy due to the revenue it generates for the firm, it was not clear if the firm always benefits from the bloatware, especially when the consumers can initiate actions to remove the bloatware. We find that selling a bloatware-included product can indeed be worse than selling a bloatware-free product. Specifically, when the additional bloatware revenue is not very high and the bloatware removal cost is neither very high nor very low, the firm's optimal strategy is to sell a bloatware-free product. Hence, it is not always in the best interest of the firm to bundle its product with the bloatware.

We next turn our attention to the question of whether the firm should make bloatware removal harder for customers assuming that the firm prefers the bloatware strategy. Surprisingly, we show that the firm does not necessarily favor a higher cost of bloatware removal. In particular, when the bloatware removal cost is already low, the firm prefers even lower cost of bloatware removal. However, if the bloatware removal cost is sufficiently high, the firm prefers even higher cost of bloatware removal.

We finally address how the cost of bloatware removal influences consumer surplus. The basic intuition suggests that a reduction in the removal cost always results in a higher consumer surplus because a reduced cost makes it easier for customers to remove the bloatware. Consistent with the intuition, we
show that the reduction improves 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 triggers the firm to change its bloatware inclusion or pricing strategies and if the reduction is not sufficiently large, consumers suffer from such a reduction in the removal cost.

While there is no consensus among firms on whether to include bloatware in their product, our results provide normative guidance to firms in the consumer electronics markets. Despite the attraction of the additional revenue that bloatware brings, our results suggest that bundling products with bloatware is not necessarily a right strategy. Although bloatware removal reduces the bloatware revenue, it is not always advisable that the firms should make their product harder to jailbreak. In fact, the firm would be better off by lowering the cost of bloatware removal when it is not too large.

Our study is not without limitations. We studied a monopolistic firm. Future research can expand our model to the situation where there is competition for consumers in the market. Our model also assumed that the firm sells only one kind of product and that it only chooses whether to go with a bloatware-free product or a bloatware-included product. Future research can investigate how offering both kinds of products together impacts the firm profit and consumer surplus. Finally, our model treated bloatware owners whose applications are included in the devices exogenous to the model. Future research can also account for bloatware owners’ decisions in the model. We believe that bloatware would be even a more controversial topic in the future as sensors and connected devices are increasingly adopted by consumers. We hope that this work will pave the way for more research on this topic.

Appendix

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

Proof of Corollary 1: A customer with type $\theta$ 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 $p_{bl} < e(U - V) / V$, 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 $p_{bl} \geq e(U - V) / V$, 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 $p_{bl} < e(U - V) / V$ as $\Pi_{bl}^1$ and the profit expression when $p_{bl} \geq e(U - V) / V$ as $\Pi_{bl}^2$. Taking the derivatives of $\Pi_{bl}^1$ and $\Pi_{bl}^2$ with respect to $p_{bl}$ and solving the expressions for $p_{bl}$ at zero give $p_{bl}^1 = (U + c - V - \sigma) / 2$ and $p_{bl}^2 = (U + c - e - \beta \sigma) / 2$, 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 \( \frac{V(U+c-\sigma)}{2(U-V)} > \Omega > \frac{V(U+c-V-\sigma)}{2(U-V)} \) 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 \( \Pi_{bl}^1(p_{bl}^1) = \Pi_{base}^* \) 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, \( \Pi_{bl}^1(p_{bl}^1) < \Pi_{base}^* \) 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 \( \Pi_{bl}^2(p_{bl}^2) = \Pi_{base}^* \) 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, \( \Pi_{bl}^2(p_{bl}^2) < \Pi_{base}^* \) if \( \beta\sigma < e \leq \Omega(\sigma) \) holds. Hence, \( \Pi_{bl}^* < \Pi_{base}^* \) 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 \( e = \Omega(\sigma) \). Let’s call the value of \( \sigma \) at this point as \( \sigma_s \). We observe that \( \beta\sigma \) (i.e., lower bound of the condition in (i)) increasing in \( \sigma \) and \( \Psi(\sigma) \) (i.e., upper bound of the condition in (i)) decreasing in \( \sigma \). Thus, \( \sigma_s \) 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
\[
\lim_{\sigma \to \sigma_{max}} \Psi(\sigma) = \frac{(c+U)^2V-4\beta\sigma(U-V+c)}{4(1-\beta)(U-V+c)}, \quad \beta \text{ has to be greater than } \frac{(U+c)(U-\sqrt{U(U-V)})}{2(U-V+c)}.
\]
(The proofs for the rest of the propositions are omitted due to space limit, and are available from the authors upon request.)

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