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Keywords: privacy regulation, privacy management, versioning, monopoly, competition

JEL Classification: D18, D61, K24, L12, L51, L86

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Privacy Regulations, Consumer Empowerment, and Versioning*

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February 27, 2025

Abstract

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1 Introduction

The European Union's General Data Protection Regulation (GDPR) is shaping the global privacy landscape in the digital age. Following its promulgation in May 2018, many jurisdictions around the world have enacted privacy regulations that mirror the GDPR or amended existing ones in line with it. PwC's Risk Atlas database indicates that there are currently more than 2,500 laws governing data privacy.[1] Albeit subject to some differences, these privacy regulations generally stipulate user empowerment whereby data subjects are given certain rights and control over their personal data, data security measures required from data controllers, and stricter enforcement for non-compliance than previous privacy regulations. Regarding user empowerment, for example, the GDPR (Article 7, recital 32) states that organizations must obtain explicit consent from individuals before collecting, processing, or storing their personal data, and consent must be specific, informed, and unambiguous. Numerous fines and notices have been issued for non-compliance, ranging from insufficient transparency in obtaining consent, poor data security arrangements, to illegal cross-border transfer of user data, etc.[2]

While these privacy regulations empower consumers by granting them greater control over their data, they have also impacted how firms price their digital services, including the rise of tiered pricing or versioning. A typical versioning model offers users a choice between ad-supported plans that require data sharing and personalized ads, and ad-free plans with limited data sharing. Examples of ad-free plans include YouTube Premium (rebranded in 2018), Apple News+ (introduced in 2019), Meta's ad-free subscription service for Facebook and Instagram (launched in 2023), and the Premium+ tier on X (formerly Twitter) introduced in 2023.[3] These examples illustrate how firms are adapting their pricing strategies to accommodate evolving user privacy preferences in the wake of new privacy regulations.

Firms have long relied on various forms of versioning even before the introduction of stricter privacy regulations. However, we argue that these regulations provide a more compelling justification for versioning, particularly in the context of data and privacy, for several reasons. First, these regulations often lead to reduced data collection (Schmitt et al., 2021; Aridor et al., 2023), compelling firms to seek alternative revenue streams, such as paid subscriptions (Choe et al., forthcoming). Second, versioning directly addresses the evolving preferences of consumers who increasingly prioritize data privacy. By offering varying levels of data sharing, firms cater to the diverse needs and comfort levels of their user base. Third, stricter enforcement mechanisms and substantial penalties for privacy violations enhance the credibility of a firm's data collection policies. This contrasts sharply with the pre-GDPR era, where weak enforcement of principle-based regulations led to widespread and unchecked data collection.[4]

[1] https://www.pwc.com/us/en/services/consulting/cybersecurity-risk-regulatory/library/privacy-reset.html

[2] For a comprehensive and up-to-date list of GDPR fines, see https://www.enforcementtracker.com/.

[3] Versioning is also employed by various streaming platforms, software companies, news websites, etc. For example, Hulu, Paramount+, and Spotify have tiers revolving around ad-supported and ad-free options; Dropbox offers basic service for free but has paid tiers with additional features, storage, or functionality; *The Economist* has three tiers of paid subscription.

[4] Before the GDPR, one of the largest fines was €150,000 on Google levied in 2014 by the CNIL, the French privacy watchdog, for failure to obtain appropriate consent for data collection and processing. This pales in comparison to the fine of €150 million the CNIL imposed on Google in 2022 for comparable breaches, which demonstrates the dramatically different regulatory landscape. Choe et al. (forthcoming) provide an in-depth

The aim of this paper is to analyze the economic impact of privacy regulations (henceforth referred to as "the regulation") by focusing on the two key aspects of the regulation: user empowerment, whereby consumers proactively make data-sharing decisions, and the firm's capacity to engage in price discrimination after the regulation. Specifically, we study the welfare effects of the regulation when the market is served by either a monopolist or competing firms, and firms engage in versioning after the regulation. As reviewed in the next section, existing studies examine consumer empowerment and firms' use of versioning in isolation or within a single market structure. Therefore, our primary contribution to the literature is to develop a model that integrates both aspects across different market structures. This enables us to analyze the differential impact of privacy regulations, which hinges on factors such as market structure, consumers' privacy preferences, and competing firms' data-driven revenue models.

We outline our model, explain the key findings, and provide the intuition underlying these results. A firm offers an online service to consumers who are heterogeneous in two dimensions: their valuation of the service and their privacy cost. The privacy cost is incurred only when the consumer shares her personal data with the firm when using the service, which we refer to as opt-in as opposed to opt-out. We define the consumer's type as (service valuation, privacy cost), which is the consumer's private information. The firm earns revenue from sales of its service called usage-based revenue and data monetization called data-driven revenue. We focus on the regulation's requirement for obtaining explicit opt-in consent for data sharing. That is, we assume that, before the regulation, opt-out purchase is not available so that all consumers must share data when buying the service; after the regulation, consumers can choose between opt-in and opt-out purchases, which we call consumer empowerment. Therefore, the firm chooses a single opt-in price before the regulation while it exercises versioning by choosing both opt-in and opt-out prices after the regulation. Given that the firm cannot observe consumer types, versioning needs to satisfy self-selection and participation constraints to be effective. We compare the equilibria before and after the regulation.

In Section 4, we analyze a monopoly model and show that the firm is better off after the regulation due to its ability to price discriminate. Consumer empowerment does not undermine monopoly profit because the firm can always revert to using a single price, as it did before the regulation. More specifically, because only an opt-in price is available before the regulation, the equilibrium is pooling where consumers with different privacy costs choose opt-in. After the regulation, despite the option to choose opt-out purchase, the same pooling equilibrium can be replicated if the firm sets a high enough opt-out price that is not chosen on the equilibrium path. The pooling equilibrium involves an implicit subsidy: the low opt-in price effectively subsidizes low-privacy-cost consumers, as it needs to be chosen to compensate high-privacy-cost consumers for the privacy cost of opting in. The firm implements a pooling equilibrium when the subsidy needed to induce high-privacy-cost consumers to opt in is not substantial compared to the data-driven revenue they generate. Otherwise, the firm employs versioning to separate consumers with different privacy costs, resulting in a separating equilibrium where high-privacy-cost consumers choose opt-out and low-privacy-cost consumers choose opt-in. When the regulation results in a separating equilibrium, the firm is strictly better off. Low-privacy-cost

discussion on this.

consumers are worse off because they no longer benefit from the implicit subsidy embedded in the pooling equilibrium. High-privacy-cost consumers may be better or worse off, depending on the trade-off between the privacy cost savings and the higher price they pay for opting out.

Section 5 analyzes a duopoly model with firms A and B, which may differ in their reliance on data monetization. We say firm A is more (less) data-driven than firm B if its marginal data-driven revenue, denoted by α_A, is larger (smaller) than firm B's marginal data-driven revenue, denoted by α_B. For example, firm A may have more (less) diverse channels for data monetization so that it generates more (less) revenue from the same amount of data than firm B.[5] Firms can adopt either a pooling strategy where only their opt-in price is effective, or a separating strategy where both opt-in an opt-out prices are effective. The opt-in price targets low-privacy-cost consumers, while the opt-out price targets high-privacy-cost consumers. As in the monopoly case, the equilibrium before the regulation is pooling, as firms compete solely on opt-in price. In the pooling equilibrium, the more data-driven firm adopts more aggressive pricing and captures a larger market share. It is because consumers only make opt-in purchases before the regulation, which allows the marginal data-driven revenue to function as an implicit subsidy from each consumer to the firm, thereby lowering the cost of serving each consumer. As a result, the more data-driven firm can set lower prices. In short, data-driven revenue serves as a source of competitive advantage for the firm before the regulation.

After the regulation, each firm's choice of pooling or separating strategy depends on the size of its marginal data-driven revenue relative to privacy costs. If the firm's marginal data-based revenue is large relative to privacy costs, then the firm chooses a pooling strategy because it does not have incentives to offer an opt-out choice when its data-driven revenue from each opt-in consumer can compensate for the privacy cost. Otherwise, the firm chooses a separating strategy. Consequently, the duopoly equilibrium is one of the following three types depending primarily on α_A and α_B. First, when both α_A and α_B are large relative to privacy costs, the equilibrium outcome is pooling, the same as that before the regulation. Second, when both α_A and α_B are small relative to privacy costs, the equilibrium is separating where firms compete on opt-out price for high-privacy-cost consumers and on opt-in price for low-privacy-cost consumers. Third, when α_A is large (small) and α_B is small (large) relative to privacy costs, the equilibrium is asymmetric where firm A adopts a pooling (separating) strategy and firm B, a separating (pooling) strategy.

The key results from the duopoly case are as follows. Since the pooling equilibrium remains unchanged by the regulation, with no consumers choosing opt-out purchase, we focus on the other equilibria. First, the less data-driven firm benefits, competing more aggressively and earning higher profits than pre-regulation. Conversely, the more data-driven firm is worse off. This stems from high-privacy-cost consumers who can switch from opt-in to opt-out purchases post-regulation. This shift erodes the competitive advantage previously held by the more data-driven firm, incentivizing the less data-driven firm to compete more aggressively for these consumers.

[5]News aggregators such as Apple News and Google News provide a relevant example. Apple launched its premium subscription-based service, Apple News+ in 2019, which was followed by Google's ad-free Google News Showcase in 2020. Given that over 70% of Apple's revenue comes from hardware sales, while Google's revenue is primarily data-driven, this exemplifies competition between firms with asymmetric data-driven revenue models. Further details are provided in Section 6.3.

Second, industry profit declines after the regulation due to intensified competition, except in the symmetric case ($\alpha_A = \alpha_B$) when industry profit does not change. Competition intensifies because the regulation increases consumer choice, leading to more ways firms can deviate from mutually beneficial outcomes.[6] Third, increased consumer empowerment and intensified competition result in higher consumer surplus following the regulation. In summary, the regulation can be pro-competitive, except in the case of symmetric firms. This contrasts sharply with the monopoly case, highlighting the nuanced effects of privacy regulations, which vary depending on market structure, the heterogeneity in consumers' privacy preferences, and the asymmetry in competing firms' data-driven revenue models.

The remainder of this paper is structured as follows. Section 2 reviews the relevant literature. Section 3 introduces our baseline model, which we analyze in a monopoly setting in Section 4 and in a duopoly setting in Section 5. Section 6 explores the impact of regulation on firms' choice of data-driven revenue models and market entry, and presents two real-world examples illustrating competition between firms with asymmetric data-driven revenue models. Section 7 concludes the paper. All proofs are provided in the appendix.

2 Related literature

Empirical evidence on the economic impact of various privacy regulations, the GDPR in particular, is vast and growing.[7] General findings are that privacy regulations adversely affect data-driven industries by reducing the amount of data collected (Schmitt et al., 2021; Congiu et al., 2022; Aridor et al., 2023), dampening incentives for innovation and investment (Bessen et al., 2020; Jia et al., 2021; Batikas et al., 2023), and increasing market concentration in mobile apps, websites and web technology services (Schmitt et al., 2021; Janßen et al., 2022; Peukert et al., 2022; Johnson et al., 2023). On the other hand, Godinho de Matos and Adjerid (2022) provide experimental evidence that shows privacy regulations may benefit advertisers by improving their targeting capabilities. Aridor et al. (2023) report similar evidence that consumers whose data are observed after the GDPR have on average a higher value to advertisers than those before the GDPR.

Compared to empirical studies, relatively less attention has been paid to theoretical analyses of privacy regulations. Fainmesser et al. (2023) study how the optimal privacy regulation depends on the firm's revenue model, although they do not model consumers' opt-in decisions nor the firm's pricing strategies. Choi et al. (2019) show that the right to opt in to data collection can be made ineffective if the monopolist can exercise price discrimination. Ke and Sudhir (2023) study a dynamic model of behavior-based price discrimination that incorporates the data rights stipulated in the GDPR. In both of these studies, consumers differ in their valuations for the relevant good but not in privacy costs whereas we allow both kinds of consumer heterogeneity. Choe et al. (forthcoming) analyze the effect of opt-in regulation allowing consumer heterogeneity

[6] This finding aligns with existing literature demonstrating that competition between symmetric firms intensifies under price discrimination (e.g., third-degree or first-degree) compared to uniform pricing (e.g., Fudenberg and Tirole, 2000; Choe et al., 2018). Our results extend this observation to a setting with competitive versioning and asymmetric firms.

[7] Johnson (2023) provides an excellent review of the literature.

both in valuations and in privacy costs. But they do not consider price discrimination nor competition, as we do in the current paper.

Our paper is related to the literature on competitive price discrimination.[8] A general finding is that the impact of more information on firm profits and consumer surplus depends on the kind of information that can be used for price discrimination, the pricing tools available to competing firms, and the extent to which competing firms are asymmetric. For example, as information becomes more refined and competition shifts from that based on uniform pricing to third-degree price discrimination and to personalized pricing, competition between symmetric firms intensifies and hurts profits (Fudenberg and Tirole, 2000; Choe et al., 2018). But the result is less clear cut when competition is in second-degree price discrimination such as non-linear pricing or bundling (Armstrong and Vickers, 2010). We contribute to this literature by studying the case where asymmetric firms compete by offering a menu of (service, price) or versioning (Shapiro and Varian, 1998). Although versioning has been studied widely in the monopoly setting following the seminar papers by Mussa and Rosen (1978) and Maskin and Riley (1984), it attracted less attention in the competitive setting. We show that competition in versioning can lower industry profits except when firms are symmetric.

Finally, our analytical framework is similar to that used in the studies on ad avoidance (e.g., Anderson and Gans, 2011; Lin, 2020; Despotakis et al., 2021; Amaldoss et al., 2024). In particular, our work complements Amaldoss et al. (2024) who analyze pricing strategies by two symmetric media platforms in two-sided markets. They show that platforms may choose uniform pricing (pooling strategy in our context) or tiered pricing (separating strategy in our context), depending on consumer benefits from multihoming, whereas we show that different types of equilibria exist, depending on the asymmetry in competing firms' data-driven revenue models.[9] In the above studies on ad avoidance, firms offer different versions of digital content based on the amount of ads consumers are exposed to when consuming the content. Such an offer is credible because consumers can directly verify their exposure to ads. In contrast, the credibility of an opt-out choice in our paper requires a commitment device such as the privacy regulation, because consumers cannot tell whether their data are shared unless the cost of data breach is realized.

3 Model

We present a model of privacy regulation that allows consumers to proactively manage their privacy when using a digital service. Specifically, we focus on the opt-in consent requirement of privacy regulation, hereafter referred to as "the regulation." Before the regulation, consumers using the service are required to share personal data with the service provider. After the regulation, consumers can opt out of data sharing when using the service. Thus, the regulation

[8]For a survey, see, for example, Armstrong (2006) or Stole (2007).

[9]Another key difference between Amaldoss et al. (2024) and our work concerns the firm's commitment to a pricing strategy. Amaldoss et al. (2024) assume firms pre-commit to a pricing strategy—either uniform or tiered—before setting prices. This simplifies the analysis by precluding consideration of deviations across pricing strategies. In contrast, we do not assume such a commitment, which necessitates an analysis of deviations both within and across pricing strategies. The relative merits of these approaches depend on how flexible or rigid firms' commitment to a chosen pricing strategy is. In addition, we follow, for example, Choi and Jeon (2021), by simplifying the data-driven revenue side, thereby avoiding explicit consideration of two-sided markets.

expands consumer choice. On the other hand, it also allows the service provider to engage in price discrimination through versioning, enabling consumer self-selection into different options. Our primary aim is to develop a simple yet plausible model to understand how the expanded consumer choice affects market outcomes and welfare.

There is a unit mass of consumers who are heterogeneous along two dimensions. First, they differ in their preferences for the service provided by the firm. Specifically, consumers are uniformly distributed on $[0, 1]$, derive value $v > 0$ from the service, but incur a transportation cost tz for some $t > 0$ when z is the distance between the consumer and the firm she patronizes. Second, they differ in the privacy costs incurred when they share data with the firm while using the service, which we call opt-in purchase.[10] The privacy costs are not incurred when consumers use the service without sharing data with the firm, which we call opt-out purchase. For tractability, we assume binary privacy costs. A fraction $\theta \in [0, 1]$ of consumers has a high privacy cost $c > 0$, called high-type or type-h consumers, and the rest has a low privacy cost normalized to zero, called low-type or type-l consumers.[11] Before the regulation, consumers must share data with the firm when buying the service, i.e., opt-out purchase is not available. After the regulation, consumers can choose between opt-in and opt-out purchase.[12] Both consumer preferences and privacy costs are private information.

In Section 4, we consider a monopoly model where the firm is located at 0 and provides the service at zero marginal cost. We ignore any fixed cost. The firm earns revenue from two sources: it earns revenue from sales of its service, which we call the usage-based revenue; it can also monetize data collected from consumers who choose opt-in purchase, which we call the data-driven revenue. The data-driven revenue is given by αD^I for some $\alpha \in [0, \alpha^M]$ where D^I is the measure of opt-in consumers, i.e., opt-in demand, and α^M is the maximum level of α. The firm may earn data-driven revenue from various channels, including advertising, data brokerage, data licensing, the sale of data products, etc. Consequently, the parameter α will be larger if the firm utilizes a greater number of these revenue streams, although α is naturally bounded above. The usage-based revenue depends on the price the firm charges for the service.

Before the regulation, the firm chooses a single price since consumer preferences and privacy costs are both private information upon which the firm cannot base its price. If the firm charges price p, then its usage-based revenue is pD where $D = D^I + D^O$ is total demand for the firm's service and D^O is opt-out demand. The firm's profit is then $\pi = (p+\alpha)D$. After the regulation, the firm can choose two prices, one for opt-in purchase denoted by p^I and the other for opt-out purchase denoted by p^O. Then its profit is $\pi = (p^I + \alpha)D^I + p^O D^O$. When suitably chosen, a menu of (price, purchase option) may let consumers with different privacy costs self-select themselves into different purchase options. Thus, if a type-i consumer ($i = h, l$) located at $x \in [0, 1]$ chooses opt-in purchase, then her net surplus is $u_i^I(x) := v - cI_i - tx - p^I$ where I_i

[10] There is growing evidence that documents consumer heterogeneity in privacy preferences (Goldfarb and Tucker, 2012; Ghose, 2017; Lin, 2022; Macha et al., 2024). To the extent that privacy regulations aim to empower consumers to better manage their privacy, acknowledging heterogeneous privacy preferences is crucial for conducting meaningful analyses of such regulations.

[11] Acquisti et al. (2015) discuss studies that cluster individuals to three privacy segments: privacy fundamentalists, pragmatists, and unconcerned. We may call type-h consumers privacy fundamentalists and type-l consumers the privacy unconcerned.

[12] Clearly, this is a simplifying assumption. But we do not expect our main insight to change in a more general model where the regulation increases the fraction of consumers who proactively make opt-in/opt-out decisions.

is an indicator function with $I_h = I_l + 1 = 1$. If she chooses opt-out purchase, then her net surplus is $u_i^O(x) := v - tx - p^O$. As a tie-breaking rule, we assume that consumers choose opt-in purchase when indifferent between opt-in and opt-out purchase.

In Section 5, we consider a duopoly model. Firm A is located at 0 and firm B is located at 1, and the two firms provide an identical service at zero marginal cost. We allow asymmetry between the two firms: firm A's marginal data-driven revenue is $\alpha_A \geq 0$ and firm B's is $\alpha_B \geq 0$. We say that firm i has a more data-driven revenue model than firm $j \neq i$ when $\alpha_i > \alpha_j$, $i, j = A, B$. The rest is the same as in the monopoly model. Each firm's revenue comprises usage-based revenue and data-driven revenue. Denote the opt-in (opt-out, resp.) demand for firm $j = A, B$ by D_j^I (D_j^O, resp.), and its total demand by $D_j = D_j^I + D_j^O$. Before the regulation, firms compete by choosing uniform prices, p_A and p_B. Firm j's profit is given by $\pi_j = (p_j + \alpha_j)D_j$. After the regulation, each firm can choose two prices. Let p_j^k be the price firm $j = A, B$ charges for purchase option $k = I, O$. Then, firm j's profit is $\pi_j = (p_j^I + \alpha_j)D_j^I + p_j^O D_j^O$.

Remark 1. A key modeling assumption in our paper is the unavailability of opt-out purchase before the regulation. While a firm might nominally offer this choice pre-regulation, such an offer lacks credibility. This is primarily due to weak enforcement, which allows the firm to renege and monetize consumer data even after an opt-out purchase. Privacy regulations like the GDPR, with their stringent enforcement and substantial fines for infringement, lend credibility to such offers.[13]

Remark 2. We study price discrimination in the form of versioning. Alternatively, one can consider a scenario where the firm does not price discriminate but offers an additional benefit, say $b > 0$, to each opt-in consumer. Then the effective price an opt-in consumer pays is $p^O - b$. Thus, if the cost of providing the benefit is b for each opt-in consumer, then the firm's profit is $(p^O + \alpha)D^I + p^O D^O - bD^I = (p^O - b + \alpha)D^I + p^O D^O$. This profit is the same as the profit when the firm price discriminates with $p^I = p^O - b$ and there is no opt-in benefit. Thus, our model is equivalent to the one without price discrimination where the firm optimally chooses the opt-in benefit.

Remark 3. Our model can be cast into a general mechanism design framework. Consider a direct mechanism given by $(d(\tau), p(\tau))$ where τ indicates consumer types, $d(\tau)$ is the amount of data to be collected from a type-τ consumer, and $p(\tau)$ is the price charged to type-τ consumers, in exchange for the firm's service. The case we study is where $d(\tau)$ is either all data (opt-in) or no data (opt-out), $p(\tau) \in \{p^I, p^O\}$, and $\tau \in \{h, l\}$.

4 Monopoly

4.1 Equilibrium before the regulation

The firm chooses price p and opt-out purchase is not possible. The marginal type-h consumer z_h is given by $u_h^I(z_h) = v - c - tz_h - p = 0$, hence $z_h = (v - c - p)/t$. The marginal type-l

[13] See Choe et al. (forthcoming) and the discussions therein for more details.

consumer z_l is given by $u_l^I(z_l) = v - tz_l - p = 0$, hence $z_l = (v-p)/t$. The firm's profit is then

$$\pi = (p+\alpha)[\theta z_h + (1-\theta)z_l] = (p+\alpha)\left(\frac{v-p-\theta c}{t}\right).$$

Maximizing π, we obtain

$$p^* = \frac{v-\alpha-\theta c}{2},\; z_h^* = \frac{v+\alpha+\theta c-2c}{2t},\; z_l^* = \frac{v+\alpha+\theta c}{2t},\; \pi^* = \frac{(v+\alpha-\theta c)^2}{4t}. \tag{1}$$

The consumer surplus is then $CS^* = \theta\int_0^{z_h^*}(v-c-tx-p^*)dx + (1-\theta)\int_0^{z_l^*}(v-tx-p^*)dx$, hence

$$CS^* = \frac{\theta(v+\alpha+\theta c-2c)^2 + (1-\theta)(v+\alpha+\theta c)^2}{8t}. \tag{2}$$

To ensure interior solutions, i.e., $z_h^*, z_l^* \in [0,1]$, we assume the following.

Assumption 1: $2c \leq v+\alpha+\theta c \leq 2t$.

Noting that the marginal consumer's location is the same as the demand from each type of consumers, we summarize the analysis above in the following lemma.

Proposition 1 *Suppose Assumption 1 holds. Then, in the equilibrium under monopoly before the regulation, the price, the demand from each type of consumers, and the firm's profit are given in (1), and the consumer surplus is given in (2).*

We make several observations. First, compared to the monopoly price $v/2$ which would prevail when $\alpha = \theta = c = 0$, the equilibrium price is discounted by $(\alpha+\theta c)/2$. The first term, $\alpha/2$, reflects the fact that α works as a price subsidy. That is, α adds to the firm's marginal revenue implying that, as α increases, the firm has incentives to cut price to increase demand from both types of consumers. Because of this, the equilibrium price can be negative if α is large enough, i.e., $v - \theta c < \alpha$. The second term, $(\theta c)/2$, represents the price discount necessary to compensate for the privacy cost borne by type-h consumers. On the other hand, type-l consumers do not bear privacy costs and, therefore, they enjoy external benefits from the price discount. The benefits stem from the firm's inability to price discriminate, and would disappear when the firm can price discriminate, as we will show later. Next, an increase in c decreases the equilibrium price and the equilibrium demand from type-h consumers, but increases the equilibrium demand from type-l consumers. When c increases, the firm needs to cut price to compensate for the higher privacy cost for type-h consumers. But the price cut does not need to fully compensate for the increase in privacy cost because it will over-compensate type-l consumers who do not bear any privacy cost. Consequently, the decrease in price following an increase in c benefits type-l consumers but hurts type-h consumers. Finally, the equilibrium profit increases in α but decreases in θ and c.

4.2 Equilibrium after the regulation

The regulation allows consumers to choose between opt-in and opt-out purchase. In response to this, the firm can offer versioning by choosing two prices, p^O for opt-out consumers and p^I for opt-in consumers. We describe below the incentive compatibility (IC) and participation (IR) constraints required for each type of consumers to choose either purchase option.

A type-h consumer x chooses opt-in purchase if the following conditions are met:

$$(IC_h^I): \quad u_h^I(x) \geq u_h^O(x) \Leftrightarrow p^I \leq p^O - c; \quad (IR_h^I): \ u_h^I(x) \geq 0.$$

The IC constraint means that the price discount for opt-in purchase needs to compensate for the privacy cost. A type-h consumer x chooses opt-out purchase if the following conditions are met:

$$(IC_h^O): \ u_h^O(x) \geq u_h^I(x) \Leftrightarrow p^I \geq p^O - c; \quad (IR_h^O): \ u_h^O(x) \geq 0.$$

A type-l consumer x chooses opt-in purchase if the following conditions are met:

$$(IC_l^I): \ u_l^I(x) \geq u_l^O(x) \Leftrightarrow p^I \leq p^O; \quad (IR_l^I): \ u_l^I(x) \geq 0.$$

A type-l consumer x chooses opt-out purchase if the following conditions are met:

$$(IC_l^O): \ u_l^O(x) \geq u_l^I(x) \Leftrightarrow p^I \geq p^O; \quad (IR_l^O): \ u_l^O(x) \geq 0.$$

We start with the following observations. First, (IC_h^I) and (IC_l^O) cannot hold simultaneously, implying that it is not possible to induce type-h consumers to choose opt-in purchase and type-l consumers to choose opt-out purchase. Second, note that $u_l^I(x) \geq u_h^I(x)$ and $u_h^O(x) = u_l^O(x)$. Thus, if a type-h consumer x chooses opt-in purchase, then so does a type-l consumer x. Third, it is not optimal for the firm to induce type-l consumers to choose opt-out purchase. Doing so requires $p^I > p^O$, which then leads type-h consumers to choose opt-out purchase as well. Instead, the firm can benefit by decreasing p^I to p^O and inducing type-l consumers to choose opt-in purchase, which generates additional data-driven revenue. That is, optimal prices must satisfy $p^I \leq p^O$. Fourth, when some type-h consumers are served through opt-in or opt-out purchase, some type-l consumers are also served through opt-in purchase. That is, it is not optimal for the firm to serve only type-h consumers. Finally, it is not optimal for the firm to serve type-l consumers only through opt-in purchase. Serving a type-l consumer through opt-in purchase requires $p^I \leq p^O$ and $u_l^I(x) \geq 0$. However, by choosing $p^O = p^I$ so that $u_h^O(x) = u_l^I(x)$, the firm can also induce a type-h consumer x to choose opt-out purchase, and earn additional data-driven revenue.

The above discussions imply that only the following two cases are possible in equilibrium: (i) a pooling outcome where both types of consumers choose opt-in purchase; (ii) a separating outcome where type-l consumers choose opt-in purchase and type-h consumers choose opt-out purchase.

4.2.1 Pooling equilibrium

For type-h consumers, (IC_h^I) is equal to $p^I \leq p^O - c$. For a type-l consumer x, (IC_l^I) is equal to $p^I \leq p^O$. Thus, (IC_l^I) is slack when (IC_h^I) is satisfied. Let z_h be the marginal type-h consumer, i.e., $u_h^I(z_h) = 0$, hence $z_h = (v - c - p^I)/t$. Let z_l be the marginal type-l consumer, i.e., $u_l^I(z_l) = 0$, hence $z_l = (v - p^I)/t$. By the definition of z_h and z_l, (IR_h^I) and (IR_l^h) are satisfied. Then the firm's problem is to choose (p^I, p^O) to maximize

$$\pi = (p^I + \alpha)\left(\frac{\theta(v - c - p^I)}{t} + \frac{(1-\theta)(v - p^I)}{t}\right) \text{ subject to } p^I \le p^O - c.$$

This problem is the same as the pre-regulation problem with p^I as the relevant price. Thus the solution is the same as that in (1) with $p^I = p^*$ and any off-the-equilibrium-path price p^O that satisfies $p^O \ge p^I + c$.[14] Given that the firm can always implement this outcome, the implication is that the firm cannot be worse off after the regulation.

4.2.2 Separating equilibrium

For type-l consumers, we have the same (IC) and (IR) as before: $p^I \le p^O$ and $z_l = (v - p^I)/t$. For type-h consumers, (IC) is now $p^I \ge p^O - c$ and the marginal consumer z_h is given by $u_h^O(z_h) = v - tz_h - p^O = 0$, hence $z_h = (v - p^O)/t$. Given z_h and z_l, (IR_h^O) and (IR_l^I) are satisfied. Then the firm's problem is to choose (p^I, p^O) to maximize

$$\pi = p^O\left(\frac{\theta(v - p^O)}{t}\right) + (p^I + \alpha)\left(\frac{(1-\theta)(v - p^I)}{t}\right) \text{ subject to } p^O - c \le p^I \le p^O.$$

Ignoring the constraints and solving for the interior optimum, we obtain

$$\hat{p}^I = \frac{v - \alpha}{2},\ \hat{z}_l = \frac{v + \alpha}{2t},\ \hat{p}^O = \frac{v}{2},\ \hat{z}_h = \frac{v}{2t},\ \hat{\pi} = \frac{\theta v^2 + (1-\theta)(v+\alpha)^2}{4t}. \tag{3}$$

The consumer surplus is then

$$\widehat{CS} = \theta\int_0^{\hat{z}_h}(v - tx - \hat{p}^O)dx + (1-\theta)\int_0^{\hat{z}_l}(v - tx - \hat{p}^I)dx = \frac{\theta v^2 + (1-\theta)(v+\alpha)^2}{8t} \tag{4}$$

The above solution is valid when $p^O - c \le p^I$ or $\alpha \le 2c$, in which case the firm's problem has an interior solution given above. Note that we have $\hat{z}_h, \hat{z}_l \in [0,1]$ by Assumption 1. If $\alpha > 2c$, then we have a boundary solution where the firm's profit is smaller than that given in (1).[15] Thus, the firm is better off implementing the pooling outcome where both types choose opt-in purchase. In sum, the separating outcome under consideration is not possible when $\alpha > 2c$.

4.2.3 Equilibrium

Based on the above analysis, the equilibrium before the regulation is fully characterized as either pooling where both types of consumers choose opt-in purchase or separating where type-l (type-h, resp.) consumers choose opt-in (opt-out) purchase. Comparing the firm's profits in (1) and (3), we have $\hat{\pi} - \pi^* = (\theta/4t)\left[2v(c-\alpha) + \alpha(2c-\alpha) - \theta c^2\right]$, hence $\hat{\pi} \ge \pi^*$ if and only if $2v(c-\alpha) + \alpha(2c-\alpha) \ge \theta c^2$. This leads us to the following result.

[14]This echoes the argument in Choi et al. (2019) that the price-discriminating monopolist can render opt-in regulations ineffective.

[15]When $\alpha > 2c$, the boundary solution at which $p^O - c = p^I$ is given by $\hat{p}^I = \frac{v-(1-\theta)\alpha-2\theta c}{2}$ and $\hat{p}^O = \frac{v-(1-\theta)\alpha+2(1-\theta)c}{2}$.

Proposition 2 *The equilibrium under monopoly after the regulation can be characterized as follows:*

- *If $2v(c-\alpha)+\alpha(2c-\alpha) < \theta c^2$ or $\alpha > 2c$, then the equilibrium is pooling where both types of consumers choose opt-in purchase, which is characterized in (1) and (2), the same as that before the regulation, hence the firm's profit is the same before and after the regulation.*
- *If $2v(c-\alpha)+\alpha(2c-\alpha) \geq \theta c^2$ and $\alpha \leq 2c$, then the equilibrium is separating where type-l consumers choose opt-in purchase and type-h consumers choose opt-out purchase, which is characterized in (3) and (4), and the firm earns larger profit than before the regulation.*

4.3 Comparing the monopoly equilibrium before and after the regulation

Our analysis has shown that the post-regulation equilibrium is either pooling or separating. The pooling equilibrium outcome is exactly the same as that before the regulation, implying that the regulation has a neutral welfare effect in the space of parameters where the pooling equilibrium exists. In the separating equilibrium, however, the firm's profit is larger hence the regulation has a nontrivial welfare effect in the space of parameters where the separating equilibrium exists. In what follows, we compare the equilibrium outcome before the regulation given in (1) and (2) with the separating equilibrium outcome after the regulation given in (3) and (4).

First, we have $p^* < \hat{p}^I$, hence type-l consumers pay a higher price after the regulation. They no longer enjoy the external benefits they receive when the firm cannot price discriminate, i.e., the price discount necessary to compensate type-h consumers for bearing the privacy cost. As a result, the price they pay increases by $(\theta c)/2$ after the regulation. Because they still choose opt-in purchase, a higher price implies that their equilibrium demand decreases after the regulation, i.e., $\hat{z}_l \leq z_l^*$. A higher price and smaller demand imply that the consumer surplus for type-l consumers decreases after the regulation. This can be verified from (2) and (4): their consumer surplus decreases from $(1-\theta)(v+\alpha+\theta c)^2/(8t)$ to $(1-\theta)(v+\alpha)^2/(8t)$.

Second, we have $p^* < \hat{p}^O$, hence type-h consumers also pay a higher price. But they choose opt-out purchase after the regulation and, therefore, do not bear the privacy cost. Consequently, despite the higher price they pay after the regulation, their equilibrium demand may increase or decrease depending on the size of privacy cost, i.e., $\hat{z}_h \geq z_h^*$ if and only if $(2-\theta)c \geq \alpha$. Moreover, by comparing (2) and (4), we note that the consumer surplus for type-h consumers changes from $\theta(v+\alpha+\theta c-2c)^2/(8t)$ before the regulation to $\theta v^2/(8t)$ after the regulation. The former is larger than the latter if and only if $\alpha \geq (2-\theta)c$. Thus, type-h consumers are more likely to be worse off after the regulation when α and/or θ are larger, subject to the conditions that ensure the existence of separating equilibrium. The intuition is as follows. First, larger α implies a larger price subsidy when the firm cannot price discriminate, which leads to a larger price increase for type-h consumers when the firm price discriminates after the regulation. Likewise, larger θ implies a larger price discount before the regulation, hence a larger price increase in the separating equilibrium. In sum, the consumer surplus for type-h consumers is likely to decrease after the regulation if α and/or θ are large within the parameter range that ensures the existence of separating equilibrium; otherwise, it can increase.

Then, how does the regulation change total consumer surplus? Since type-l consumers are unambiguously worse off after the regulation, total consumer surplus can increase only when type-h consumers' gain is significant. By comparing (2) and (4), we find that total consumer surplus increases after the regulation if $\alpha < c$ and $1 - \frac{(c-\alpha)(2v+\alpha-c)}{3c^2} < \theta \leq \frac{2v(c-\alpha)+\alpha(2c-\alpha)}{c^2}$ where the upper bound for θ is from the condition for the existence of separating equilibrium; otherwise, it decreases. Thus, the regulation can increase total consumer surplus only when α is sufficiently small relative to c. In this case, type-h consumers can benefit from the regulation by choosing opt-out purchase.

Finally, given that the firm's profit is larger than before the regulation in the separating equilibrium, we discuss when the separating equilibrium is more likely to exist. The conditions for the existence of separating equilibrium, i.e., $2v(c-\alpha)+\alpha(2c-\alpha) \geq \theta c^2$ and $\alpha \leq 2c$, are more likely to be satisfied when α and θ are smaller, and c is larger. These conditions can be interpreted as follows. In the separating equilibrium, the firm exercises price discrimination to extract larger surplus from each type of consumers than before the regulation. But type-h consumers choose opt-out purchase in the separating equilibrium, leading to a loss in data-driven revenue for the firm. This loss is smaller when α is smaller, i.e., the firm relies less on data-driven revenue, or when θ is smaller, i.e., there are fewer type-h consumers. Next, the firm's profit before the regulation decreases in c because the price is chosen to compensate for the privacy cost borne by type-h consumers, as shown in (1). However, in the separating equilibrium after the regulation, the profit is independent of c as shown in (3) because type-h consumers choose opt-out purchase. We summarize the above discussions below.

Proposition 3 *Comparing the equilibrium under monopoly before the regulation with the separating equilibrium after the regulation, we have the following.*

- *The firm's profit is larger after the regulation, which is more likely when the firm's revenue is less data-driven, i.e., α is smaller, the fraction of type-h consumers (θ) is smaller, and the privacy cost (c) is larger.*

- *The consumer surplus for type-l consumers is smaller after the regulation.*

- *The consumer surplus for type-h consumers is smaller after the regulation if and only if $\alpha \geq (2-\theta)c$, subject to the conditions for the existence of separating equilibrium.*

- *Total consumer surplus is larger after the regulation if $\alpha < c$ and $1 - \frac{(c-\alpha)(2v+\alpha-c)}{3c^2} < \theta \leq \frac{2v(c-\alpha)+\alpha(2c-\alpha)}{c^2}$; otherwise, it is smaller.*

The gist of our findings in the monopoly case can be summarized as follows. The privacy regulation offers more purchase options to consumers by allowing them to proactively manage privacy. In response to this, the firm can adopt versioning, which can be used to let consumers self-select themselves into different purchase options. In the pooling equilibrium after the regulation, the firm can replicate the same pricing strategy used before the regulation, hence has the same profit before and after the regulation. But the firm is strictly better off after the regulation in the separating equilibrium where consumers with high privacy cost choose opt-out purchase and those with low privacy cost choose opt-in purchase. Proposition 3 summarizes when the separating equilibrium is more likely to occur. Importantly, the firm with smaller data-driven revenue is more likely to benefit from the regulation because smaller data-driven revenue implies that it is less costly for the firm to separate different types of consumers through versioning. In the separating equilibrium, consumers with low privacy cost are worse off because they continue to choose opt-in purchase but pay a higher price, while the welfare impact on consumers with high privacy cost depends on comparing their privacy cost savings with a higher price they pay after the regulation.

5 Competition

In the previous section, we studied how the monopolistic firm can benefit from the regulation by employing price discrimination that separates different types of consumers. Then, does the ability to price discriminate after the regulation also benefit competing firms? On the one hand, firms tend to be worse off when they compete using finer degrees of price discrimination because it intensifies competition (e.g., Fudenberg and Tirole, 2000; Choe et al., 2018). On the other hand, as consumers have more options, it becomes more difficult for a firm to poach its rival's customers, which tends to soften competition (Chen et al., 2020). Thus, the overall effect of the regulation on competition is not obvious, which is what we study in this section.

Recall that we consider a simple duopoly model of Hotelling competition where firm A is located at 0 and firm B is located at 1. As in Armstrong and Vickers (2010), we focus on the case where the market is fully covered. Let $u_{ij}^k(x)$ denote the net surplus of type-i ($i = h, l$) consumer located at x when she buys the service from firm $j = A, B$ by choosing purchase option $k = I, O$, and p_j^k be the price firm j charges for purchase option k. Let z_{ij} be the type-i marginal consumer who chooses firm j. Given that the market is fully covered, we have $z_{iA} = z_{iB}$. Thus we will drop the firm subscript and denote the type-i marginal consumer by z_i. We assume the following.

Assumption 2: $v \geq \frac{6t+(3-\theta)c}{4}$.

Assumption 3: $-3t < \alpha_A - \alpha_B < 3t$.

Assumption 2 is necessary to ensure the existence of all possible equilibria with full market coverage. It means that consumers' valuation of the service is large enough relative to the privacy and transportation costs incurred in consuming the service, and guarantees that the (IR) constraints are satisfied for all consumers in all possible equilibria. Note that $v \geq (3t)/2$ ensures full market coverage in the standard Hotelling model. Given the additional privacy cost, full market coverage requires larger values of v. Assumption 3 means that the two firms are not too asymmetric in their data-driven revenue. This is to rule out the possibility that the market is monopolized by one firm. For example, if $\alpha_A - \alpha_B \geq 3t$, then firm A monopolizes the market before the regulation, as will be shown below.

5.1 Equilibrium before the regulation

Opt-in is the only purchase option before the regulation, which allows us to drop the superscript for purchase option. If firm A chooses p_A and serves $[0, z_i]$ of type-i consumers, then its profit is

$\pi_A = (p_A+\alpha_A)[\theta z_h+(1-\theta)z_l]$. If firm B chooses p_B and serves $[z_i, 1]$ of type-i consumers, then its profit is $\pi_B = (p_B+\alpha_B)[\theta(1-z_h)+(1-\theta)(1-z_l)]$. Since consumer z_i is indifferent between choosing either firm, we have $z_h = z_l = z := (t-p_A+p_B)/(2t)$. Clearly, the marginal consumer's location is the same for both types given that firms cannot price discriminate different types of consumers. Firm A chooses p_A to maximize $\pi_A = (p_A+\alpha_A)[\theta z_h+(1-\theta)z_l] = (p_A+\alpha_A)z$ and firm B chooses p_B to maximize $\pi_B = (p_B+\alpha_B)(1-z)$. Solving the problems, we obtain

$$p_A^* = \frac{3t-2\alpha_A-\alpha_B}{3}, \quad p_B^* = \frac{3t-\alpha_A-2\alpha_B}{3}, \quad z^* = z_h^* = z_l^* = \frac{3t+\alpha_A-\alpha_B}{6t},$$
$$\pi_A^* = \frac{(3t+\alpha_A-\alpha_B)^2}{18t}, \quad \pi_B^* = \frac{(3t-\alpha_A+\alpha_B)^2}{18t}, \tag{5}$$
$$CS^* = v-\frac{5t}{4}-\theta c+\frac{(\alpha_A-\alpha_B)^2+18t(\alpha_A+\alpha_B)}{36t}.$$

Given Assumptions 2 and 3, it is easy to verify that the market is fully covered, with neither firm monopolizing the market. Furthermore, because all consumers have to choose opt-in purchase, firms must price below the Hotelling price t to compensate type-h consumers for bearing the privacy cost. We summarize the above discussions below.

Proposition 4 *Given Assumption 2, both types of consumers are fully served in the equilibrium under competition before the regulation, where prices, market shares, profits, and consumer surplus are as in (5).*

Because all consumers choose opt-in purchase and their data is an additional source of revenue, α_A (α_B, resp.) effectively functions as a per-unit subsidy for firm A (B, resp.) from each consumer. Consequently, competition intensifies when firms have larger data-driven revenue: equilibrium prices decrease in α_A and α_B, and firm A's market share increases (decreases, resp.) in α_A (α_B, resp.). Moreover, the more data-driven firm, i.e., the firm with larger α, plays more aggressively and undercuts its rival and secures a larger market share: for $i = h, l$, we have $p_A^* < p_B^*$ and $z_i^* > 1/2$ if and only if $\alpha_A > \alpha_B$.

5.2 Equilibrium after the regulation

After the regulation, firm $j = A, B$ chooses (p_j^I, p_j^O). As in the monopoly case, each firm's versioning strategy needs to satisfy the relevant (IC) and (IR) constraints for consumers for whom each version is intended. Since consumers can choose either firm, they have more options to choose from than when there is a monopolistic supplier. But we show in Lemma 1 that only the following two pricing strategies are used in equilibrium. We will describe these strategies for firm A. Symmetric discussions apply for firm B.

First, both types of consumers are served through opt-in purchase. The relevant (IC) and (IR) constraints for such a pooling outcome can be stated as

$$p_A^I \le p_A^O - c, \quad p_A^I \le \min\{v-c-tz_h, v-tz_l\}. \tag{6}$$

This strategy can be optimal when α_A is large, θ is large, or c is small. The reasoning is as follows. When the firm charges the same price to both types of consumers to induce opt-in purchase, it subsidizes type-l consumers because the price should be chosen to compensate type-h consumers for bearing privacy cost c, which type-l consumers do not bear. In return, the firm earns data-driven revenue from both types of consumers. The benefits from the latter are likely to outweigh the costs from the former if α_A is large, the proportion of type-l consumers, i.e., $1-\theta$, is small, or c is small. There is another pooling strategy where both types of consumers are induced to choose opt-out purchase. But the firm will never choose this strategy because of our tie-breaking assumption that type-l consumers choose opt-in purchase when indifferent. Thus, we call the pricing strategy aimed at inducing opt-in purchase from both types of consumer the *pooling strategy.*

Second, firm A can choose p_A^O for type-h consumers on $[0, z_h]$ and p_A^I for all type-l consumers on $[0, z_l]$. To implement such a separating outcome, (p_A^O, p_A^I) needs to satisfy type-l consumers' (IC) constraints for choosing opt-in purchase, type-h consumers' (IC) constraints for choosing opt-out purchase, and the (IR) constraints for both types of consumers. These constraints can be shown to be equal to

$$p_A^O - c \leq p_A^I \leq p_A^O, \quad p_A^I \leq v - tz_l, \quad p_A^O \leq v - tz_h. \tag{7}$$

We call this the *separating strategy.* For reasons explained above, the separating strategy is more likely to be optimal when α_A and θ are smaller, or c is larger.

There are other strategies feasible for firm A. For example, firm A may serve only one type of consumers and exclude the other type. In the following lemma, we provide the derivation of conditions (6) and (7), and show that only the above two pricing strategies are consistent with consumers' incentive and participation constraints, and the firm's optimal choice of prices.

Lemma 1 *After the regulation, only the following two strategies satisfy the relevant (IC) and (IR) constraints for consumers, and are consistent with each firm's optimal choice of prices:*

- *Pooling strategy where both types of consumers choose opt-in purchase, which requires (6);*
- *Separating strategy where type-l consumers choose opt-in purchase and type-h consumers choose opt-out purchase, which requires (7).*

Proof: See the appendix. ∎

We now solve for all possible equilibria. Given that each firm has two possible pricing strategies, there are four possible types of equilibria. We proceed as follows. First, we will posit a putative equilibrium where firm A chooses one of the two pricing strategies in Lemma 1 and firm B chooses another pricing strategy. We then solve for a candidate equilibrium given the chosen pair of pricing strategies. Second, we will consider all possible deviations when one firm chooses a different pricing strategy while the other firm stays with the pricing strategy in the candidate equilibrium. Any profitable deviation by either firm implies that the putative equilibrium cannot be an equilibrium. We solve for the putative equilibrium that survives all possible deviations by both firms.

5.2.1 Pooling equilibrium

Let us start with an equilibrium in which both types of consumers choose opt-in purchase. The required conditions are (6), the corresponding conditions for firm B, and the indifference conditions $u^I_{hA}(z_h) = u^I_{hB}(z_h)$ and $u^I_{lA}(z_l) = u^I_{lB}(z_l)$. The two indifference conditions lead to the identical marginal consumer, $z_h = z_l = (t - p^I_A + p^I_B)/(2t)$. Thus, we have the same problem as that before the regulation characterized in (5). The only difference is that the pooling equilibrium may exist for a smaller range of parameter values due to the additional conditions required to ensure its existence. We spell out these conditions below.

First, consider (6). As in the pooling equilibrium before the regulation, the (IC) and (IR) constraints for the pooling equilibrium here are satisfied under Assumption 2. In addition, to sustain this equilibrium, the off-the-path opt-out price p^O_j must satisfy $p^I_j \leq p^O_j - c$ for $j = A, B$, preventing type-h consumers from opting out.

It remains to check if any additional conditions are needed to ensure that firms do not deviate. In the proof of the following lemma, we show that neither firm deviates from the pooling equilibrium if

$$c < \min\{\alpha_A, \alpha_B\}. \tag{8}$$

If condition (8) is not satisfied, then at least one firm can benefit by deviating to the separating strategy. For example, if $\alpha_A < c$, then firm A can deviate by choosing the separating strategy. Firm A can benefit from the deviation by increasing the price for type-h consumers who opt out, which more than compensates for the lost data-driven revenue from these consumers. Thus we have the following result.

Lemma 2 *The pooling equilibrium exists if and only if $c < \min\{\alpha_A, \alpha_B\}$ and the equilibrium outcome is the same as that before the regulation, which is characterized in (5).*

Proof: See the appendix. ∎

The above lemma shows that the pooling equilibrium exists for a smaller set of parameter values after the regulation than before the regulation. This is because the regulation allows firms more ways to deviate from the putative equilibrium. The additional condition for the existence of pooling equilibrium is $c < \min\{\alpha_A, \alpha_B\}$. That is, both firms earn considerable data-driven revenue relative to the privacy cost they need to compensate type-h consumers for choosing opt-in purchase. A corollary to the above lemma is that the pooling equilibrium fails to exist when firms are sufficiently asymmetric in their data-driven revenue. As discussed above, if $\alpha_A < c < \alpha_B$, then firm A benefits from deviating from the pooling equilibrium.

5.2.2 Separating equilibrium

Consider now the case where both firms choose the separating strategy, which leads to a putative separating equilibrium where all type-l consumers choose opt-in purchase and all type-h consumers choose opt-out purchase. The putative separating equilibrium requires conditions (7), the corresponding conditions for firm B, and the following indifference conditions:

$$u^O_{hA}(z_h) = u^O_{hB}(z_h) \Leftrightarrow z_h = (t - p^O_A + p^O_B)/(2t);$$

$$u^I_{lA}(z_l) = u^I_{lB}(z_l) \Leftrightarrow z_l = (t - p^I_A + p^I_B)/(2t).$$

Given the above conditions, each firm's profit can be written as follows:

$$\pi_A = p^O_A \theta z_h + (p^I_A + \alpha_A)(1-\theta)z_l; \quad \pi_B = p^O_B \theta(1-z_h) + (p^I_B + \alpha_B)(1-\theta)(1-z_l).$$

When firms compete using versioning, they compete separately for each consumer type, subject only to the relevant constraints. As is clear from the above profit functions, each firm's optimization problem for type-l consumers is the same as that before the regulation, while the problem for type-h consumers is the same as the standard Hotelling problem. Ignoring the constraints for now and solving the firms' problems, we obtain

$$\begin{gathered} \hat{p}^I_A = \frac{3t - 2\alpha_A - \alpha_B}{3}, \; \hat{p}^I_B = \frac{3t - \alpha_A - 2\alpha_B}{3}, \; \hat{z}_l = \frac{3t + \alpha_A - \alpha_B}{6t}, \\ \hat{p}^O_A = \hat{p}^O_B = t, \; \hat{z}_h = 1/2, \\ \widehat{CS} = v - \frac{5t}{4} + \frac{(1-\theta)\left((\alpha_A - \alpha_B)^2 + 18t(\alpha_A + \alpha_B)\right)}{36t}, \\ \hat{\pi}_A = \frac{t\theta}{2} + \frac{(1-\theta)(3t + \alpha_A - \alpha_B)^2}{18t}, \; \hat{\pi}_B = \frac{t\theta}{2} + \frac{(1-\theta)(3t - \alpha_A + \alpha_B)^2}{18t}. \end{gathered} \tag{9}$$

Note that the equilibrium price does not change for type-l consumers. For type-h consumers, the equilibrium price and each firm's market share change. Since they choose opt-out purchase after the regulation, α_A and α_B do not play a role in competition for type-h consumers.

Let us verify the (IC) and (IR) constraints necessary for the putative equilibrium in (9). Given Assumption 2, it is straightforward to confirm that the (IR) constraints are satisfied. In addition, it is easy to verify that the (IC) constraint for type-l consumers is satisfied, while the (IC) constraint for type-h consumers is satisfied if and only if

$$3c \geq \max\{2\alpha_A + \alpha_B, \alpha_A + 2\alpha_B\}. \tag{10}$$

The final step is to verify whether either firm has profitable deviations and to derive any additional conditions that ensure no such deviations exist. In the proof of Lemma 3, we derive the threshold functions $\overline{\alpha}_A(\alpha_B)$ and $\overline{\alpha}_B(\alpha_A)$, and show that the no-deviation conditions are given by $\alpha_A < \overline{\alpha}_A(\alpha_B)$ and $\alpha_B < \overline{\alpha}_B(\alpha_A)$. Moreover, condition (10) is satisfied under these additional conditions. Thus, the no-deviation conditions impose an upper bound on the size of marginal data-driven revenue for both firms. As discussed previously, the separating strategy is more likely to be optimal for both firms if their data-driven revenue is not significant.

Lemma 3 *If $\alpha_A < \overline{\alpha}_A(\alpha_B)$ and $\alpha_B < \overline{\alpha}_B(\alpha_A)$, where $\overline{\alpha}_A(\alpha_B)$ and $\overline{\alpha}_B(\alpha_A)$ are derived in the appendix, then there exists a separating equilibrium characterized in (9).*

Proof: See the appendix. ∎

In contrast to the pooling equilibrium, the separating equilibrium exists when the marginal data-driven revenue is small relative to the privacy cost. For example, if $\alpha_A = \alpha_B = \alpha$, then the separating equilibrium exists when $c \geq \alpha$, whereas the pooling equilibrium exists when $c < \alpha$.

The intuition is clear. Firms are more likely to separate the two types of consumers if the lost data-driven revenue from type-h consumers from doing so is not significant. In addition, (10) implies that α_A and α_B cannot exceed $(3c)/2$. Thus, the existence of separating equilibrium requires that there is not a significant degree of asymmetry in data-driven revenue across firms.

5.2.3 Asymmetric equilibria

We now examine the possibility of an asymmetric equilibrium where one firm chooses the separating strategy and the other firm chooses the pooling strategy. Intuitively, such an asymmetric equilibrium is possible when firms are sufficiently asymmetric in their data-driven revenue. Suppose α_A is small and α_B is large. Then, firm A is likely to choose the separating strategy and firm B, the pooling strategy. This can be an equilibrium outcome for following reasons. First, firm A's deviation to the pooling strategy can be costly because the deviation involves cutting its opt-in price but at no significant gains in data-driven revenue. Second, firm B's deviation to the separating strategy can be costly because the deviation entails losing data-driven revenue from type-h consumers.

We solve for the asymmetric equilibrium discussed above. Suppose firm A chooses the separating strategy (p_A^I, p_A^O) while firm B chooses the pooling strategy p_B^I. These prices need to satisfy the relevant (IC) and (IR) constraints. The marginal type-l consumer is given by $z_l = (t - p_A^I + p_B^I)/(2t)$ and the marginal type-h consumer is given by $z_h = (t + c - p_A^O + p_B^I)/(2t)$. Then, firm A's profit is $\pi_A = p_A^O \theta z_h + (p_A^I + \alpha_A)(1-\theta) z_l$ and firm B's profit is $\pi_B = (p_B^I + \alpha_B)\left[\theta(1-z_h) + (1-\theta)(1-z_l)\right]$. Solving the firms' problems, we obtain

$$\begin{gathered}
\hat{p}_A^I = \frac{6t - \theta c - (4-\theta)\alpha_A - 2\alpha_B}{6}, \ \hat{p}_A^O = \frac{6t + (3-\theta)c - (1-\theta)\alpha_A - 2\alpha_B}{6}, \\
\hat{p}_B^I = \frac{3t - \theta c - (1-\theta)\alpha_A - 2\alpha_B}{3}, \\
\hat{z}_l = \frac{6t - \theta c + (2+\theta)\alpha_A - 2\alpha_B}{12t}, \ \hat{z}_h = \frac{6t + (3-\theta)c - (1-\theta)\alpha_A - 2\alpha_B}{12t}, \\
\hat{\pi}_A = \frac{4(\alpha_A - \alpha_B + 3t)^2 + \theta(\alpha_A - c)((1-5\theta)\alpha_A + 8\alpha_B - (9-5\theta)c - 24t)}{72t}, \\
\hat{\pi}_B = \frac{(\alpha_B - (1-\theta)\alpha_A + 3t - \theta c)^2}{18t}.
\end{gathered} \tag{11}$$

We now check the (IC) and (IR) constraints necessary for the above equilibrium. First, it is easy to verify that the (IR) constraints are satisfied under Assumption 2. Second, for consumers served by firm A, type-l consumers' (IC) constrains are satisfied since $\hat{p}_A^O > \hat{p}_A^I$, and type-$h$ consumers' (IC) constraints hold if and only if $c \geq \alpha_A$. Third, for consumers served by firm B, the (IC) constraints are satisfied given a suitable restriction on off-the-path price $\hat{p}_B^O$. Thus, given Assumption 2, the (IC) and (IR) constraints for the asymmetric equilibrium are satisfied if and only if

$$\alpha_A \leq c. \tag{12}$$

For the prices in (11) to constitute the asymmetric equilibrium under consideration, we also need to check that neither firm has incentives to deviate from the putative equilibrium. First, consider firm A's deviation to the pooling strategy. This is unlikely to be profitable given (12), since $c \geq \alpha_A$ implies that firm A cannot benefit from inducing type-h consumers to choose opt-in purchase. On the other hand, firm B may benefit from the deviation to the separating strategy if the decrease in data-driven revenue from type-h consumers following the deviation is not large. This implies that firm B is unlikely to deviate from the pooling strategy if its data-driven revenue is significant, or α_B is above a certain threshold. In the proof of Lemma 4, we derive the threshold value of α_B, denoted by $\underline{\alpha}_B(\alpha_A)$ such that, firm B does not deviate from the pooling strategy if and only if $\alpha_B \geq \underline{\alpha}_B(\alpha_A)$.

Following the same analysis, we can identify conditions under which a mirroring asymmetric equilibrium exists where firm A chooses the pooling strategy and firm B chooses the separating strategy. First, the condition required to satisfy (IC) and (IR) constraints mirror (12), which is given by

$$\alpha_B \leq c. \tag{13}$$

Second, the condition for no deviation by firm A requires a lower bound for α_A, similar to the no deviation condition for firm B, which we denote by $\underline{\alpha}_A(\alpha_B)$.

Lemma 4 *There are two possible asymmetric equilibria as follows.*

- *If $\alpha_A \leq c$ and $\alpha_B \geq \underline{\alpha}_B(\alpha_A)$ where $\underline{\alpha}_B(\alpha_A)$ is derived in the appendix, then there exists an asymmetric equilibrium where firm A chooses the separating strategy and firm B chooses the pooling strategy, which is characterized in (11).*

- *If $\alpha_B \leq c$ and $\alpha_A \geq \underline{\alpha}_A(\alpha_B)$ where $\underline{\alpha}_A(\alpha_B)$ is derived in the appendix, then the asymmetric equilibrium that mirrors the above asymmetric equilibrium exists where firm A chooses the pooling strategy and firm B chooses the separating strategy.*

Proof: See the appendix. ∎

5.2.4 Equilibrium

Based on the analysis so far, we can fully characterize all possible equilibria after the regulation as follows.

Proposition 5 *The equilibrium under competition after the regulation is given as follows.*

- *If $c < \min\{\alpha_A, \alpha_B\}$, then the pooling equilibrium exists and is given in (5).*

- *If $\alpha_A < \overline{\alpha}_A(\alpha_B)$ and $\alpha_B < \overline{\alpha}_B(\alpha_A)$, then the separating equilibrium exists and is given in (9).*

- *If $\alpha_A \leq c$ and $\alpha_B \geq \underline{\alpha}_B(\alpha_A)$, then the asymmetric equilibrium exists where firm A chooses the separating strategy and firm B chooses the pooling strategy, which is given in (11).*

- *If $\alpha_B \leq c$ and $\alpha_A \geq \underline{\alpha}_A(\alpha_B)$, then the asymmetric equilibrium that mirrors the above asymmetric equilibrium exists where firm A chooses the pooling strategy and firm B chooses the separating strategy.*

As shown in the proof of Lemma 4, $\underline{\alpha}_B(\alpha_A)$ decreases in α_A, $\underline{\alpha}_B(c) = c$, and $\underline{\alpha}_B(0) > c$. In addition, one can verify that $\underline{\alpha}_B(\alpha_A) < \overline{\alpha}_B(\alpha_A)$. This implies that, in the region where $\alpha_A \leq c$ and $\underline{\alpha}_B(\alpha_A) < \alpha_B < \overline{\alpha}_B(\alpha_A)$, the separating equilibrium and the asymmetric equilibrium in (11) can coexist. Likewise, one can verify $\underline{\alpha}_A(\alpha_B) < \overline{\alpha}_A(\alpha_B)$, which implies that, in the region where $\alpha_B \leq c$ and $\underline{\alpha}_A(\alpha_B) < \alpha_A < \overline{\alpha}_A(\alpha_B)$, the separating equilibrium and the mirroring asymmetric equilibrium can coexist. The existence of multiple equilibria is due to the fact that each firm makes choice in two steps, the choice of pricing strategy – pooling or separating – and the choice of prices given the chosen pricing strategy. Given this, multiplicity results from the firm's different expectations about the other firm's choice of pricing strategy in the first step. We explain this below.

Suppose one firm, say firm A, expects firm B to choose the separating strategy, and responds to this by choosing the separating strategy when α_A is small. To this, firm B's best response is indeed to choose the separating strategy if α_B is small, which leads to the separating equilibrium where prices are given in (9). Suppose now firm A forms a different expectation that firm B will choose the pooling strategy because α_B is not too small in the sense that $\underline{\alpha}_B(\alpha_A) < \alpha_B < \overline{\alpha}_B(\alpha_A)$. To this, firm A's best response is to choose the separating strategy given that α_A is small, but with different best response function in the second step. Firm B's best response to this is indeed to choose the pooling strategy, which leads to the asymmetric equilibrium and equilibrium prices given in (11). To summarize, when α_A is small and α_B is in the intermediate range, the equilibrium can be separating or asymmetric depending on firm A's expectations: it is separating if firm A expects firm B to choose the separating strategy; it is asymmetric if firm A expects firm B to choose the pooling strategy.

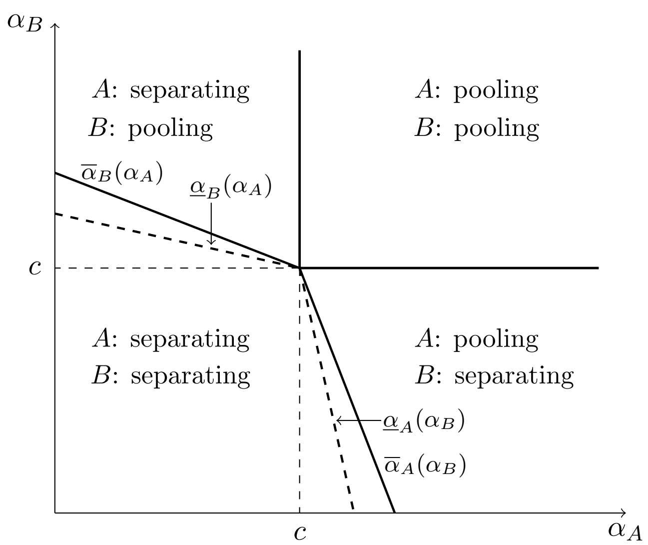

Figure 1: Equilibria corresponding to different values of (α_A, α_B)

In Figure 1, we show the values of (α_A, α_B) that correspond to different types of equilibria. Black, solid lines divide the (α_A, α_B) space into four regions, as described in Proposition 5. Solid lines labeled $\overline{\alpha}_A(\alpha_B)$ and $\overline{\alpha}_B(\alpha_A)$ satisfy the following properties as shown in the proof of Lemma 3: $\overline{\alpha}_i(\alpha_j)$ decreases in α_j, $\overline{\alpha}_i(c) = c$, and $c \leq \overline{\alpha}_i(\alpha_j) < 3c/2 - \alpha_j/2$, for $i, j = A, B$ and $i \neq j$. Although not shown in the figure, in the region where $\alpha_A \leq c$ and $\underline{\alpha}_B(\alpha_A) < \alpha_B < \overline{\alpha}_B(\alpha_A)$, there is also an asymmetric equilibrium where firm B chooses the pooling strategy. Likewise, in the region where $\alpha_B \leq c$ and $\underline{\alpha}_A(\alpha_B) < \alpha_A < \overline{\alpha}_A(\alpha_B)$, there is also an asymmetric equilibrium where firm A chooses the pooling strategy.

5.3 Comparing the duopoly equilibrium before and after the regulation

In this section, we compare the equilibrium before and after the regulation. Since the outcome in the pooling equilibrium is the same as the equilibrium outcome before the regulation, we focus our discussions on the comparison with the separating and asymmetric equilibria after the regulation. To facilitate our discussions, we provide Table 1 which shows changes in profit and consumer surplus after the regulation in different types of equilibria, where (+) indicates an increase and (–), a decrease, and CS_θ denotes type-θ consumers' surplus, $\theta = h, l$.

Table 1: Welfare change in the duopoly equilibrium after the regulation

	Separating	Asymmetric ($\alpha_A \leq \alpha_B$)	Asymmetric ($\alpha_A > \alpha_B$)
$\Delta\pi_A$	(+) iff $\alpha_A \leq \alpha_B$	(+)	(–)
$\Delta\pi_B$	(+) iff $\alpha_A \geq \alpha_B$	(–)	(+)
$\Delta\pi = \Delta(\pi_A + \pi_B)$	(–)	(–)	(–)
ΔCS_h	(+)	(+)	(+)
ΔCS_l	no change	(+)	(+)
$\Delta CS = \Delta(CS_h + CS_l)$	(+)	(+)	(+)

Let us start with the separating equilibrium. That is, we compare (5) and (9). Consider consumer surplus. Type-l consumers choose opt-in purchase both before and after the regulation and their opt-in price does not change, implying that their consumer surplus does not change. Type-h consumers switch from opt-in purchase to opt-out purchase, so that the effective price they pay changes from $p_A^* + c$ (or $p_B^* + c$) to t. It is easy to check $p_A^* + c \geq t$ and $p_B^* + c \geq t$ under the condition for the separating equilibrium, i.e., $3c \geq \max\{2\alpha_A + \alpha_B, \alpha_A + 2\alpha_B\}$. So all type-$h$ consumers pay a lower effective price after the regulation. In addition, two firms have an equal share of type-h consumers after the regulation. With two firms located at a maximal distance from each other, the average transportation cost is minimized when the marginal consumer is located at 1/2, which is the case after the regulation. Put together, type-h consumers benefit from the regulation from the lower effective price and the smaller transportation cost. Given this and the fact that the consumer surplus for type-l consumers stays the same, total consumer surplus increases after the regulation.

Then how does the regulation affect firms? Since each firm's profit from type-l consumers remains the same, the impact of regulation on profits is only through type-h consumers. Before the regulation, type-h consumers choose opt-in purchase. This implies that the more data-driven firm, i.e., the firm with larger α, has an advantage over the less data-driven firm because α plays a role as a price subsidy. As shown previously, the more data-driven firm is more aggressive before the regulation: it charges a lower price and secures a larger market share before the regulation. But such an advantage disappears after the regulation when facing type-h consumers because they choose opt-out purchase. After the regulation, both firms charge the same opt-out price, which increases the market share for the less data-driven firm and increases its profit. Specifically, firm A's profit from type-h consumers is $(1-\theta)(3t+\alpha_A-\alpha_B)^2/(18t)$ before the regulation, and is equal to $(1-\theta)t/2$ after the regulation. The former is larger than the latter if and only if $\alpha_A \geq \alpha_B$. In sum, the less data-driven firm's profit increases while the more data-driven firm's profit decreases after the regulation.

On the other hand, the decrease in the amount of data shared results in smaller industry profit after the regulation. To see this, note that the industry profit from type-l consumers remains the same but that from type-h consumers changes from $(1-\theta)[(3t+\alpha_A-\alpha_B)^2+(3t+\alpha_B-\alpha_A)^2]/(18t)$ before the regulation to $(1-\theta)t$ after the regulation. It is easy to see that the former is larger than the latter, and they are equal to each other if and only if $\alpha_A = \alpha_B$. In sum, the industry profit decreases in the separating equilibrium after the regulation unless firms are symmetric in their data-driven revenue.

The comparison with the asymmetric equilibrium can be done similarly. First, compared to the equilibrium before the regulation, the firm that chooses the separating strategy has higher profit, the firm that chooses the pooling strategy has lower profit, but the industry profit is lower in the asymmetric equilibrium. Again, this is because the regulation reduces the competitive disadvantage that the less data-driven firm has before the regulation. As a result, the less data-driven firm chooses the separating strategy, which intensifies competition for type-l consumers and hurts the more data-driven firm. On the other hand, prices adjusted for privacy costs are lower after the regulation, implying that consumer surplus increases after the regulation for both types of consumers, hence the total consumer surplus increases. Comparing (5) and (11), we can verify that $\hat{p}_B^I < p_B^*$, $\hat{p}_A^I < p_A^*$, and $\hat{p}_A^O < p_A^* + c$.

Proposition 6 *Comparing the equilibrium under competition before the regulation with the separating or asymmetric equilibria after the regulation, we have the following:*

- *The firm with smaller (larger, resp.) α has higher (lower, resp.) profit after the regulation.*
- *Industry profit is smaller after the regulation for all $\alpha_A \neq \alpha_B$.*
- *Total consumer surplus is larger after the regulation.*

Proof: See the appendix. ∎

Our analysis shows that the regulation benefits consumers but hurts industry profit whether the post-regulation equilibrium is separating or asymmetric. This is in stark contrast to the monopoly case. In Section 4, we have shown that the monopolistic firm's profit increases in the separating equilibrium after the regulation. Under competition, however, industry profit decreases, the main driver of which is consumers who switch from opt-in to opt-out purchase after the regulation. The less data-driven firm becomes more aggressive in competing for these consumers, which intensifies competition and benefits consumers. The key takeaway from this analysis is that privacy regulations have nuanced effects on market outcomes, with different impact on profits and consumer surplus depending on the market structure.

6 Extensions and Discussions

6.1 Strategic choice of revenue models

One of the main findings from our analysis is that the regulation has differential effects on competing firms depending on their data-driven revenue models. In all post-regulation equilibria except the pooling equilibrium, the firm with a more data-driven revenue model (larger α) is worse off after the regulation. This may prompt the firm to adjust its revenue model in response to the regulation. For example, suppose $\alpha_A > \alpha_B$ so that firm A has a more data-driven revenue model than firm B. The regulation erodes firm A's competitive advantage and makes firm B more aggressive and, as a result, firm A's profit decreases. Then, the relevant question is how firm A should adjust α_A following the regulation. If firm A reduces α_A, for example, by cutting down the number of its data-driven revenue streams, then the direct effect is a decrease in data-driven revenue. But it has an indirect strategic effect: by reducing α_A, firm A can mitigate firm B's aggressive pricing following the regulation. As can be checked from (9) and (11), firm B's equilibrium price increases when α_A decreases. Conversely, increasing α_A presents a trade-off between higher data-driven revenue and increased price competition. Firm A's optimal choice of α_A is based on balancing the above trade-off, which is analyzed below.

We analyze firm A's problem of choosing $\alpha_A \in [0, \alpha^M]$ at no cost, assuming that firm B does not change α_B.[16] Firm A's optimal choice of α_A depends on the post-regulation equilibrium given the pre-regulation values of α_A and α_B. Observe from (5), (9), and (11) that firm A's profit in the post-regulation equilibrium increases in α_A in the following three types of equilibria: (pooling, pooling), (separating, separating), and (pooling, separating).[17] In these cases, provided that firm A's adjustment of α_A does not induce a change in equilibrium type, its profit increases in α_A, making $\alpha_A = \alpha^M$ its optimal choice. Consequently, the optimal value of α_A may deviate from α^M only in the asymmetric equilibrium (separating, pooling), or when firm A adjusts α_A to shift the equilibrium to a different type. To explain this, we present Figure 2, which depicts firm A's profit as a function of α_A in different post-regulation equilibria across three ranges of α_B, given the parameters $t = 1$, $\theta = 0.9$, and $c = 2$.

We start by noting that, in the equilibrium (separating, pooling), firm A's profit is quadratic in α_A with a U-shaped profit function, as evident from (11). This implies that firm A's profit increases (decreases, resp.) when α_A decreases if the pre-regulation value of α_A lies to the left (right, resp.) of the symmetric axis of its profit function. The intuition is as follows. In the asymmetric equilibrium (separating, pooling), a decrease in α_A increases firm A's profit from type-h consumers because lowering α_A softens competition, given that firm B adopts the pooling strategy. This enables firm A to raise its opt-out price $\hat{p}_A^O$, without any change in data-driven revenue from type-h consumers as they choose opt-out. However, firm A's profit from type-l consumers decreases when α_A decreases due to the decrease in data-driven revenue, i.e., $\hat{p}_A^I + \alpha_A$ decreases. Consequently, if the proportion of type-h consumers (θ) is sufficiently large,

[16] A more general approach involves solving each firm's problem of choosing optimal α at some costs. This would require an assumption about the form of cost function, regarding which we remain agnostic. Therefore, we focus only on analyzing one firm's best response problem.

[17] In (11), firm A chooses the separating strategy. Since the asymmetric equilibrium (pooling, separating) mirrors the asymmetric equilibrium (separating, pooling) characterized in (11), firm A's profit in the former is equivalent to firm B's profit in the latter, with α_A and α_B interchanged.

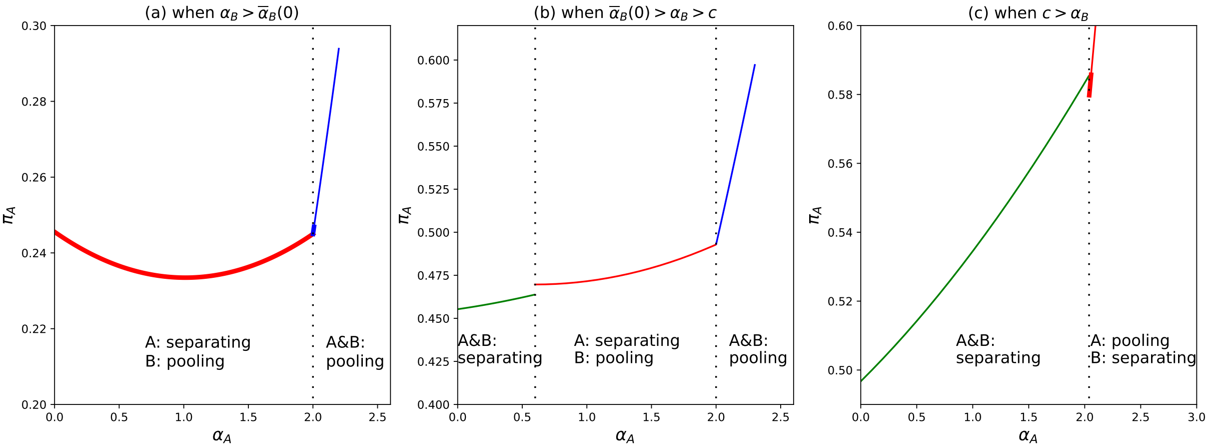

Figure 2: Firm A's profit in the post-regulation equilibrium

the increase in profit from type-h consumers can outweigh the decrease in profit from type-l consumers. Conversely, if the proportion of type-h consumers is small, the opposite holds. In summary, in the asymmetric equilibrium (separating, pooling), firm A can increase its profit by reducing α_A, necessary conditions of which include sufficiently large θ and α_B.

Panel (a) of Figure 2 shows firm A's equilibrium profit when $\alpha_B \geq \overline{\alpha}_B(0)$. In this case, α_B is large enough so that firm B always adopts the pooling strategy. Then, the post-regulation equilibrium is pooling when $\alpha_A \geq c$ and firm A's profit monotonically increases in α_A. However, as α_A decreases below the threshold $\alpha_A = c$, the equilibrium transitions to (separating, pooling), and firm A's profit is a U-shaped function of α_A, as discussed above. Consequently, firm A's optimal choice is either $\alpha_A = \alpha^M$ (the maximum possible value of α) or $\alpha_A = 0$ (a complete shutdown of its data-driven revenue streams), depending on α^M and the location of the symmetric axis of firm A's profit function.

Panel (b) of Figure 2 illustrates firm A's equilibrium profit when $\overline{\alpha}_B(0) > \alpha_B > c$. As depicted in the figure, as α_A decreases, the post-regulation equilibrium transitions from (pooling, pooling) to (separating, pooling) and then to (separating, separating), with the boundaries at $\alpha_A = c$ and $\alpha_A = \overline{\alpha}_B^{-1}(\alpha_B)$ where $\overline{\alpha}_B^{-1}(\cdot)$ is the inverse function of $\overline{\alpha}_B(\cdot)$. Firm A's profit in the pooling equilibrium is uniformly higher than that in the separating equilibrium. Moreover, the condition $\alpha_B > c$ implies that $\alpha^M > c$. Consequently, $\alpha_A = 0$ is never the optimal choice for firm A in this case. Within the remaining range of α_A, the equilibrium is either asymmetric or pooling, which mirrors case (a). It follows that firm A's optimal choice is either $\alpha_A = \alpha^M$ or $\alpha_A = \overline{\alpha}_B^{-1}(\alpha_B)$, depending on the values of α^M, α_B, and θ, with the specific conditions detailed in the appendix.

Finally, panel (c) of Figure 2 illustrates the case where $\alpha_B \leq c$, implying that firm B always adopts the separating strategy. As firm A reduces α_A, the equilibrium transitions from (pooling, separating) to (separating, separating), with the boundary at $\alpha_A = \overline{\alpha}_A(\alpha_B)$. Firm A's profit increases in α_A in both equilibria, but it is discontinuous at the boundary $\alpha_A = \overline{\alpha}_A(\alpha_B)$. The discontinuity arises because, at the boundary, firm A is indifferent between adopting the separating strategy and deviating to the pooling strategy, given that firm B's price is fixed at the level in the separating equilibrium. Since firm B's price in the (pooling, separating) equilibrium differs from that in the separating equilibrium, π_A is discontinuous at $\alpha_A = \overline{\alpha}_A(\alpha_B)$. Notably, at the boundary, firm A's profit in the (pooling, separating) equilibrium is always lower than that in the separating equilibrium. Consequently, firm A's optimal choice is either $\pi_A = \alpha^M$ or, if α^M is not too large, $\alpha_A = \overline{\alpha}_A(\alpha_B)$.

Proposition 7 *Given α_B, firm A's optimal choice of α_A following the regulation is as follows:*

- $\alpha_A = 0$ *or* $\alpha_A = \alpha^M$ *if* $\alpha_B > \overline{\alpha}_B(0)$*;*
- $\alpha_A = \overline{\alpha}_B^{-1}(\alpha_B)$ *or* $\alpha_A = \alpha^M$ *if* $\overline{\alpha}_B(0) > \alpha_B > c$*;*
- $\alpha_A = \overline{\alpha}_A(\alpha_B)$ *or* $\alpha_A = \alpha^M$ *if* $c > \alpha_B$*;*

where $\overline{\alpha}_B^{-1}(\cdot)$ *is the inverse function of* $\overline{\alpha}_B(\cdot)$*.*

Proof: See the appendix. ∎

The main takeaway from the above analysis is that firms may respond to the regulation by optimally adjusting their data-driven revenue models. However, the adjustment is not uniform, as it depends on various factors such as the competitor's revenue model, the proportion of privacy-conscious consumers, and the firm's data-riven revenue model prior to the regulation. The key consideration lies in the trade-off between the changes in profit from more privacy-conscious consumers and those from less-privacy conscious consumers. This trade-off ultimately shapes how firms adapt their strategies in response to the regulatory environment. Interestingly, the more data-driven firm may strategically choose to reduce its dependence on data, even though a more data-driven model is feasible under the regulation.

6.2 Privacy regulations and firm entry

There is substantial evidence that the regulation has created entry barriers for new firms, especially small firms and startups (Jia et al., 2021; Janßen et al., 2022; Peukert et al., 2022; Goldberg et al., 2024). First, high compliance costs and legal risks have made entry less attractive to small startups that lack resources.[18] Second, many new firms often rely on data-driven business models, so the reduction in data sharing following the regulation makes it harder for the entrants to compete with incumbents with large existing datasets. Third, the regulation has led to a sustained decline in both the number and size of venture capital deals for technology startups, with the impact particularly pronounced for data-reliant, consumer-facing ventures and early-stage startups.

Beyond the direct costs and operational adjustments imposed by the regulation, other strategic factors can further exacerbate or mitigate how the regulation affects firm entry. As our analysis has shown, the regulation can create a relative advantage for firms with less data-driven revenue models. This suggests that the regulation can ease entry for firms whose core operations are not heavily reliant on data, particularly when competing against incumbents with more data-driven revenue models. Conversely, firms with more data-driven revenue models

[18] Demirer et al. (2024) suggest that GDPR compliance costs can range from $1.7 million for small to medium-sized firms to $70 million for large ones.

may find entry more challenging after the regulation. This section examines how the regulation affects firm entry by exploring the strategic dynamics that shape its impact on competition.

Suppose firm A is an incumbent located at 0 on the Hotelling line, while firm B is a potential entrant. To simplify the analysis, we assume that firm B locates at 1 if it enters. Entry requires a one-off cost F, and the parameters α_A and α_B are exogenously given. Our objective is to study how the regulation influences firm B's likelihood of entry. To this end, we compare the set of (α_B, F) for which entry occurs before and after the regulation, given α_A.[19]

Before the regulation, firm B's post-entry profit is given in (5). Thus, firm B will enter if

$$\pi_B^* = \frac{(3t - \alpha_A + \alpha_B)^2}{18t} \geq F. \tag{14}$$

Denote the set of (α_B, F) that satisfies (14) by E^b.

The post-regulation entry game can lead to three types of equilibria depending on (α_A, α_B). Let E^a denote the set of (α_B, F) for which firm B's profit in the post-regulation equilibrium is higher than F. First, if the post-regulation equilibrium is pooling, then firm B's profit remains unchanged before and after the regulation, as does the condition for its entry. Thus, in this case, we have $E^b = E^a$ subject to the condition for the existence of pooling equilibrium, i.e., $\min\{\alpha_A, \alpha_B\} > c$. Second, if the post-regulation equilibrium is separating, then we have $\hat{\pi}_B \geq \pi_B^*$ if and only if $\alpha_B \leq \alpha_A$ where $\hat{\pi}_B$ is given in (9). Thus, the regulation makes firm B's entry easier, hence $E^b \subset E^a$, if and only if $\alpha_B \leq \alpha_A$ subject to the conditions for the existence of separating equilibrium. The same is true if the post-regulation equilibrium is asymmetric: in the post-regulation equilibrium where firm B plays the separating strategy, firm B's profit is higher after the regulation, so its entry is more likely. We summarize our discussions below.

Proposition 8 *The regulation makes firm entry easier if the entrant has a less data-driven revenue model than the incumbent, but harder if the entrant has a more data-driven revenue model than the incumbent.*

6.3 Two examples of competition between firms with asymmetric data-driven revenue models

6.3.1 News aggregators: Apple News vs Google News

A news aggregator is an online platform that collects news articles and other information from diverse sources, prioritizes content using algorithms based on user preferences, and provides a tailored news feed by consolidating content in a single location. Apple News and Google News are two main players in this market. As we discuss below, competition between these two news aggregators can be characterized by asymmetric data-driven revenue models.

Apple News has always included ad-supported content since its launch in September 2015. The platform aggregates news articles from various publishers, many of which rely on advertising for revenue. Apple News+, introduced in March 2019, is a subscription-based service within the

[19] We assume that F remains unchanged before and after the regulation. However, to the extent that compliance and other regulatory costs can increase F after the regulation, our result may overstate the positive effect of the regulation on firm entry.

Apple News app that provides access to a wide range of premium content, including hundreds of magazines and newspapers, and limited ads compared to the free version of Apple News. The subscription to Apples News+ costs $12.99 per month in the US.[20]

Like Apple News, Google News has also been an ad-supported service since its launch as a beta version in 2002 and an official release as an app in 2006. Although Google News itself does not generate direct revenue, it plays a crucial role in Google's overall ecosystem and contributes to the success of Google's advertising-driven business model. For example, Google News diverts traffic to publishers' websites, allowing publishers to monetize the traffic they receive through ads, with Google sharing the ad revenue. In 2020, Google News launched Google News Showcase, which is essentially ad-free and is designed to highlight curated content from participating publishers and provide financial support to the news industry.[21]

Apple is primarily a product-based company. The majority of Apple's revenue comes from hardware sales and services (App Store, Apple Music, etc.). Although the share of service-based revenue has been gradually increasing, hardware sales still account for the lion's share. For example, in the fourth quarter of 2024, Apple's revenue breakdown was as follows: iPhone (49%), services (26%), wearables, home, and accessories (10%), Mac (8%), and iPad (7%). On the other hand, Google is mainly a data-dependent company. Its core business model revolves around advertising, which relies heavily on user data to deliver targeted ads effectively. Google's financial results for the fourth quarter of 2024 show that advertising—combining Google search, Youtube and Google network ads—accounted for 68.2% of its total revenue, while the remainder came from other services such as subscriptions, other platform services, Google Cloud, etc. While it is worth noting that Google Cloud and other non-advertising segments have been gaining more prominence recently, Google's revenue model remains heavily data-driven.

6.3.2 Connected cars and usage-based insurance

Connected cars are vehicles equipped with internet connectivity and mobile technology, enabling two-way communication with external systems. These vehicles can transmit and receive data, supporting a wide range of features and services that enhance safety, efficiency, and user experience. The industry involves various types of firms, including traditional automakers, technology companies, and automotive suppliers. However, because connected cars collect extensive data about users,[22] the Mozilla Foundation has labeled them a "privacy nightmare,"[23] and the Federal Trade Commission also expressed concerns on multiple occasions regarding data collection and potential privacy violations associated with connected vehicles.[24] Below, we discuss how Ford and Tesla address these issues and argue that competition between these two automakers

[20] https://www.apple.com/apple-news/

[21] https://support.google.com/news/publisher-center/answer/10018888

[22] For example, a consumer disclosure report from LexisNexis provided to a Chevy Bolt driver spanned over 130 pages, detailing every drive over a six-month period and tracking metrics such as speed, braking intensity, and acceleration patterns. This was highlighted in the court case of Romeo Chicco against GM, OnStar, LLC, and LexisNexis on March 13, 2024 (https://www.reuters.com/legal/legalindustry/dashboard-confessions-unveiling-privacy-issues-connected-cars-2024-04-25/).

[23] https://foundation.mozilla.org/en/privacynotincluded/articles/its-official-cars-are-the-worst-product-category-we-have-ever-reviewed-for-privacy/

[24] https://www.ftc.gov/policy/advocacy-research/tech-at-ftc/2024/05/cars-consumer-data-unlawful-collection-use

also involves asymmetric data-driven revenue models.

Ford's US Privacy Notice[25] states that Ford and Lincoln vehicles are equipped with systems that record information related to vehicle performance, driving behavior, location, and environmental conditions. The categories of data collected from connected vehicles include vehicle data, driving data, vehicle location, audio/visual data, media analytics, and vehicle analytics. Similarly, Tesla's Customer Privacy Notice[26] outlines that Tesla collects data from or about a customer's vehicle, including vehicle information, customer support interactions, and claims information. Tesla also collects detailed driving data, such as forward collision warnings, hard breaking, aggressive turning, unsafe following distance, excessive speeding, and other metrics, which are then used to calculate the customer's "Safety Score."

Following the implementation of stricter privacy regulations, both Ford and Tesla have established privacy policies outlining consumer rights, particularly in US states with privacy laws. Ford's US Privacy Notice allows customers to access, edit, and delete some of the personal information collected, typically by logging into their account. Ford's California customers have additional rights under the California Consumer Privacy Act (CCPA), including the right to delete personal information under certain circumstances, subject to specific exceptions. Tesla's privacy policies also grant customers various data rights, including the right to be informed about, access, correct, and delete their personal data. Like Ford, Tesla also recognizes the specific rights of California residents under the CCPA, including the right to delete data and the right to opt out of the sale and sharing of their personal information. In summary, both Ford and Tesla have privacy policies that allow consumers to opt out of data collection from connected cars.[27]

The aforementioned discussion shows that both automakers employ versioning: opt-in with data collection and opt-out without data collection. While these options are not directly reflected in the vehicle's purchase price, they significantly impact insurance costs. Both companies offer data-driven usage-based insurance (UBI) programs, such as pay-how-you-drive options, for customers who choose to share more data. These programs typically offer premium discounts based on driving behavior. For example, Tesla's Safety Score updates regularly, leading to potential monthly adjustments in insurance premiums.[28] However, customers who limit data sharing may not be eligible for these UBI programs and will likely need to purchase standard insurance, potentially at a higher cost compared to UBI-based premiums. Therefore, the choice regarding data sharing indirectly affects the overall cost of vehicle ownership through insurance expenses.

Ford and Tesla employ distinct revenue models, reflecting their differing approaches to connected car technology. Ford primarily generates revenue from traditional vehicle sales and automotive services, though it is actively transitioning towards electric vehicles. Despite this shift, sales of combustion engine vehicles still constitute the vast majority of Ford's revenue. In 2022, Ford reported approximately $158 billion in total revenue, with over 95% attributed to

[25] https://www.ford.com/help/privacy/

[26] https://www.teslainsuranceservices.com/privacy-policy

[27] Opting out does not mean completely ceasing all data collection from a connected car, as this can be challenging and may impact vehicle functionality. Instead, opting out typically relates to specific types of data or the sharing of data with third parties, rather than stopping all data collection.

[28] https://www.tesla.com/support/insurance/tesla-real-time-insurance

vehicle sales. Revenue from services and data initiatives, particularly through Ford Next (formerly Mobility), remains a small fraction of total revenue, accounting for less than 5%.[29] Tesla's business model, in contrast, deeply integrates data collection and software services. Leveraging its Autopilot and Full Self-Driving (FSD) features, Tesla gathers extensive vehicle data to refine its software and enhance safety. This data-driven approach allows Tesla to generate significant revenue from software sales, notably through FSD packages. In 2024, Tesla reported approximately $97.7 billion in total revenue, with $10.53 billion (10.7%) derived from services and other sources, which includes revenue from software sales such as FSD features.[30] In summary, Ford's revenue model remains predominantly product-driven, centered on vehicle sales, while Tesla's is comparatively more data- and software-driven, leveraging its connected car technology and related services.

7 Conclusion

This paper has analyzed the economic impact of privacy regulations, focusing on consumer empowerment and versioning strategies adopted by firms. We have developed a model where consumers are heterogeneous in service valuation and privacy costs, and firms respond to the regulation by employing versioning strategies for opt-in and opt-out data sharing. In a monopoly, firms benefit from the regulation due to their ability to price discriminate, which outweighs the impact of increased consumer choice. However, in a duopoly, the regulation intensifies competition unless firms are symmetric in their data-driven revenue models, leading to decreased industry profits and increased consumer surplus. Our analysis has thus highlighted the nuanced effects of privacy regulations on market outcomes and welfare, depending on the market structure, consumers' privacy preferences, and firm characteristics.

The paper also underscores the importance of considering multi-dimensional consumer heterogeneity in studying privacy regulations, as well as the strategic adjustments firms may make in response to regulatory changes. We have shown that firms with less data-driven revenue models benefit from the regulation, while those with more data-driven models face significant challenges, highlighting how firms may adjust their data-driven revenue models following the regulation. We have also discussed the regulatory impact on firm entry and, consequently, market dynamics. These findings suggest avenues for future research. For example, empirical studies could examine the long-term effects of privacy regulations such as how firms in different sectors adapt their business models and data strategies over time to mitigate the impact of these regulations.

Appendix

Proof of Lemma 1: We start by discussing all purchase options available to consumers given (p_A^I, p_A^O). A type-h consumer $x \in [0, z_h]$ chooses opt-in purchase from firm A iff

$$(IC_{hA}^I):\ u_{hA}^I(x) \geq u_{hA}^O(x) \Leftrightarrow p_A^I \leq p_A^O - c; \quad (IR_{hA}^I):\ u_{hA}^I(x) \geq 0 \Leftrightarrow p_A^I \leq v - c - tx.$$

[29] https://shareholder.ford.com/Investors/financials/default.aspx
[30] https://stockanalysis.com/stocks/tsla/metrics/

A type-h consumer $x \in [0, z_h]$ chooses opt-out purchase from firm A iff

$$(IC_{hA}^O): \ u_{hA}^I(x) \leq u_{hA}^O(x) \Leftrightarrow p_A^I \geq p_A^O - c; \quad (IR_{hA}^O): \ u_{hA}^O(x) \geq 0 \Leftrightarrow p_A^O \leq v - tx.$$

A type-h consumer x does not buy the service from firm A iff

$$(N_{hA}) : u_{hA}^I(x), u_{hA}^O(x) \leq 0 \Leftrightarrow v - tx \leq \min\{p_A^I + c, p_A^O\}.$$

A type-l consumer $x \in [0, z_l]$ chooses opt-in purchase from firm A iff

$$(IC_{lA}^I): \ u_{lA}^I(x) \geq u_{lA}^O(x) \Leftrightarrow p_A^I \leq p_A^O; \quad (IR_{lA}^I): \ u_{lA}^I(x) \geq 0 \Leftrightarrow p_A^I \leq v - tx.$$

A type-l consumer $x \in [0, z_l]$ chooses opt-out purchase from firm A iff

$$(IC_{lA}^O): \ u_{lA}^I(x) \leq u_{lA}^O(x) \Leftrightarrow p_A^I \geq p_A^O; \quad (IR_{lA}^O): \ u_{lA}^O(x) \geq 0 \Leftrightarrow p_A^O \leq v - tx.$$

A type-l consumer x does not buy the service from firm A iff

$$(N_{lA}) : u_{lA}^I(x), u_{lA}^O(x) \leq 0 \Leftrightarrow v - tx \leq \min\{p_A^I, p_A^O\}.$$

Based on the above purchase options available to consumers, we discuss all possible pricing strategies available to firm A. To start, we note that firm A will never induce type-l consumers to choose opt-out purchase. It is because the required (IC) constraint dictates $p_A^I \geq p_A^O$. If a type-l consumer chooses opt-out purchase from firm A given $p_A^I \geq p_A^O$, then firm A can reduce p_A^I until $p_A^I = p_A^O$, which will induce the type-l consumer to choose opt-in purchase due to our tie-breaking assumption. This benefits firm A thanks to the data-driven revenue earned from the opt-in consumer. In short, choosing pricing strategies that satisfy (IC_{lA}^O) is not optimal for firm A. Given that firm A will never induce type-l consumers to choose opt-out purchase, we have the following possibilities.

First, both types of consumers choose opt-in purchase. This pooling strategy requires (IC_{hA}^I), (IR_{hA}^I), (IC_{lA}^I), and (IR_{lA}^I), which lead to (6). Second, type-l consumers choose opt-in purchase and type-h consumers choose opt-out purchase. In this case, p_A^O is chosen for all type-h consumers on $[0, z_h]$ and p_A^I for all type-l consumers on $[0, z_l]$. This strategy can be implemented given (IC_{hA}^O), (IR_{hA}^O), (IC_{lA}^I), and (IR_{lA}^I), which lead to (7).

This leaves two more possibilities. First, firm A serves only type-l consumers on $[0, z_l]$ through opt-in purchase and excludes type-h consumers. This cannot be optimal because firm A can set $p_A^O = p_A^I$, induce type-h consumers on $[0, z_l]$ to choose opt-out purchase, and earn additional usage-based revenue. Second, firm A serves only type-h consumers on $[0, z_h]$ and excludes type-l consumers. Again, this cannot be optimal because firm A can choose $p_A^I = p_A^O$, which will induce type-l consumers on $[0, z_h]$ to choose opt-in purchase. ∎

Proof of Lemma 2: It suffices to show that neither firm has incentives to deviate from the pooling equilibrium iff $c < \min\{c_A, c_B\}$. Consider firm A's deviation incentives. Firm A can deviate by choosing the separating or type-l only strategies. But the deviation to the type-l only strategy cannot be profitable. It is because firm A already serves type-l consumers through opt-in purchase in the putative equilibrium and, given firm B's price in the putative equilibrium, firm A's optimal opt-in price is the one in the putative equilibrium. But then, serving only type-l consumers results in lower profits for firm A than when it serves both types of consumers through opt-in purchase.

Consider now firm A's deviation to the separating strategy. Notice first that firm A continues to choose the same opt-in price as in the putative equilibrium. To see this, recall that firm A's profit in the pooling equilibrium is $\pi_A = (p_A^* + \alpha_A)z^*$ where $z^* = z_h^* = z_l^* = (1 - p_A^* + p_B^*)/(2t)$. Given firm A's deviation opt-in price denoted by $\tilde{p}_A^I$, its deviation profit from opt-in consumers is equal to $(\tilde{p}_A^I + \alpha_A)(1-\theta)\tilde{z}_l$ where $\tilde{z}_l = (1 - \tilde{p}_A^I + p_B^*)/(2t)$. Thus, the first-order condition for firm A's choice of opt-in price is essentially the same and, so is its optimal opt-in price given the same opt-in price chosen by firm B. That is, firm A's deviation to the separating strategy involves its opt-out price only, which is intended to induce some type-h consumers to switch from opt-in purchase to opt-out purchase.

Denote firm A's deviation opt-out price by $\tilde{p}_A^O$. Then the marginal type-h consumer $\tilde{z}_h$ is given by

$$v - t\tilde{z}_h - \tilde{p}_A^O = v - c - t(1 - \tilde{z}_h) - p_B^* \quad \Leftrightarrow \quad \tilde{z}_h = \frac{t + c - \tilde{p}_A^O + p_B^*}{2t}.$$

Following the deviation, firm A's profit from type-h consumers changes from $(p_A^* + \alpha_A)\theta z_h^*$ to $\tilde{p}_A^O\theta\tilde{z}_h$, but its profit from type-l consumers stays the same. Moreover, to ensure that type-h consumers choose opt-out purchase rather than opt-in purchase, $\tilde{p}_A^O \le p_A^* + c$ should hold. Solving for the optimal deviation price by maximizing $\tilde{p}_A^O\theta\tilde{z}_h$, we obtain firm A's optimal deviation price: $\tilde{p}_A^O = (6t + 3c - \alpha_A - 2\alpha_B)/6$ when $c \ge \alpha_A$ and $\tilde{p}_A^O = p_A^* + c = (3t + 3c - 2\alpha_A - \alpha_B)/3$ when $c < \alpha_A$.

We now calculate the change in firm A's profit from the deviation, $\Delta\tilde{\pi}_A := \tilde{p}_A^O\theta\tilde{z}_h - (p_A^* + \alpha_A)\theta z_h^*$. First, when $c \ge \alpha_A$, we have

$$\tilde{z}_h = \frac{6t + 3c - \alpha_A - 2\alpha_B}{12t},$$

hence

$$\Delta\tilde{\pi}_A = \frac{\theta(12t + 3c + \alpha_A - 4\alpha_B)(c - \alpha_A)}{24t} \ge 0$$

where the inequality follows since $c \ge \alpha_A$ and $12t+3c+\alpha_A-4\alpha_B = 4(3t+\alpha_A-\alpha_B)+3(c-\alpha_A) \ge 0$ by Assumption 3. Thus, the deviation is always profitable when $c \ge \alpha_A$. Second, when $c < \alpha_A$, we have

$$\tilde{z}_h = \frac{3t + \alpha_A - \alpha_B}{6t},$$

hence

$$\Delta\tilde{\pi}_A = \frac{\theta(3t + \alpha_A - \alpha_B)(c - \alpha_A)}{6t} < 0$$

where the inequality follows since $3t + \alpha_A - \alpha_B > 0$ by Assumption 3 and $c < \alpha_A$. Thus, the deviation is never profitable when $c < \alpha_A$.

Applying the same argument to firm B's deviation, we can show that firm B does not benefit from the deviation to the separating strategy if $c < \alpha_B$. Thus, neither firm deviates from the pooling equilibrium if $c < \min\{\alpha_A, \alpha_B\}$; otherwise, at least one firm can benefit by deviating to the separating strategy. ∎

Proof of Lemma 3: We derive the conditions for no profitable deviation to the pooling strategy. Suppose firm A deviates by choosing the pooling strategy. Let $\tilde{p}_A^I$ be firm A's deviation price and let $\tilde{z}_h$ and $\tilde{z}_l$ be the corresponding marginal consumers when firm B stays with the prices in the putative equilibrium, i.e., $(\hat{p}_B^I, \hat{p}_B^O)$. Then, $\tilde{z}_l$ is given by $\tilde{z}_l = (t - \tilde{p}_A^I + \hat{p}_B^I)/(2t)$. For $\tilde{z}_h$, the indifference condition is $v - c - t\tilde{z}_h - \tilde{p}_A^I = v - t(1 - \tilde{z}_h) - \hat{p}_B^O$, hence $\tilde{z}_h = (t - c - \tilde{p}_A^I + \hat{p}_B^O)/(2t)$. Firm A's deviation profit is $\tilde{\pi}_A = (\tilde{p}_A^I + \alpha_A)[\theta\tilde{z}_h + (1-\theta)\tilde{z}_l]$. Maximizing $\tilde{\pi}_A$, we find firm A's optimal deviation price as

$$\tilde{p}_A^I = \frac{6t - 3\theta c - (4-\theta)\alpha_A - 2(1-\theta)\alpha_B}{6}.$$

Note that the above deviation is not profitable if

$$c > \frac{2t}{2-\theta} + \frac{(4-\theta)\alpha_A + 2(1-\theta)\alpha_B}{3(2-\theta)}. \tag{15}$$

If (15) holds, then firm A's demand from type-h consumers becomes zero. In this case, the optimal deviation price is $\tilde{p}_A^I = 2t - c$, when firm A is worse off than in the putative equilibrium.

Firm A's optimal deviation profit is smaller than its profit in the putative equilibrium iff

$$-(8+\theta)\alpha_A^2 + (4(1-\theta)\alpha_B + 6c(2+\theta) - 36t)\alpha_A + 4(1-\theta)\alpha_B^2 - 12c(1-\theta)\alpha_B + 9c(4t - \theta c) > 0. \tag{16}$$

The (LHS) of (16) is a quadratic function of α_A, which we denote by $f(\alpha_A) := b_1\alpha_A^2 + b_2\alpha_A + b_3$. Since $b_1 = -(8+\theta) < 0$, if $b_3 > 0$, then we have $f(\alpha_A) > 0$ for all $\alpha_A \in [0, \overline{\alpha}_A]$ where $f(\overline{\alpha}_A) = 0$. Denote b_3 by $g(\alpha_B) := 4(1-\theta)\alpha_B^2 - 12c(1-\theta)\alpha_B + 9c(4t - \theta c)$, which is a quadratic function of α_B. The minimum value of $g(\alpha_B)$ is attained at $\alpha_B = (3c)/2$ and $g((3c)/2) = 9c(4t - c) > 0$ iff $4t > c$. Therefore, we have $b_3 = g(\alpha_B) > 0$ if $4t > c$. Since $b_1 < 0$ and $b_3 > 0$ in this case, (16) holds if and only if

$$\alpha_A < \overline{\alpha}_A(\alpha_B) := \frac{2(1-\theta)\alpha_B + 3c(\theta+2) - 18t + 6\sqrt{9t^2 + 2(1-\theta)(c-\alpha_B)t + (1-\theta)(c-\alpha_B)^2}}{8+\theta}.$$

In the above, we have shown that (16) holds when $4t > c$ and $\alpha_A < \overline{\alpha}_A(\alpha_B)$.

We now show (16) also holds when $4t < c$ and $\alpha_A < \overline{\alpha}_A(\alpha_B)$. First, if $b_3 > 0$, then our previous proof continues to be valid. So, suppose $b_3 < 0$. Let $\underline{\alpha}_A$ and $\overline{\alpha}_A$ be the two roots of the equation $f(\alpha_A) = 0$ where $\underline{\alpha}_A \leq \overline{\alpha}_A$. Since $f(\alpha_A)$ is inverse-U-shaped, (16) holds for all $\alpha_A \in [\underline{\alpha}_A, \overline{\alpha}_A]$. We will show below that there is no profitable deviation for firm A if $\alpha_A \leq \underline{\alpha}_A$. This then implies that, when $4t < c$, (16) also holds for all $\alpha_A < \overline{\alpha}_A$.

It remains to prove that firm A cannot profitably deviate when $\alpha_A \leq \underline{\alpha}_A$. If (15) holds at $\alpha_A = \underline{\alpha}_A$, then (15) also holds for all $\alpha_A \leq \underline{\alpha}_A$. Subtracting the (RHS) from the (LHS) in (15) and evaluating at $\alpha_A = \underline{\alpha}_A$, we obtain

$$\frac{2(4-\theta)\sqrt{9t^2 + 2(1-\theta)(c-\alpha_B)t + (1-\theta)(c-\alpha_B)^2}}{(8+\theta)(2-\theta)} + \frac{8(1-\theta)(c+t-\alpha_B)}{(8+\theta)(2-\theta)}. \tag{17}$$

If (17) is positive, then there is no profitable deviation for all $\alpha_A \leq \underline{\alpha}_A$. We consider two cases: (i) $\alpha_B \leq c+t$; (ii) $\alpha_B > c+t$. If $\alpha_B \leq c+t$, then (17) is clearly positive. If $\alpha_B > c+t$, then the second term in (17) is negative. Squaring the two terms in (17) and calculating the difference, we obtain

$$\frac{4\{(16-7\theta)t^2 + 2\theta(1-\theta)t(c-\alpha_B) + \theta(1-\theta)(c-\alpha_B)^2\}}{(8+\theta)(2-\theta)^2}.$$

One can verify that the above expression is strictly positive if $\alpha_B > c+t$. Thus, we have shown that (17) is always positive, which implies that there is no profitable deviation for all $\alpha_A \leq \underline{\alpha}_A$.

Similarly, firm B does not deviate to the pooling strategy iff

$$-(8+\theta)\alpha_B^2 + (4(1-\theta)\alpha_A + 6c(2+\theta) - 36t)\alpha_B + 4(1-\theta)\alpha_A^2 - 12c(1-\theta)\alpha_A + 9c(4t-\theta c) > 0,$$

which translates to

$$\alpha_B < \overline{\alpha}_B(\alpha_A) := \frac{2(1-\theta)\alpha_A + 3c(\theta+2) - 18t + 6\sqrt{9t^2 + 2(1-\theta)(c-\alpha_A)t + (1-\theta)(c-\alpha_A)^2}}{8+\theta}.$$

We can also verify that $\overline{\alpha}_i(\alpha_j)$ decreases in α_j, $\overline{\alpha}_i(c) = c$, and $c \leq \overline{\alpha}_i(\alpha_j) < 3c/2 - \alpha_j/2$ given (10), for $i, j = A, B$ and $i \neq j$. ■

Proof of Lemma 4: We derive conditions that ensure neither firm benefits from deviating from the asymmetric equilibrium. We consider firm A's deviation to the pooling strategy and firm B's deviation to the separating strategy.

Suppose firm A chooses $\tilde{p}_A^I$ and deviates to the pooling strategy. Following the deviation, the marginal consumers are given by $\tilde{z}_l = \tilde{z}_h = (t - \tilde{p}_A^I + p_B^I)/(2t)$, and firm A's deviation profit is $\tilde{\pi}_A = (\tilde{p}_A^I + \alpha_A)\left[\theta \tilde{z}_h + (1-\theta)\tilde{z}_l\right]$. The optimal deviation price is $\tilde{p}_A^I = t - \frac{\theta c + (4-\theta)\alpha_A + 2\alpha_B}{6}$. Firm A's deviation profit is smaller than its profit in the putative equilibrium iff

$$(1+2\theta)\alpha_A - 4\alpha_B + (3-2\theta)c + 12t > 0.$$

In the putative equilibrium, we have $\hat{z}_l \geq 0$, hence $4\alpha_B \leq 12t - 2\theta c + 2(2+\theta)\alpha_A$. This implies $(1+2\theta)\alpha_A - 4\alpha_B + (3-2\theta)c + 12t \geq 3(c-\alpha_A) \geq 0$ since $c \geq \alpha_A$ by (12). This shows that firm A's deviation to the pooling strategy is unprofitable.

Suppose now firm B deviates to the separating strategy by choosing $(\tilde{p}_B^I, \tilde{p}_B^O)$. Then, the marginal consumers are $\tilde{z}_l = (t - \hat{p}_A^I + \tilde{p}_B^I)/(2t)$ and $\tilde{z}_h = (t - \hat{p}_A^O + \tilde{p}_B^O)/(2t)$. Firm B's deviation profit is $\tilde{\pi}_B = \tilde{p}_B^O \theta(1-\tilde{z}_h) + (\tilde{p}_B^I + \alpha_B)(1-\theta)(1-\tilde{z}_l)$. To ensure that type-$h$ consumers choose opt-out purchase, the deviation prices must satisfy the condition $\tilde{p}_B^O \leq \tilde{p}_B^I + c$. On the other hand, to ensure that type-l consumers choose opt-in purchase, the deviation prices must satisfy $\tilde{p}_B^I < \tilde{p}_B^O$. This latter condition, however, turns out to be non-binding in the subsequent analysis. Solving for firm B's optimal deviation prices, we obtain $\tilde{p}_B^O = t + \frac{(3-\theta)c - (1-\theta)\alpha_A - 2\alpha_B}{12}$ and $\tilde{p}_B^I = t - \frac{\theta c + (4-\theta)\alpha_A + 8\alpha_B}{12}$ when $3c - \alpha_A - 2\alpha_B > 0$, and $\tilde{p}_B^I = t - \frac{5\theta c + 2(1-\theta)\alpha_A + (4-3\theta)\alpha_B}{6}$ and $\tilde{p}_B^O = \tilde{p}_B^I + c$ when $3c - \alpha_A - 2\alpha_B \leq 0$. Substituting these prices into the deviation profit, we find that firm B's deviation to the separating strategy is unprofitable iff

$$4\alpha_B^2 + \alpha_B(48t - 4(1-\theta)\alpha_A - 4(1+\theta)c) - 3(1-\theta)\alpha_A^2 + 10c(1-\theta)\alpha_A - c(48t + (3-7\theta)c) \geq 0,$$

which translates to

$$\alpha_B \geq \underline{\alpha}_B(\alpha_A) = \frac{1}{2}\left((1-\theta)\alpha_A + (1+\theta)c - 12t\right) + \frac{1}{2}\sqrt{144t^2 + 24(1-\theta)(c-\alpha_A)t + (4-\theta)(1-\theta)(c-\alpha_A)^2}. \tag{18}$$

Therefore, the asymmetric equilibrium exists given (12) and (18). We can verify $\underline{\alpha}_B(\alpha_A)$ decreases in α_A, $\underline{\alpha}_B(c) = c$, and $\underline{\alpha}_B(0) > c$.

Similarly, the mirroring asymmetric equilibrium in which firm A uses the pooling strategy and firm B uses the separating strategy exists given (13) and $\alpha_A \geq \underline{\alpha}_A(\alpha_B)$ where $\underline{\alpha}_A(\alpha_B)$ can be found by replacing α_A by α_B in $\underline{\alpha}_B(\alpha_A)$. We can also verify $\underline{\alpha}_A(\alpha_B)$ decreases in α_B, $\underline{\alpha}_A(c) = c$, and $\underline{\alpha}_A(0) > c$. ∎

Proof of Proposition 6: The comparison of the equilibrium before the regulation and the separating equilibrium after the regulation is straightforward, hence is omitted. We will only show the comparison with the asymmetric equilibrium after the regulation where firm A chooses the separating strategy and firm B chooses the pooling strategy, i.e., when $\alpha_A \leq c$ and $\alpha_B > \underline{\alpha}_B(\alpha_A)$. We can apply the same argument to the other asymmetric equilibrium.

Comparing firm A's profits, we find that firm A's profit is larger after the regulation iff $24t + (9-5\theta)c + (5\theta-1)\alpha_A - 8\alpha_B > 0$. The inequality can be shown to hold under the conditions, $\alpha_B < \alpha_A + 3t$ and $\alpha_A < c$, which is satisfied by Assumption 3. Firm B earns lower profits after privacy regulations iff $6t - \theta c - (2-\theta)\alpha_A + 2\alpha_B > 0$; the industry profits are lower after privacy regulations iff $(7+\theta)\alpha_A - 16\alpha_B + (9-\theta)c < 0$. Both inequalities can be validated under the constraints $\hat{p}_B^I + \alpha_B > 0$, $\alpha_A < c$, and $\alpha_B > c$.

Type-l consumers have higher surplus after the regulation iff $36t + \theta(c-\alpha_A) + 4(\alpha_B - \alpha_A) > 0$, which holds under $\alpha_B > c > \alpha_A$. Type-h consumers have higher surplus after the regulation iff $36t(1+\theta) + (3-\theta)^2 c + (3-\theta)(1+\theta)\alpha_A - 4(3-\theta)\alpha_B > 0$, which can also be proven under the conditions, $\alpha_B < \alpha_A + 3t$ and $\alpha_A < c$. Consequently, the total consumer surplus increases after the regulation. ∎

Proof of Proposition 7: Recall that π_A increases in α_A in all equilibria except the asymmetric equilibrium (separating, pooling). In the latter, π_A is a U-shaped quadratic function of α_A and its symmetric axis is given by

$$\alpha'_A := \frac{4\alpha_B + 5\theta c - 12t}{(4+5\theta)}.$$

Given α_B fixed at the pre-regulation level, the relevant range of α_A for the asymmetric equilibrium (separating, pooling) is $\alpha_A \in [0, c]$ when $\alpha_B \geq \overline{\alpha}_B(0)$, and $\alpha_A \in [\tilde{\alpha}_A, c]$ when $\overline{\alpha}_B(0) > \alpha_B > c$, where $\tilde{\alpha}_A$ is defined by $\overline{\alpha}_B(\tilde{\alpha}_A) = \alpha_B$. We derive conditions under which firm A's optimal choice is $\alpha_A = 0$, $\alpha_A = \tilde{\alpha}_A = \overline{\alpha}_B^{-1}(\alpha_B)$, $\alpha_A = \overline{\alpha}_A(\alpha_B)$, or $\alpha_A = \alpha^M$. Since case (c) was discussed in the text, we only consider cases (a) and (b).

Consider case (a) where $\alpha_B \geq \overline{\alpha}_B(0)$. In this case, π_A can decrease in α_A if and only if $\alpha'_A > 0$. In addition, $\pi_A(\alpha_A = 0) > \pi_A(\alpha_A = c)$ if and only if $\alpha'_A > c/2$, which is equivalent to $8\alpha_B + (5\theta - 4)c - 24t > 0$. This inequality is more likely to hold when α_B and θ are sufficiently large. Next, we compare $\pi_A(\alpha_A = 0)$ and $\pi_A(\alpha_A = \alpha^M)$. Direct calculation shows

$$\begin{aligned}
&\pi_A(\alpha_A = 0) > \pi_A(\alpha_A = \bar{\alpha}) \\
\iff &\frac{4(3t-\alpha_B)^2 + 8\theta c(3t-\alpha_B) + \theta c(9c - 5\theta c)}{72t} > \frac{(3t-\alpha_B+\bar{\alpha})^2}{18t} \\
\iff &\frac{1}{2}\sqrt{4(3t-\alpha_B)^2 + 8\theta c(3t-\alpha_B) + \theta c(9c-5\theta c)} > 3t - \alpha_B + \bar{\alpha} \\
\iff &\frac{1}{2}\sqrt{4(3t-\alpha_B)^2 + 8\theta c(3t-\alpha_B) + \theta c(9c-5\theta c)} - (3t-\alpha_B) > \bar{\alpha}.
\end{aligned}$$

In the above, we have derived the conditions under which $\alpha_A = 0$ can be firm A's optimal choice, i.e., α_B, θ are sufficiently large and α^M is not too large. If these conditions are not satisfied, then $\alpha_A = \alpha^M$ is firm A's optimal choice.

Next, consider case (b) where $\overline{\alpha}_B(0) > \alpha_B > c$. In this case, π_A can decrease in α_A if and only if α'_A satisfies

$$\alpha'_A > \tilde{\alpha}_A = \frac{(1-\theta)(\alpha_B - 3c) + 3\sqrt{(1-\theta)(\alpha_B - c)(\alpha_B + 4t - c)}}{2(\theta - 1)}$$

In addition, π_A is maximized at $\alpha_A = \tilde{\alpha}_A$, rather than at $\alpha_A = c$, if and only if $\alpha'_A > (\tilde{\alpha}_A + c)/2$. As before, we can directly calculate $\pi_A(\alpha_A = \tilde{\alpha}_A) - \pi_A(\alpha^M)$, and derive conditions for when firm A's optimal choice is either $\alpha_A = \tilde{\alpha}_A$ or $\alpha_A = \alpha^M$, which is omitted. ∎

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