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under opt-in privacy regulation**

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Price discrimination and product quality under opt-in privacy regulation

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Abstract

We study how privacy regulation limiting the scope for price discrimination by a monopolist who sells online affects product quality and consumer surplus. We consider an opt-in regime where consumers may share personal data or not, in line with the recent EU GDPR. If consumers share data, they gain an additional benefit from buying related to the complementarity between information and quality, and they pay personalized prices instead of a uniform price. We find that, if the complementarity is strong enough, then product quality is higher with than without the opt-in regime. We also find that the opt-in regime has conflicting effects on consumers with different attitudes towards privacy, and that an increase in quality is a necessary condition for improving total consumer surplus. Overall, this study contributes to the debate on privacy protection by stressing the importance of analysing the relation between personal information and product quality.

JEL classification: L12, L15, L51

Keywords: Privacy regulation; Opt-in regime; Price discrimination; Product quality

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1. Introduction

Thanks to significant advances in information technology, firms are increasingly able to collect and use a huge amount of personal data to segment markets in view of setting targeted prices and product offerings.¹ The widespread availability of personal data has raised privacy concerns, and the need for protecting consumers has prominently emerged in the public debate. In the EU, the General Data Protection Regulation (GDPR) marks a radical change in perspective in privacy policy, since it provides data subjects with the option of controlling access to personal data.²

As long as privacy regulation enables data subjects to manage their information assets, it makes more difficult for firms to have access to personal data and infer consumers' valuations for the products. This, in turn, limits the scope for price discrimination, and thereby may challenge the incentives to invest in product quality.

In this paper, we study how the amount of shared data, which is controlled by consumers under privacy regulation, is related to prices, product quality, and consumer surplus. We intend to shed light on the following issues: Does privacy regulation restraining the scope for price discrimination come at the expense of product quality? Does enhanced privacy protection improve consumer surplus? Ultimately, should consumers be provided with more or less control over personal data?

We develop a theoretical model where a monopolist sells a product online. We assume that, under privacy regulation, consumers' willingness to pay (hereafter, wtp) for the product is private information. Consumers decide whether to share personal data or not, being aware that the firm can use such data for profiling purposes. We consider two markets, which include consumers with different attitudes towards privacy. The first market consists of consumers who may opt for sharing personal data. Instead, the second market consists of consumers who do not leave traces on the web, since they would receive more harm than benefit from sharing data.³

¹ For instance, consumers' searches and purchases at internet stores provide firms with a wealth of personal information on gender, age, location, preferences, and other relevant data that identify consumers' types.

² See e.g.: <https://eugdprcompliant.com/eu-citizens-rights>. See also Section 2 for further details on data protection policies both in the EU and in the US.

³ These consumers might have a taste for privacy, or a very high disutility from information sharing (think of consumers who decide to avoid any registration on websites, or to avoid using social networks and/or geolocation devices).

Consumers who remain anonymous would have to pay a uniform price. Consumers who share data face a trade-off. On the one hand, they pay personalized prices based on their wtp. We assume that, having obtained consumer data, the firm has an imperfect ability to price discriminate and extract consumer surplus (e.g. because she uses a tracking technology with some degree of inaccuracy). On the other hand, by releasing personal data customers enhance their consumption experience. Indeed, the perceived product quality increases with information provision. Moreover, the benefits of data sharing increase with product quality. In this sense, personal information and product quality are complements from the consumers' perspective.

A striking example is sport equipment such as connected athletic gear. Technological progress allows users to enjoy special services in exchange for access to location or other personal data from smartphones. For instance, the UA HOVR running shoes track a wide array of data, from running basics as distance, pace and splits, to details including cadence and stride length. Using this data, the application MapMyRun provides each runner with a personalized coaching experience.⁴

More generally, there are plenty of examples of firms selling bundles of the core product and some add-on services. To fix ideas, consider the case of electronic devices or software programs. First, customers can enjoy additional services such as delivery conditions, after-sale assistance, training or tutoring given that they release personal data (e.g. by registering on websites). Second, these services are more valuable to users when the core product has a higher degree of sophistication or complexity.

Our main finding is that privacy regulation limiting the scope for price discrimination does not necessarily reduce the incentives to innovate, and may even induce the firm to provide higher quality.⁵ In such a case, there is no privacy-quality trade-off. For this to occur, the complementarity between information and quality should be sufficiently strong. This is because the firm strategically increases both product quality and the uniform price to induce even high-wtp consumers in the first market to share personal data and pay personalized prices.

⁴ Another example of smart clothing is NikeConnect jersey, which provides NBA fans with access to exclusive contents. After downloading an accompanying app, NikeConnect wearers are able to unlock highlights, stats, game tickets, Spotify playlists, and limited exclusive apparel deals (among other benefits), by scanning the 'jock tag' of the jersey. Through this device, Nike identifies who has purchased the jersey, and learns where she/he lives, and where she/he scans it from.

⁵ As a benchmark, we consider the case where privacy regulation is not active, and thereby the firm is completely informed about the wtp for the product of consumers in the first market (even without their explicit consent).

We find that consumers in the first market benefit from the improved quality, since they receive a greater total benefit from sharing data, while avoiding the costly option to buy at the uniform price. However, privacy regulation generates an indirect negative externality on consumers who are less prone to sharing data. Indeed, the option to choose anonymity for consumers in the first market puts an upward pressure on the uniform price that reduces consumer surplus in the second market.

We also find that an increase in quality under privacy regulation is a necessary condition for an increase in total consumer surplus. However, consumer surplus may decrease with a higher quality. Given that privacy regulation limits the scope for price discrimination, the firm may strategically use quality to extract surplus. In this sense, quality is an effective substitute for personalized prices.

Conversely, if the complementarity between information and quality is weak then the additional benefit to users from revealing information is not high enough to induce the firm to increase quality. Thus, in such a case, privacy regulation reduces product quality, consumer surplus, and social welfare.

We show that the main qualitative results are not affected in the case where the monopolist cannot use the uniform price to induce consumers to share data. Finally, we show that introducing the opt-in regime will more likely result in a quality improvement in the presence of further privacy protection measures (that is, when the firm has a limited ability to target consumers), which also serve to mitigate the negative externality on consumers due to the increase in the uniform price.

This paper is organized as follows. Section 2 examines the policy debate and reviews the relevant literature. Section 3 introduces the model. Section 4 considers the benchmark case without privacy regulation. Section 5 analyses the opt-in privacy regime. Section 6 evaluates the effects of this regime on product quality and consumer surplus. Section 7 checks the robustness of the results and discusses the impact of ancillary privacy protection measures. Section 8 contains some concluding remarks.

2. Policy debate and literature review

Privacy regulation generally imposes restrictions on the collection and/or use of personal information. In the former case, firms are allowed to gather certain types of data but not others, while in the latter case firms are constrained in disclosing personal data to third parties.

For our purposes, it is worth distinguishing the *opt-out* and *opt-in* privacy regimes. In the opt-out regime, firms can collect and use personal data given that consumers do not make objections at some (privacy) cost.

When the cost of opting-out is relatively high the option is rarely exercised, and firms may rely on data about existing or potential customers to set tailored prices and product offerings.

On the other hand, in the opt-in regime shaped by the new European GDPR, firms are required to cancel stored data (*tabula rasa*) and are allowed to collect and use personal information only after explicit consent of data subjects.⁶ Overall, this regime increases consumers' awareness of the importance of personal data. The ultimate goal of the GDPR is to strike the right balance of economic power between data subjects and data holders, thereby governing the potential trade-offs related to sharing personal data for consumers, firms, and society as a whole.

The EU is deemed to have a stricter and more systematic data protection policy than the US, where there is not yet a federal digital privacy law. Recently, data protection has become an increasingly important issue following massive breaches that have compromised personal information of millions of Internet users. Many have argued that, to restore trust in the digital economy, companies like social networks with global footprint should be regulated as to how they collect and use people's data.⁷

Despite the growing concern about the protection of consumer privacy, there is no clear consensus among scholars on the desirability of sealing personal data. Since the pioneering works of Stigler (1980) and Posner (1981), economists have long investigated how consumer privacy affects economic efficiency (for a review, see Acquisti *et al.*, 2016). Recently, they have studied how different regimes of privacy protection affect the interested parties in the light of the advent of digital technologies.

A first strand of literature assesses the welfare effects of a privacy policy that limits the scope for charging tailored prices. Taylor and Wagman (2014), among others, assume that consumers remain anonymous under privacy regulation. They find that consumer surplus under oligopoly may increase with no privacy. In contrast,

⁶ The EU introduced the opt-in regime since 2002, when it passed the 'Privacy and Electronic Communications Directive', as to the placement of *web bugs* to track consumers. In 2009, the EU updated the 2002 Directive and extended the opt-in regime to the placement of *cookies* to track browsers across websites. Finally, in 2016 the EU adopted the GDPR (entered into force in May 2018), which integrates and reinforces the measures included in the earlier Directive (see Fuller, 2018).

⁷ In July 2018, the White House spokeswoman said the administration "aims to craft a consumer privacy protection policy that is the appropriate balance between privacy and prosperity" (www.reuters.com/article/us-usa-internet-privacy/trump-administration-working-on-consumer-data-privacy-policy). See also: The Economist, *America Should Borrow from Europe's Data-Privacy Law*, April 5, 2018 (<https://www.economist.com/news/leaders/21739961-gdprs-premise-consumers-should-be-charge-their-own-personal-data-right>).

Liu and Shuai (2016), using a two-dimensional spatial differentiation model, obtain that consumer surplus is lower under duopoly price discrimination. Some papers consider an opt-out regime where consumers can protect themselves at a ‘hiding cost’. Belleflamme and Vergote (2016) show that, even under monopoly, consumers may be better off when they cannot hide personal data. Montes *et al.* (2018) analyse the role of data brokers, and discuss the desirability of exclusivity deals to sell consumer data.

Instead, we study an opt-in privacy regime where consumers should give their consent on sharing data; absent regulation, the firm is aware of the valuations of consumers who leave traces of their web activities. This information structure is at the heart of the rationale for the European GDPR.⁸

Different from the literature on consumer tracking (see e.g. Villas Boas, 2004), even when it deals with online environments (see e.g. Acquisti and Varian, 2005; Conitzer *et al.*, 2012), we assume that the firm has an imperfect ability to price discriminate and extract consumer surplus when she obtains personal information. For instance, this may be due to a tracking technology that enables the firm to achieve a partial identification of consumers (as in Belleflamme and Vergote, 2016).⁹

A further strand of literature focuses on the value of consumer data to online platforms that make profit from disclosing such data to third parties. Consumers are assumed to have control over personal data and to choose how much information to reveal. In this framework, Casadesus-Masanell and Hervas-Drane (2015) study how the provision and disclosure of consumer data shape the competitive interaction of firms. Bo and Manduchi (2017) assess pros and cons of data provision for consumers in the case where it increases competition in the product market. Choi *et al.* (2019) analyze the role of information externalities in the collection of personal data from a welfare perspective.

A distinguishing feature of our model is that it studies how privacy regulation affects the incentives to innovate. To our knowledge, Lefouili and Toh (2018) is the only theoretical paper focusing on this issue.¹⁰ They find that a cap on information disclosure to third parties improves product quality when it increases substantially the sensitivity of demand to changes in quality.

⁸ In a different context, Esteban and Hernández (2017) show that a regulatory policy aimed at protecting consumer privacy, by banning the use of direct advertising without permission, may result in lower social welfare.

⁹ Ezrachi and Stucke (2016) argue that big data analytics can help firms to identify consumers and set personalized prices.

¹⁰ A number of empirical studies have found that privacy regulation may increase the costs and/or reduce the benefits of data-driven innovation, thereby dampening the incentives to invest (see Goldfarb and Tucker, 2012).

We share with the authors the idea that there is a complementarity between personal data and product quality. However, in our paper, the privacy regime shapes the scope for price discrimination. Thus, we consider a combination of endogenous information sharing (under privacy regulation), price discrimination, and quality investment, which has not been addressed in the relevant literature.¹¹

3. The model

A monopolist sets the quality and the price of the product that she sells online. Under the opt-in privacy regime, consumers have private information on their valuation for the product. Let the gross utility of a consumer of type θ who buys a product of (baseline) quality q be:

$$U(\theta) = \theta q + \gamma q^k x, \quad (1)$$

where the binary variable x indicates the choice between releasing personal data ($x = 1$) or not ($x = 0$). When releasing information, type θ enjoys an enhanced experience in consuming the product. Specifically, the additional benefit of information provision increases with product quality, and the increase is stronger the higher the values of parameters γ and k , where $\gamma \in (0, 1)$ and $k > 0$. Thus, parameters γ and k affect the strength of the complementarity between information and quality. On the other hand, the utility from not buying is normalized to zero.

A consumer of type θ who reveals information has to pay a personalized price $P(\theta)$ for buying the product. We assume that the firm has an imperfect ability to extract consumer surplus (e.g. due to an inaccurate tracking technology) that is measured by parameter α , where $\alpha \in (0, 1)$. This means that a monopolist with ability α sets $P(\theta) = \alpha(\theta q + \gamma q^k)$ when type θ reveals information. On the other hand, if consumers do not reveal information then the firm does not know their types, and they would have to pay a uniform price P (without gaining any additional benefit from purchasing).

We assume that types θ are uniformly distributed between 0 and 1 with unit density in two distinct markets. Consumers in the first market may decide to reveal their valuation, whereas consumers in the second market prefer to conceal their valuation since they would receive more harm than benefit from sharing data. This

¹¹ Some related studies assess the impact of (third-degree) price discrimination on product quality (see e.g. Alexandrov and Deb, 2012; Nguyen, 2014). They all find that price discrimination improves quality. Notable exceptions are Matteucci and Reverberi (2017, 2018), who show that quality may be higher under uniform pricing. We add to this literature by considering that privacy regulation affects the amount of information that the firm can use to set targeted prices.

means that, for any type θ in the second market, variable x in (1) is invariably equal to zero. Consumers who remain anonymous (either in the first or in the second market) would have to pay the same price P .¹²

Let $\widehat{\theta}$ be the consumer in the first market who is indifferent between sharing personal data, thereby paying $P(\theta)$, and protecting privacy, thereby paying P . Thus, we have $(1 - \alpha)(\widehat{\theta}q + \gamma q^k) = \widehat{\theta}q - P$, and therefore we find:

$$\widehat{\theta} = \frac{P}{\alpha q} + \frac{(1 - \alpha)}{\alpha} \gamma q^{(k-1)} \quad (2)$$

Consumers θ such that $\theta \in [\widehat{\theta}, 1]$ prefer to conceal data, whereas consumers θ such that $\theta \in [0, \widehat{\theta}]$ decide to share data. Since the firm cannot extract all surplus, even the consumer with the lowest wtp has a positive net utility from purchasing. Hence, the first market is fully covered.

On the other hand, consumers in the second market decide whether to buy at P or not to buy at all. Then, all consumers θ such that $\theta \in [\widetilde{\theta}, 1]$ are active in the market, where $\widetilde{\theta} = P/q$ is the marginal consumer (i.e. the one who is indifferent between buying and not buying).

Thus, the monopolist's profit function is:

$$\Pi = \int_0^{\widehat{\theta}} P(\theta) d\theta + \int_{\widehat{\theta}}^1 P d\theta + \int_{\widetilde{\theta}}^1 P d\theta - C(q) \quad (3)$$

where $C(q) = q^2/2$ is the cost the firm incurs to obtain quality q , and the consumer surplus is:

$$CS = \int_0^{\widehat{\theta}} (\theta q + \gamma q^k - P(\theta)) d\theta + \int_{\widehat{\theta}}^1 (\theta q - P) d\theta + \int_{\widetilde{\theta}}^1 (\theta q - P) d\theta \quad (4)$$

We consider the following three-stage game. At the first stage, the monopolist undertakes R&D and sets product quality. At the second stage, for a given quality, the monopolist manufactures the product (without

¹² Alternatively, we could consider a two-dimensional model where consumers are heterogeneous across two dimensions. Specifically, they are characterized by a parameter $\theta \in [0,1]$, which is related to the valuation of the baseline quality of the product (dimension 1), and a parameter $\beta \in \{\beta_L, \beta_H\}$, measuring the nuisance from sharing personal data (dimension 2). Then, the utility (gross of price) of consumer (θ, β) would be $U(\theta, \beta) = \theta q + \gamma q^k x - \beta x$. If we assume that: (i) consumers are uniformly distributed across dimension 1 and split evenly across dimension 2; (ii) β_L is sufficiently small (e.g. tends to zero); and (iii) β_H is large enough to satisfy $\beta_H > (\theta q + \gamma q^k)$, then the main results of this alternative model specification would be similar to our basic model.

loss of generality, we normalize marginal costs to zero) and sets an array of personalized prices as well as the uniform price. At the third stage, consumers in the first market decide whether to reveal information (and buy at personalized prices) or not (and buy at the uniform price). Consumers in the second market decide whether to buy at the uniform price or not.¹³

Henceforth, to obtain closed-form solutions for quality levels we set $k = 2$, which means that the utility of releasing data increases more than proportionally with quality. This assumption enables us to analyse the most interesting case for our study, where the firm can effectively use product quality as a strategic tool to obtain consumer data.¹⁴ Since k is fixed, then the complementarity between information and quality is shaped solely by parameter γ .

Moreover, we assume that the following conditions are met: i) $\alpha \geq \frac{1}{2}$; ii) $\alpha\gamma < \frac{1}{2}$. Condition i) excludes that the firm finds it profitable to set a uniform price in both markets, while condition ii) ensures that the profit function is concave in q .

4. Benchmark case (no privacy regulation)

As a benchmark, we consider the case where privacy regulation is not active. We assume that, in such a case, the monopolist knows the types of consumers in the first market. Indeed, in their web activities these consumers release personal data that the firm can use to target them even without an explicit consent. On the other hand, consumers in the second market do not leave traces on the web, since they receive more harm than benefit from sharing data. Therefore, they are anonymous.

In this framework, the firm uses the imperfect tracking technology to charge personalized prices to all consumers in the first market, which is fully covered, whereas she acts as a standard uninformed monopolist

¹³ In Section 7, we check the robustness of our results by solving the model under an alternative timing in which the monopolist sets prices after observing consumers' privacy choices.

¹⁴ Setting $k = 2$ allows for the concavity of the profit function with respect to quality. A graphical inspection shows that the main results hold for $\bar{k} \leq k \leq 2$, where $\bar{k} > 1$, meaning that the additional benefit of data sharing has to be sufficiently convex in quality. Indeed, from (2) we have that $\partial \hat{\theta} / \partial q = -\frac{P}{\alpha q^2} + \gamma(k-1) \frac{(1-\alpha)}{\alpha} q^{(k-2)}$ is negative if $k \leq 1$. It follows that, when $k \leq 1$, a higher quality reduces the number of consumers who share personal data. We find that, when $k = 1$, the opt-in regime results in lower quality and higher prices relative to the case with no privacy regulation, thereby reducing consumer surplus. In such a case, privacy regulation should not be enforced because it negatively affects social welfare.

in the second market. Then, at the second stage, the uniform price that maximizes (3), with $\widehat{\theta} = 1$, is $P = q/2$. We thus find $\tilde{\theta} = 1/2$, so that the firm serves the top half of the second market. Substituting $\widehat{\theta} = 1$ and $\tilde{\theta} = 1/2$ into (4), the consumer surplus for a given quality is $CS = \int_0^1 (1 - \alpha)(\theta q + \gamma q^2) d\theta + \int_{1/2}^1 (\theta q - q/2) d\theta$.

At the first stage, the monopolist sets quality to maximize $\Pi(q) = \int_0^1 \alpha(\theta q + \gamma q^2) d\theta + q/4 - q^2/2$.

Thus, in equilibrium, we find (subscript B stands for *benchmark case*):

$$q_B = \frac{(2\alpha + 1)}{4(1 - 2\alpha\gamma)} \quad (5)$$

$$P_B = \frac{(2\alpha + 1)}{8(1 - 2\alpha\gamma)} \quad (6)$$

$$CS_B = \frac{(1 - \alpha)(2\alpha + 1)(2 + \gamma - 2\alpha\gamma)}{16(1 - 2\alpha\gamma)^2} + \frac{(2\alpha + 1)}{32(1 - 2\alpha\gamma)} \quad (7)$$

From (5), we have that the optimal quality is increasing in α and γ . Thus, the higher the ability to extract consumer surplus, and the stronger the complementarity between information and quality, the greater the incentive to improve product quality. Indeed, both α and γ positively affect the marginal revenue from improving quality, and the effects of the two parameters are mutually reinforcing. From (6), the exogenous parameters affect in the same way the uniform price in the second market, given that it is simply proportional to quality.

From (7), a stronger complementarity between information and quality is beneficial to the total consumer surplus, while the impact of α is ambiguous. Specifically, consumer surplus in the second market (i.e. the second term in (7)) is increasing in α , since it is proportional to the quality level.¹⁵ On the other hand, consumer surplus in the first market (i.e. the first term in (7)) as well as the total consumer surplus may be decreasing in α , depending on the value of γ . Overall, the larger the value of γ , the higher the probability that the positive effect of α on product quality outweighs the negative effect due to the increase in price.

¹⁵ In the benchmark case, the equilibrium demand in the second market is not affected by α and γ . In terms of consumer surplus, the positive effect of the improved quality due to a higher α prevails over the negative effect of the higher price.

5. Opt-in privacy regime

Under the opt-in regime, consumers' valuations for the product are private information. In this framework, the monopolist maximizes her profit by encouraging consumers in the first market to reveal personal data. For this purpose, she strategically uses product quality and the uniform price.

At the second stage, the monopolist anticipates that in the first market types θ such that $\theta \in [0, \widehat{\theta}]$ will release personal data, while types θ such that $\theta \in [\widehat{\theta}, 1]$ will not release data, where $\widehat{\theta}$ is found by inserting $k = 2$ in (2). The firm also anticipates that types θ such that $\theta \in [\widetilde{\theta}, 1]$ will be active in the second market, where $\widetilde{\theta} = P/q$. Then, the firm sets the uniform price that maximizes (3), subject to $\widehat{\theta} \leq 1$ and $\widetilde{\theta} \geq 0$. There are two cases to consider, an interior solution (when $\widehat{\theta} < 1$) and a corner solution ($\widehat{\theta} = 1$), depending on the values of parameters α and γ .¹⁶ We solve the two cases separately.

5.1 Interior solution: Some consumers in the first market remain anonymous

First, in an interior solution, we obtain that the equilibrium uniform price at the second stage is:

$$P(q) = \frac{\alpha q(2 + \gamma q)}{(1 + 2\alpha)} \quad (8)$$

From (8) we find that, for a given quality, the monopolist sets a higher price if consumers' wtp is private information than in the benchmark case (where $P = q/2$). In doing so, she makes concealing information more costly for consumers. By substituting (8) respectively in $\widehat{\theta}$ and $\widetilde{\theta}$, we obtain:

$$\widehat{\theta} = \frac{2\alpha + \gamma q(1 + 2\alpha - 2\alpha^2)}{\alpha(1 + 2\alpha)} \quad (9)$$

and

$$\widetilde{\theta} = \frac{\alpha(2 + \gamma q)}{(1 + 2\alpha)} \quad (10)$$

From (9) and (10), both $\widehat{\theta}$ and $\widetilde{\theta}$ increase in q . Thus, a higher product quality enlarges the share of consumers in the first market who opt for releasing personal data. However, different from the benchmark case, the resulting increase in the uniform price reduces demand in the second market.

At the first stage, the monopolist solves the trade-off when she sets the optimal quality:

¹⁶ We easily find that $\widetilde{\theta} > 0$ is always satisfied.

$$q_I = \frac{\alpha \left(\Gamma - \sqrt{\Gamma^2 - 12\gamma^2\Lambda} \right)}{3\gamma^2\Lambda} \quad (11)$$

where $\Gamma = (1 + 2\alpha(1 - 2\gamma))$, $\Lambda = (1 + 2\alpha(1 - \alpha^2))$, and subscript I stands for *interior solution*.

Therefore, the uniform price is:

$$P_I = \frac{\alpha^2 \left(\Gamma - \sqrt{\Gamma^2 - 12\gamma^2\Lambda} \right) \left(6\Lambda\gamma + \alpha \left(\Gamma - \sqrt{\Gamma^2 - 12\gamma^2\Lambda} \right) \right)}{9\Lambda^2\gamma^3(1 + 2\alpha)} \quad (12)$$

Substituting (11) into (9) and imposing $\hat{\theta} < 1$, the condition for an interior solution is $\gamma < \bar{\gamma}(\alpha)$, where

$$\bar{\gamma}(\alpha) = \frac{2(-4\alpha^3 + 6\alpha^2 - 1)}{(-12\alpha^4 + 10\alpha^3 + 12\alpha^2 - 12\alpha + 7)} \text{ and } \frac{\partial \bar{\gamma}(\alpha)}{\partial \alpha} > 0. \text{ It follows that, for any given } \alpha, \text{ when the complementarity}$$

between information and quality is sufficiently weak, the monopolist is not able to obtain personal data from high-wtp consumers. From a different perspective, if the ability to extract consumer surplus is low ($\alpha \rightarrow 1/2$), then even high-wtp consumers are eager to release data (since $\bar{\gamma}(\alpha) \rightarrow 0$). As the ability rises ($\alpha \rightarrow 1$), this becomes less likely ($\bar{\gamma}(\alpha) \rightarrow 0.4$), because the additional benefit of data sharing has to be high enough to offset the utility loss due to personalized prices.

The following proposition summarizes the equilibrium outcome in the case of an interior solution.

Proposition 1. *There is a critical value $\bar{\gamma}(\alpha)$ of γ such that, when $\gamma < \bar{\gamma}(\alpha)$, only consumers $\theta \in [0, \hat{\theta}]$, where*

$$\hat{\theta} = \frac{6\gamma\Lambda + (\Gamma - \sqrt{\Gamma^2 - 12\gamma^2\Lambda})(1 + 2\alpha - 2\alpha^2)}{3\gamma\Lambda(1 + 2\alpha)}, \text{ reveal personal data and buy at personalized prices in the first market.}$$

Consumers $\theta \in [\hat{\theta}, 1]$ in the first market and $\theta \in [\tilde{\theta}, 1]$ in the second market, where $\tilde{\theta} =$

$$\frac{\alpha(6\gamma\Lambda + \alpha(\Gamma - \sqrt{\Gamma^2 - 12\gamma^2\Lambda}))}{3\gamma\Lambda(1 + 2\alpha)}, \text{ do not share data and buy at the uniform price. Thus, product quality, the uniform price, and consumer surplus respectively are:}$$

$$q_I = \frac{\alpha \left(\Gamma - \sqrt{\Gamma^2 - 12\gamma^2\Lambda} \right)}{3\gamma^2\Lambda}$$

$$P_I = \frac{\alpha^2 \left(\Gamma - \sqrt{\Gamma^2 - 12\gamma^2\Lambda} \right) \left(6\Lambda\gamma + \alpha \left(\Gamma - \sqrt{\Gamma^2 - 12\gamma^2\Lambda} \right) \right)}{9\Lambda^2\gamma^3(1 + 2\alpha)}$$

$$CS_I = \frac{\left(\Gamma - \sqrt{\Gamma^2 - 12\gamma^2\Lambda} \right)}{6\gamma\Lambda^2(1 + 2\alpha)^2} \left(\frac{\alpha^2(1 + 4\alpha + \alpha^2 - 8\alpha^3 + 4\alpha^4) \left(\Gamma - \sqrt{\Gamma^2 - 12\gamma^2\Lambda} \right)^2}{9\gamma^2\Lambda^2} \right. \\ \left. + \frac{(4\alpha^3 - 8\alpha^4) \left(\Gamma - \sqrt{\Gamma^2 - 12\gamma^2\Lambda} \right)}{3\gamma\Lambda} + 2 \right)$$

Proposition 1 shows that both product quality and the uniform price are increasing in γ . As in the benchmark case, if γ is high then the gross utility of consumers who reveal personal information increases significantly with the quality level, and so is for the number of consumers who are willing to share data (note that the uniform price rises because of the higher average wtp of consumers who hide information). This, in turn, generates large revenues for the monopolist from surplus extraction.

Different from the benchmark case, the effect of α on product quality may be negative. Under privacy regulation, when the firm's ability to extract consumer surplus is high, consumers are less likely to share data. Thus, when γ is also high, an increase in α produces a significant loss of revenue due to the larger number of consumers who hide. Since the marginal revenue curve shifts downward, then the firm reduces the quality level. In such a case, the uniform price may also be decreasing in α .

In terms of consumer surplus, parameter γ has contrasting effects. As γ increases, the number of consumers who share personal data increases, while the number of consumers who remain anonymous decreases in both markets. When γ is higher, consumers who share data benefit from higher quality, while anonymous consumers are worse off, since the harm from the increase in the uniform price outweighs the benefit from quality improvement. Overall, the positive effect of γ on consumers revealing information prevails over the negative effect on consumers paying the uniform price, and thereby the total consumer surplus increases in γ (except when α is very close to 1). On the contrary, a higher α always reduces total consumer surplus.

5.2 Corner solution: All consumers in the first market opt for sharing data

If the complementarity between information and quality is strong enough (i.e., $\gamma \geq \bar{\gamma}(\alpha)$), then we have a corner solution where all the consumers in the first market share personal data and buy at personalized prices (i.e. $\hat{\theta} = 1$).

Compared to the equilibrium with no privacy regulation (benchmark case), we distinguish two situations. In the first situation, the monopolist has to modify her choice and set the uniform price so as to make the highest-wtp consumer in the first market indifferent between sharing personal data or not. In the second situation, the monopolist behaves as in the benchmark case, and nonetheless the highest-wtp consumer prefers to share personal data. This occurs when the uniform price in the benchmark case is higher than the price that makes such consumer indifferent between sharing data or not under the opt-in regime. Then, privacy regulation

is not binding in equilibrium.¹⁷ It follows from the foregoing statements that the equilibrium price in a corner solution is the highest price between the one with privacy regulation and the one in the benchmark case.

Let us consider the first situation. Then, the equilibrium uniform price at the second stage is such that the highest-wtp consumer is indifferent between sharing personal data or not. We thus find:

$$P = \alpha q - (1 - \alpha)\gamma q^2 \quad (13)$$

Therefore, the marginal consumer in the second market is:

$$\tilde{\theta} = (\alpha - (1 - \alpha)\gamma q) \quad (14)$$

where $\tilde{\theta}$ is decreasing in the quality level. Different from an interior solution, in a corner solution a higher quality increases demand in the second market since the positive effect of the quality improvement overcomes the negative effect of the increase in price.¹⁸

At the first stage, the optimal quality maximizes (3) where the uniform price is given by (13), $\hat{\theta} = 1$, and $\tilde{\theta}$ is given by (14). Hence, we find:

$$q_C = \frac{Z + \sqrt{Z^2 + \Psi(3\alpha - 2\alpha^2)}}{\Psi} \quad (15)$$

where $Z = (2\gamma(4\alpha - 2\alpha^2 - 1) - 1)$, $\Psi = 6\gamma^2(1 - \alpha)^2$, and subscript C stands for *corner solution*.

Inserting (15) into (13), we obtain:

$$P_C = \frac{\alpha\Psi \left(Z + \sqrt{Z^2 + \Psi(3\alpha - 2\alpha^2)} \right) - (1 - \alpha)\gamma \left(Z + \sqrt{Z^2 + \Psi(3\alpha - 2\alpha^2)} \right)^2}{\Psi^2} \quad (16)$$

We can prove that $P_C \geq P_B$ as long as $\gamma \leq \bar{\gamma}_U(\alpha)$, where $\bar{\gamma}_U(\alpha) = \frac{(4\alpha-2)}{(6\alpha^2-3\alpha+1)}$. If the complementarity between information and quality is sufficiently weak (i.e. $\gamma \leq \bar{\gamma}_U(\alpha)$), then the monopolist finds it profitable to raise the uniform price relative to the benchmark case so as to avoid that some high-wtp consumers opt for not sharing data. On the other hand, when $\gamma > \bar{\gamma}_U(\alpha)$ the corner solution under the opt-in regime is the same as the equilibrium in the benchmark case. For any given α , if the degree of complementarity exceeds the critical value $\bar{\gamma}_U(\alpha)$ then the firm has a strong incentive to invest in quality irrespective of the privacy regime. This, in turn, results in a relatively high price, so that no consumer in the first market prefers anonymity.

¹⁷ Thus, when privacy regulation is binding the uniform price is higher under the opt-in regime than in the benchmark case (a similar result is found in Belleflamme and Vergote, 2016).

¹⁸ We can prove that in equilibrium $\tilde{\theta} \geq 1/2$ holds, where $\tilde{\theta} = 1/2$ is the marginal consumer in the benchmark case.

The following proposition summarizes the equilibrium outcome in the case of a corner solution.

Proposition 2. When $\gamma \geq \bar{\gamma}(\alpha)$, all the consumers in the first market reveal personal data and buy at personalized prices, whereas consumers θ in the second market such that $\theta \in [\tilde{\theta}, 1]$, where $\tilde{\theta} = \frac{6\alpha\gamma(1-\alpha) - Z - \sqrt{Z^2 + \Psi(3\alpha - 2\alpha^2)}}{6\gamma(1-\alpha)}$, do not share data and buy at the uniform price. There are two situations:

(i) if $\bar{\gamma}(\alpha) \leq \gamma \leq \bar{\gamma}_U(\alpha)$, then product quality, uniform price, and consumer surplus respectively are:

$$q_c = \frac{Z + \sqrt{Z^2 + \Psi(3\alpha - 2\alpha^2)}}{\Psi}$$

$$P_c = \frac{\alpha\Psi \left(Z + \sqrt{Z^2 + \Psi(3\alpha - 2\alpha^2)} \right) - (1-\alpha)\gamma \left(Z + \sqrt{Z^2 + \Psi(3\alpha - 2\alpha^2)} \right)^2}{\Psi^2}$$

$$CS_c = \frac{(1-\alpha) \left(Z + \sqrt{Z^2 + \Psi(3\alpha - 2\alpha^2)} \right)}{2\Psi} \left(\frac{\left(Z + \sqrt{Z^2 + \Psi(3\alpha - 2\alpha^2)} \right)^2}{36\gamma^2(1-\alpha)^3} + (2 - \alpha) \left(\frac{2Z + 2\sqrt{Z^2 + \Psi(3\alpha - 2\alpha^2)}}{3\gamma(1-\alpha)^2} + 1 \right) \right);$$

(ii) if $\gamma > \bar{\gamma}_U(\alpha)$, then the equilibrium is the same as without privacy regulation.

Proposition 2 shows that, as in the previous cases, product quality and the uniform price are increasing in γ . However, different from an interior solution, a stronger complementarity generates a benefit from the increase in quality that is larger than the harm due to the increase in the uniform price, thereby increasing demand in the second market.¹⁹ Thus, parameter γ positively affects the surplus of consumers paying both personalized prices and the uniform price.

Product quality increases with the ability to extract consumer surplus (except when α is very close to 1)²⁰, while the uniform price is always increasing in α . As to the effect of α on total consumer surplus, it depends on the value of γ . Specifically, if the complementarity between information and quality is strong, the negative

¹⁹ In a corner solution where all consumers in the first market share personal data, when γ is higher the monopolist has less incentives to raise the uniform price.

²⁰ When α is close to 1, the uniform price is relatively high, and a small number of high-wtp consumers are active in the second market. In such a case, an increase in quality would yield a sharp increase in the uniform price, and consequently a significant loss in revenues from the second market.

effect of the increase in price due to a higher value of α may be offset by the positive effect on consumers' utility due to the improved quality.

6. Comparison of results with and without privacy regulation

Let us now assess the effects of the opt-in regime on the incentives to invest in quality and on consumer surplus. For this purpose, we compare the equilibrium values of product quality and consumer surplus under the opt-in regime and in the benchmark case. In doing so, we focus on the parameter region where (compared to the benchmark case) privacy regulation affects the equilibrium outcome (i.e. $\gamma \leq \bar{\gamma}_U(\alpha)$), that is, where the uniform price is higher than in the benchmark case.

6.1 Product quality

Consider first product quality. We can prove that, in an interior solution (i.e., when $\gamma < \bar{\gamma}(\alpha)$), quality is lower under the opt-in regime than in the benchmark case (i.e., $q_I < q_B$ holds).²¹ If the complementarity between information and quality is relatively weak, then, for a given quality, high-wtp consumers in the first market would have a small benefit from sharing data, while having to pay personalized prices. Since quality is costly, then (irrespective of the ability to extract consumer surplus) the monopolist does not find it profitable to improve quality to the extent that such consumers are induced to reveal data. Thus, the monopolist reacts to the profit loss caused by the opt-in regime (that limits the scope for price discrimination) by reducing product quality, thereby using only the uniform price to deter some consumers from hiding.

As γ increases, product quality and consumers' incentive to reveal information also increase (see Section 5). Thus, when $\gamma \geq \bar{\gamma}(\alpha)$, we find a corner solution where all consumers in the first market opt for sharing data. We show that, if the complementarity between information and quality is strong enough (i.e., when $\gamma \geq \bar{\gamma}_L(\alpha) > \bar{\gamma}(\alpha)$, where $\bar{\gamma}_L(\alpha) = \frac{(4\alpha-2)}{2\alpha^2-\alpha+3}$), then the monopolist can use product quality as a tool to obtain

²¹ To prove this result, we study the sign of the first derivative of $\Pi(q)$ in an interior solution with respect to quality, evaluated at the optimal quality in the benchmark case. We find that $\partial\Pi/\partial q|_{q=q_B} = \gamma^2(3(1+2\alpha)^3 - \alpha^3(70+24\alpha^2-104\alpha)) + 16\gamma\alpha^2(4\alpha^2-8\alpha+3) - 8\alpha(1-2\alpha)^2 < 0$ when $\gamma_1 < \gamma < \gamma_2$ (expressions of γ_1 and γ_2 are omitted for brevity). Since $\gamma_1 < 0$ and $\gamma_2 \geq \bar{\gamma}(\alpha)$, the condition $\gamma_1 < \gamma < \gamma_2$ is always satisfied in an interior solution. Thus, under opt-in regulation the monopolist increases her profit by reducing quality with respect to the benchmark level. It follows that the equilibrium in an interior solution is such that $q_I < q_B$.

information from high-wtp consumers, without having to raise the uniform price significantly. Indeed, these consumers are provided with a large additional benefit from sharing data when buying an improved product. Then, when the complementarity between information and quality is strong enough, privacy regulation may lead the monopolist to provide higher quality to reduce the profit loss compared to the benchmark case. It follows that, even though privacy regulation reduces profit, it does not necessarily result in lower incentives to invest in quality.²²

The following proposition states our main result.

Proposition 3. *Assume that all the consumers in the first market reveal personal data (i.e., $\gamma \geq \bar{\gamma}(\alpha)$) and that privacy regulation is binding (i.e., $\gamma \leq \bar{\gamma}_U(\alpha)$). Then, product quality is higher under the opt-in regime than in the benchmark case as long as the complementarity between information and quality is strong enough.*

Formally, we have $q_C \geq q_B$ as long as $\gamma \geq \bar{\gamma}_L(\alpha) = \frac{(4\alpha-2)}{2\alpha^2-\alpha+3}$.

[insert Figure 1 about here]

Figure 1 illustrates the results. In the figure, the dark grey area highlights the combinations of parameter values such that $\bar{\gamma}_L(\alpha) \leq \gamma \leq \bar{\gamma}_U(\alpha)$, for which quality is higher under the opt-in regime. Conversely, the white area includes parameter combinations for which quality is lower under the opt-in regime. Finally, in the light grey area the opt-in regime is not binding.

6.2 Consumer surplus

As to the effects on consumer surplus, consider first the situation where the opt-in regime reduces quality compared to the benchmark case. Then, privacy regulation also reduces total consumer surplus. Indeed, fewer consumers are active in the second market, and they pay a higher price for a lower quality. In the first market, consumers who buy at personalized prices are worse off because of the lower quality. We can prove that consumers who choose to hide personal data are often better off, but this positive effect of privacy regulation does not offset the negative effect on the other consumers.

²² Let us evaluate $\partial\Pi/\partial q$ in a corner solution at the optimal quality in the benchmark case. We find that $\partial\Pi/\partial q|_{q=q_B} = -\frac{3\gamma^2(2\alpha+1)^2(1-\alpha)^2}{(4-8\alpha\gamma)^2} + \frac{2(2\alpha+1)(\gamma(4\alpha-2\alpha^2-1)-1/2)}{(4-8\alpha\gamma)} + \alpha\left(\frac{3}{2} - \alpha\right) > 0$ when $\bar{\gamma}_L(\alpha) \leq \gamma \leq \bar{\gamma}_U(\alpha)$, where $\bar{\gamma}_L(\alpha) = \frac{(4\alpha-2)}{2\alpha^2-\alpha+3} > \bar{\gamma}(\alpha)$. In this region, profit rises if quality is higher than in the benchmark case. Thus, in equilibrium, we have $q_C \geq q_B$.

It follows that an increase in quality is a necessary condition for consumer surplus to increase under the opt-in regime. Nonetheless, a quality improvement is not always associated with a higher consumer surplus, because privacy regulation has conflicting effects on consumers in the two markets, and the overall impact depends on their relative strength.

Let $\Delta CS_i = CS_{C,i} - CS_{B,i}$ be the change in consumer surplus in market i ($i = 1, 2$) between the privacy regime (in a corner solution) and the benchmark case. Let also $\Delta q = q_C - q_B > 0$. We find that consumers in the first market benefit from the improved quality induced by privacy regulation. Given that all of them buy at personalized prices, the change in surplus in the first market (compared to the benchmark case) is simply driven by the change in quality. Formally, we have:

$$\Delta CS_1 = (1 - \alpha)\Delta q \left[\frac{1}{2} + \gamma(2q_B + \Delta q) \right] > 0 \quad (17)$$

On the other hand, privacy regulation reduces consumer surplus in the second market. Somewhat paradoxically, the opt-in regime hurts exactly those consumers for which protecting personal data is more valuable. Indeed, the option to choose anonymity for consumers in the first market generates an indirect negative externality on consumers in the second market. Compared to the benchmark case, it increases the uniform price and reduces the number of active consumers in the second market. Formally, for any α and γ such that privacy regulation leads to higher quality, we find that:

$$\Delta CS_2 = \frac{q_C}{2}(1 - \alpha)^2(1 + \gamma q_C)^2 - \frac{q_B}{8} < 0 \quad (18)$$

We remark that the higher the value of γ , the lower the need for the firm to strategically use the uniform price to induce information sharing, and thereby the smaller the negative variation in CS_2 . Thus, as γ tends to $\bar{\gamma}_U(\alpha)$, the decline in CS_2 becomes relatively small compared to the increase in CS_1 . We can show that, in the relevant parameter region, there is a critical value $\bar{\gamma}^*(\alpha)$ such that, when $\gamma > \bar{\gamma}^*(\alpha)$ we obtain $|\Delta CS_1| > |\Delta CS_2|$, namely, the increase in consumer surplus in the first market more than compensates the decline in consumer surplus in the second market.

Proposition 4 summarizes the result.

Proposition 4. *If the complementarity between information and quality is strong enough, then the increase in quality with privacy regulation leads to a higher consumer surplus than in the benchmark case. Formally, if γ is such that $\bar{\gamma}^*(\alpha) < \gamma < \bar{\gamma}_U(\alpha)$ then we have $\Delta CS = \Delta CS_1 + \Delta CS_2 > 0$.*

[insert Figure 2 about here]

The dark grey area in Figure 2 highlights the values of α and γ for which the total consumer surplus increases under the opt-in regime, whereas the white area includes parameter values for which consumer surplus decreases under the opt-in regime (in the light grey area, the regime is not binding).

7. Discussion

In this section, we shed light on two specific issues. First, we check the robustness of our results by considering an alternative timing where the firm sets prices after observing consumers' choices about information sharing. Second, we discuss the effects of introducing the opt-in regime in the light of the presence of further privacy protection measures limiting the firm's ability to target consumers.

Let us analyse the first issue. In our basic model, the monopolist sets prices before consumers decide whether sharing personal data or not. This implies that she can use both product quality and the uniform price to induce consumers to share data. Consider now an alternative timing where consumers make their privacy choices after observing the baseline quality of the product, but before the firm sets prices (so that consumers decide about personal data based on anticipated prices).

Compared to the basic model, high-wtp consumers in the first market are more likely to remain anonymous, that is, the parameter region for a corner solution is smaller. Nonetheless, we find that the main qualitative results do hold, and indeed are strengthened, under the different timing. Thus, when the complementarity between information and quality is sufficiently strong, privacy regulation increases product quality. In this alternative model specification, quality is always higher with than without privacy regulation in a corner solution, and may also be higher in an interior solution.

Moreover, a higher product quality is a necessary condition for the total consumer surplus to increase under privacy regulation. Overall, the parameter region where consumer surplus increases is larger than in the basic model. Specifically, consumer surplus always increases when all consumers in the first market reveal personal information, and may also increase when some high-wtp consumers remain anonymous. This is because the

firm has less incentives to raise the uniform price when the share of consumers providing personal data is taken as given at the time when the price is set.

We also find that the inability to affect consumers' privacy choices through the uniform price leads to a lower profit for the monopolist, as compared to the original timing. This means that, whenever possible, the firm aims at setting prices in advance, while anticipating consumers' privacy choices. Indeed, in online markets, it is quite common to observe different pricing offers depending on whether consumers release personal information or not. Generally, consumers are provided with these alternative offers before they decide whether to reveal or conceal personal data.

As to the second issue, we should consider that the legal and regulatory framework where the monopolist operates is likely to influence the extent to which she is able to target consumers. For our purposes, one could think of measures such as restrictions on the combination of data from multiple sources and on trading of data, or outright bans on the collection and use of certain types of sensitive data. For any given degree of accuracy of the tracking technology, these measures reduce the firm's ability to extract consumer surplus, which in our model is reflected by the value of parameter α .

In what follows, we analyse how the effects of introducing the opt-in regime are related to the environment in which it is applied. In doing so, we study how the sign and the magnitude of the changes in product quality and consumers surplus induced by the opt-in regime depend on α .

Let us assume that the opt-in regime is binding (i.e. $\gamma < \bar{\gamma}_U(\alpha)$). We can draw from Figure 1 that, in this region, for any given γ , product quality increases under the opt-in regime for relatively low values of α . Thus, when the regulatory framework limits the firm's ability to target consumers, the monopolist uses product quality as a substitute for price discrimination. Note that $\bar{\gamma}_L(\alpha)$, the lowest degree of complementarity such that $q_C > q_B$, is increasing in α .²³ This means that, when the ability to extract consumer surplus is restricted, the monopolist finds it profitable to increase product quality even if the complementarity between information and quality is weaker.

²³ We find that the critical value $\bar{\gamma}_U(\alpha)$ is also increasing in α . Both $\bar{\gamma}_L(\alpha)$ and $\bar{\gamma}_U(\alpha)$ tend to 1/2 as α tends to 1.

Moreover, we can prove that, when product quality is lower under the opt-in regime than in the benchmark case (i.e., $\Delta q = q_i - q_B < 0$, with $i = I, C$), the lower the value of α , the smaller the quality gap, that is, Δq becomes less negative as α decreases.

Consider now consumer surplus. Assume that the opt-in regime is binding (i.e. $\gamma < \bar{\gamma}_U(\alpha)$). Figure 2 shows that, in this region, when γ is sufficiently high, we have an increase of the total consumer surplus for relatively low values of α . From (17), we know that an increase in quality (relative to the benchmark case) makes consumers in the first market better off. From Figure 1, low values of α are likely to induce an increase in quality under the opt-in regime, which, in turn, increases consumer surplus in the first market. Furthermore, when the protection of consumer data is stronger (lower α), the negative effect of the opt-in regime on consumers in the second market is smaller. This is because consumers in the first market are encouraged to share personal data,²⁴ thereby reducing the firm's incentive to raise the uniform price.²⁵

This analysis shows that a legal and regulatory framework that is oriented toward the protection of personal data makes more likely that introducing the opt-in regime improves product quality, while mitigating the impact on consumers harmed by the increase in the uniform price. The policy implication is that, to achieve welfare benefits, the opt-in regime should be implemented in combination with additional policy measures aimed at strengthening consumer privacy protection.

8. Conclusions

We have studied how privacy regulation limiting the scope for price discrimination by a monopolist who sells online does affect product quality and consumer surplus. We have considered an opt-in regime that provides consumers with the choice whether to reveal personal data or not. If consumers reveal data, then they gain an additional benefit from buying due to the complementarity between information and quality, but they have to pay personalized prices instead of a uniform price.

We have found that, despite privacy regulation reduces profit, it does not necessarily dampen the incentives to invest in product quality. Indeed, when the complementarity between information and quality is sufficiently

²⁴ Substituting (11) into (9) we find that, as α decreases, $\hat{\theta}$ tends to 1.

²⁵ The lower the value of α , the smaller the difference between the equilibrium (uniform) prices under privacy regulation and in the benchmark case.

strong, the monopolist strategically increases product quality (and the uniform price) to induce even high-wtp consumers to share personal data and pay personalized prices. In such a case, there is no trade-off between consumer privacy and product quality.

Generally, the opt-in regime has conflicting effects on consumers with different attitudes towards privacy. Perhaps surprisingly at first sight, consumers who are harmed by privacy regulation are those who are less prone to sharing personal data. We have found that an increase in quality is a necessary condition for an increase in total consumer surplus. However, consumer surplus may decrease with a higher quality. Since privacy regulation limits the scope for price discrimination, then the firm reacts by using product quality and the uniform price as effective means to extract consumer surplus.

We have also found that the main qualitative results still hold (and, indeed, are strengthened) under an alternative timing where the monopolist sets prices after consumers have made their privacy choices. Finally, we have shown that the opt-in regime is more likely to be beneficial when the ability to profile consumers from released information is limited. This result points to the importance of relying on a number of complementary policy measures aimed at protecting consumer data.

Our analysis contributes to the worldwide debate on the need for protecting consumer privacy, given that technological advances allow firms to collect and use personal data for the purpose of (among others) setting targeted prices. We have shown that the complementarity between information and quality is a key factor to consider when assessing whether consumers should be provided with more or less control over personal data. If the complementarity is strong, then we expect that the opt-in regime has a positive effect on product quality and possibly on consumer surplus. Conversely, if the complementarity is weak then the opt-in regime should not be enforced, since it reduces quality, consumer surplus, and thereby social welfare.

Our theoretical analysis should ideally be complemented by an empirical investigation of the relevance and the nature of the relation between personal information and product quality, which could be specific to products or industries. More generally, there is the need for further empirical research on the interaction between privacy regulation and product innovation to check the validity of theoretical results and related policy implications.

In this paper, consumers have been assumed to decide whether to reveal personal data or not when product quality is sunk. Alternatively, they could exercise their option before the firm invests in R&D. In this framework, collecting information on consumers' preferences and valuations is essential for the firm to obtain

an improved product. In future work, we intend to investigate whether our results on the welfare effects of privacy regulation are robust to this alternative model specification.

Recent technological developments and new business models (both of established firms such as telecom incumbents and of innovative startups) may enable data subjects to commercially benefit from trading their information assets under the opt-in regime. Thus, in an extension of our analysis, we could study whether the firm would use the financial incentive as a substitute or complement to product quality as a means to induce consumers to reveal personal data.

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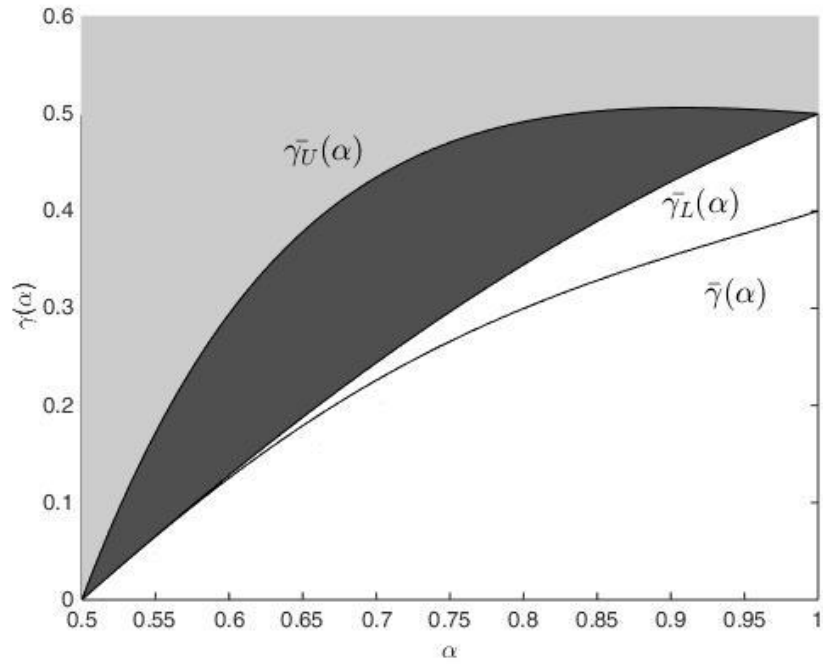


Figure 1. A comparison of product quality with and without privacy regulation.

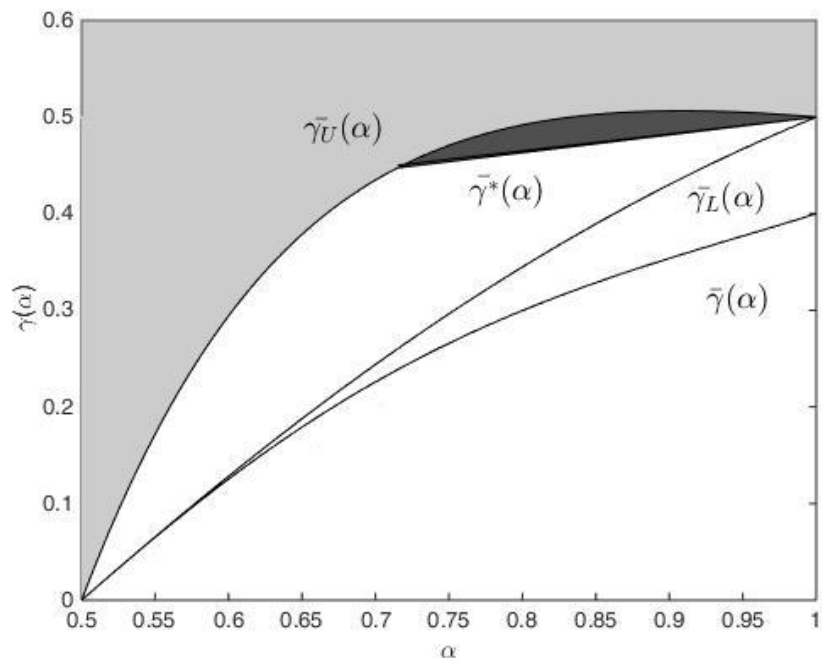


Figure 2. A comparison of consumer surplus with and without privacy regulation.