Journal of
Theoretical and Applied Electronic Commerce Research

MDPI

Article

Consumers' Strategic Misrepresentation Under Data-Driven Personalization: A Game-Theoretic Analysis of Pricing, Consumer Information Collection and Welfare

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Abstract

The collection and application of consumer information raise privacy concerns. Consumers may misrepresent their personal information, which may mitigate their privacy concerns. False information presents paradoxes for both firms and consumers. Hence, firms need to adjust their pricing strategies considering consumer misrepresentation. This paper employs a three-stage theoretical model to examine the impact of consumer misrepresentation on the firm and consumers at the same information-collection intensity. The results show that strategic misrepresentation always increases the equilibrium price, while its effects on demand, firm profit, consumer surplus, and social welfare depend on the unit profit of true personal information and the proportion of privacy-sensitive consumers. Under specific conditions, strategic misrepresentation generates a firm–consumer win–win outcome with higher social welfare. Privacy-sensitive consumers truthfully disclose their personal information below a behavioral threshold and begin to misrepresent above it. The firm's optimal information-collection intensity may lie below, at, or above the behavioral threshold, depending on the unit profit of true personal information, the unit information-processing cost, and the reduction in disclosure accuracy. We contribute to the literature on information systems and data strategy by revealing how strategic consumer falsification reshapes firm decision-making and welfare in data-driven markets.

Keywords: consumer information; consumer falsification; privacy concerns; pricing strategy; social welfare

1. Introduction

The rapid development of information technology potentially enables e-commerce firms to collect more consumer information, such as information about consumers' personal characteristics, browsing and search histories, shopping-cart interactions, and purchase histories. Through judicious analysis of this collected consumer information, firms can effectively analyze consumer behavioral patterns and preferences, and provide personalized services, such as personalized recommendations and targeted advertisements. The utilization of consumer information not only accrues benefits for firms but also affords consumers notable advantages, including elevated shopping experiences and lower search costs. Hence, consumers are willing to disclose personal information during their online shopping. Nevertheless, the utilization of consumer information inevitably raises privacy concerns [1,2]. Consumers attach considerable importance to the confidentiality of their personal information; privacy concerns may reduce their willingness to disclose such infor-

Check for updates

Academic Editor: Ting Chi

Received: 29 July 2026
Revised: 9 October 2026
Accepted: 12 October 2026
Published: 13 October 2026

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mation. When these concerns become sufficiently strong, consumers may even refuse to provide the requested information or discontinue their interactions with firms that collect it.

To mitigate the risks associated with disclosing personal information, consumers employ self-protection measures to enhance their control over personal information [3–5]. These measures include the application of privacy protection software, misrepresentation by providing false personal information, filtering spam emails, and engaging in anonymous usage [6,7]. Several papers [2,8,9] indicate that misrepresentation is a common method employed by consumers in practice. Although misrepresentation may help consumers mitigate privacy risks, it may also result in more irrelevant content, such as unrelated recommendations or intrusive advertisements, and weaken the alignment between personalized service and consumers' true preferences. In other words, consumers are cautious about disclosing their personal information because of privacy concerns and potential risks.

Although the utilization of consumer information can help firms conduct precision marketing, it also incurs costs for firms, including data collection, storage and management, data analysis, and security protection costs. False consumer information has no value for actual marketing activities [10], raises firms' information costs, and diminishes the precision of personalized service. Nevertheless, strategic misrepresentation may benefit firms. To a certain extent, it could mitigate privacy concerns, increase consumers' willingness to disclose information, enable privacy-sensitive consumers to continue participating, and enhance the probability of purchasing. That is, firms may benefit from strategic misrepresentation by obtaining more useful consumer information and increased product sales.

In summary, consumers' strategic misrepresentation behavior presents paradoxes for both firms and consumers. For consumers, such behavior may mitigate their privacy risks but concurrently expose them to the potential hazard of inaccurate personalized service. For firms, the presence of false consumer information diminishes the intrinsic value of consumer information, but it may increase the likelihood of consumers disclosing information and increase consumers' purchase intentions. Hence, firms need to carefully contemplate the impact of strategic misrepresentation and choose their marketing strategies.

Using a game-theoretic model, we investigate the impact of strategic misrepresentation on a firm's consumer-information-collection and pricing strategies. Specifically, we first examine the firm's equilibrium pricing strategies and profit, as well as social welfare, both in the presence and absence of false consumer information. Then, we compare the equilibrium outcomes of the two scenarios and derive the optimal consumer-information-collection strategy.

Several key findings are derived. First, privacy-sensitive consumers do not misrepresent at low collection intensity and misrepresent a positive fraction only if the collection intensity of consumer information crosses a threshold. Second, at a common collection intensity, misrepresentation always raises the equilibrium price because it both increases the privacy-sensitive consumer's optimized utility and reduces the firm's expected profit. Nevertheless, the equilibrium demand increases when the privacy benefit from misrepresentation dominates the lost value of consumer true information. Third, a firm–consumer win–win outcome exists only under an explicit profitability condition. Fourth, the firm's optimal collection intensity is below the critical collection level that triggers consumer misrepresentation when the processing cost exceeds the unit profit of true personal information, equals that level when the unit profit of true personal information is insufficient to offset the processing cost, and exceeds it only when the value of additional true personal information is sufficiently high. This critical collection level indicates when privacy-sensitive consumers begin to misrepresent their information, rather than providing a universal criterion for excessive data collection.

https://doi.org/10.3390/jtaer21100367

The rest of this paper is organized as follows. Section 2, "Related Literature", summarizes the related literature on our research topic. Section 3, "Model Setup", introduces the setting of our game-theoretic model. The equilibrium solutions and analyses are presented in Section 4, "Equilibrium Analysis". Then, we extend our analysis in Section 5, "Extensions". Finally, the main findings and limitations are given in Section 6, "Conclusion".

2. Related Literature

Our research topic is related to two streams of research: (1) consumer information disclosure and protection; and (2) the relationship between personalized service and consumer information disclosure.

First, this paper is closely related to the literature on consumer information disclosure and protection. Consumers disclose their personal information consciously or unconsciously [1,11–13]; firms use this personal information in product R&D [14–16], risk analysis [17–20], personalized service [21–24] and other activities. However, such use may expose consumers to more risks [17,24,25] and raise privacy concerns [9,26,27], which influence consumers' willingness to disclose personal information and the corresponding self-protection measures. The application of personal information protection measures can mitigate privacy concerns [2]. A stream of research [28–30] has studied the measures that consumers undertake to protect their personal information when engaging in personal information disclosure. Alkire et al. [31] concluded that consumers undertake personal information protection measures, including refraining from providing personal information, controlling the volume of personal information disclosed, disclosing false information, and constraining the collection of their personal information. Disclosing false information is considered to be an effective measure of protecting consumers' personal information [32–34]; it alters the amount and accuracy of the personal information disclosed [33]. Punj [35] examined consumers' intentions to falsify personal information and their influence on the firm. He argued that consumers resort to misrepresentation as an effective way of protecting their personal information since it is difficult to protect their personal information online. He also highlighted that misrepresentation has a social cost because it lowers social welfare and marketing efficiency. Building upon the findings of these studies, this paper considers that consumers misrepresent to protect themselves. Unlike the existing literature, we distinguish the amount of consumer information collected by the firm from the accuracy of that information. The firm's information-collection intensity determines the amount of information processed and the personalized service level supported by the collected information. Consumer misrepresentation does not reduce this service level directly; instead, it reduces the proportion of collected information that reflects the consumer's true characteristics and therefore affects the effective alignment of personalized service. We incorporate this distinction into consumers' disclosure and purchase decisions and examine its implications for the firm's strategy.

This paper is also related to the literature on the relationship between personalized service and consumer information disclosure. Several scholars have studied the influence of personalized service on consumers' willingness to disclose personal information. Zhu et al. [36] concluded that firms' personalized services encourage consumers to disclose more personal information. Gouthier et al. [37] derived a similar conclusion, and they argued that consumers' perceived utility plays a mediating role. Mothersbaugh et al. [38] checked the relationship between personalized service and consumer information disclosure within a fictional online TV program; they found that the benefits from personalized service can overcome the negative impact of personal information disclosure. Kim and Kim [39] found that the perceived benefits from personalized recommendation systems affect consumers' willingness to disclose their personal information. Trang and Weiger [40]

demonstrated that the personalized gamified service can lead to greater willingness to disclose personal information. Another stream has analyzed the impact of consumer information disclosure on the firms' personalized services. More consumer information is thought to increase the personalized service level and conversion rate [41]. Casadesus-Masanell and Hervas-Drane [42] found that the collected volume of consumer information influences firms' personalized service levels. Goldfarb and Tucker [43] summarized that consumers benefit from reduced search costs and higher personalized service by disclosing personal information. Hence, when consumers disclose more personal information, they can receive better personalized service. Tucker [44] thought that when consumers can control the process of their personal information disclosure, they respond more favorably to personalized advertisements. Martin and Murphy [45] concluded that providing consumers with personal information controls can make them more receptive to personalized service. Korganbekova and Zuber [46] found that personalization based on consumer information increases seller and platform profits and improves consumer–product matching. Their findings also indicated that the restriction of consumer information can balance the paradox of privacy concerns and personalization. These papers show that when consumers control their personal information disclosure, personalized service becomes more effective. Unlike the above literature, we think that consumers may misrepresent during their personal information disclosure and examine its impact on the firm's personalized service strategy. We show that the firm can still achieve a higher profit when it collects a moderate volume of consumer information, despite the presence of false consumer information. Although disclosing false information reduces the personalized service level, in certain scenarios it still enhances the market demand, firm profit, consumer surplus and social welfare.

Table 1 clarifies the distinction between the closest studies and the present model.

Table 1. Comparison with closely related research.

Study	Primary Focus	Misrepresentation	Endogenous Information Collection	Welfare Analysis
Son and Kim [1]	Taxonomy of privacy-protective responses	No	No	No
Sannon et al. [8]	Motives and contexts of privacy lies	Behavioral evidence	No	No
Punj [35]	Intention and ethical justification for false disclosure	Behavioral intention	No	Discussed conceptually
Cloarec [34]	Privacy controls and data quality in AI personalization	Yes	No	No
Casadesus-Masanell and Hervas-Drane [42]	Privacy and market competition	No	Yes	Yes
Ke and Sudhir [30]	Privacy rights, security, and data markets	No	Yes	Yes
This study	Strategic misrepresentation, pricing, collection intensity, and welfare	Yes	Yes	Yes

3. Model Setup

We consider a unit monopolistic market in which a firm serves consumers who are uniformly distributed over the market. Each consumer demands at most one unit of the product and has an intrinsic valuation for the product of $\theta \tilde{} U[0,1]$. Consumers are categorized into privacy-sensitive consumers and non-privacy-sensitive consumers based on their attitudes toward the application of their personal information. A share of $g \in (0,1)$ of consumers is privacy-sensitive and the remaining share $1 - g$ is non-privacy-sensitive. In the rest of this paper, we adopt different subscripts to distinguish the two types of consumers, where the subscript "m" represents privacy-sensitive consumers, and the subscript "n" represents non-privacy-sensitive consumers. Both the firm and consumers

are risk neutral, and the firm seeks to maximize its profit and consumers make decisions based on their utilities.

The firm also provides personalized service based on its collected consumer information $y \in [0,1]$, which is defined as information-collection intensity. It represents the breadth or depth of consumer attributes that the firm requires and processes relative to the maximum amount of consumer information. The firm does not choose a personalized service level as a separate decision variable. Rather, the level of personalized service provided by the firm is determined by the collected consumer information, y. A higher information-collection intensity enables the firm to use more consumer information when providing personalized service, while directly increasing its information-processing cost. In our game, the firm first determines the information-collection intensity. Based on the selected collection intensity, the firm designs the intended level of data-enabled personalized service that can be provided if consumers disclose the requested information accurately. Thus, y determines the information requirement and the scope of personalization, whereas the personalized service received by an individual consumer is realized only after that consumer provides information. To focus on the impact of strategic misrepresentation, we assume the trade between consumers and the firm is data-conditioned. That is, a consumer who purchases from the firm accepts the stated information requirement, whereas a consumer who rejects the requirement neither purchases nor discloses information.

After observing the information-collection intensity and price, a privacy-sensitive consumer may misrepresent a fraction $\alpha \in [0,1]$ of the requested information to alleviate privacy concerns, whereas a non-privacy-sensitive consumer discloses all requested information truthfully. Correspondingly, $1 - \alpha$ denotes the accuracy of the personal information provided by a privacy-sensitive consumer. The firm cannot distinguish misrepresented information from truthful information and therefore provides personalized service based on the entire amount of collected information, y. Accordingly, consumer misrepresentation does not change the personalized service level provided by the firm. However, when a fraction, α, of the collected information is misrepresented, only $(1 - \alpha)y$ is consistent with the consumer's true characteristics and preferences. The service provided on the basis of the collected information may consequently deviate from the service that would be generated from truthful information. In summary, y determines the personalized service level provided by the firm, whereas $(1 - \alpha)y$ determines the effective level of personalized service perceived by the consumer. Therefore, misrepresentation does not change the level of personalized service provided by the firm, which is determined by the consumer information collected; instead, it weakens the alignment between the service and the consumer's true preferences. In other words, misrepresentation creates service–preference misalignment.

Following Casadesus-Masanell and Hervas-Drane [42], if a consumer does not misrepresent, his/her perceived utility from personalized service is $y(1 - y)V$, where $V > 0$ scales the unit value of data-enabled personalized service, which also represents the magnitude of information-related utility. Accordingly, if a privacy-sensitive consumer misrepresents, his perceived utility from personalized service is $(1 - \alpha)y[1 - (1 - \alpha)y]V$. This reduced-form specification captures both the benefit generated by personalized service based on effective true information and the diminishing or adverse utility associated with greater use of true personal information. Misrepresentation therefore affects consumer utility by alleviating privacy concerns while changing the accuracy and fit of the realized personalized service. Misrepresentation is costly; we assume the cost of misrepresentation is $c_m(\alpha y)^2$, where c_m represents the unit cost of misrepresentation. The consumer consequently chooses the misrepresentation fraction by balancing the reduction in privacy concerns against the utility

consequences of the service deviation and the direct cost of misrepresentation. Then, the utility function of a privacy-sensitive consumer is given by:

$$u_m = \theta + (1 - \alpha)y[1 - (1 - \alpha)y]V - p - c_m(\alpha y)^2 \quad (1)$$

Correspondingly, the utility function of non-privacy-sensitive consumers is:

$$u_n = \theta + y(1 - y)V - p \quad (2)$$

A consumer discloses personal information and buys when the maximized utility is nonnegative; otherwise, the consumer will not choose the firm. Let d_m and d_n denote the purchase probabilities within the privacy-sensitive and non-privacy-sensitive groups. The total demand $D = gd_m + (1 - g)d_n$.

Processing consumer information is costly for the firm. We assume the unit information-processing cost is $c_d > 0$. For a consumer who does not misrepresent, the firm can earn an indirect marginal data profit of $(b - c_d)y$, where b is the unit profit of true personal information. For a consumer who misrepresents a fraction, α, of the requested information, the firm earns an indirect data profit only from $(1 - \alpha)y$ units of true personal information but processes all y units of information. The firm's profit function is therefore:

$$\pi = [p + b(1 - \alpha)y - c_d y]gd_m + [p + (b - c_d)y](1 - g)d_n \quad (3)$$

Consumer surplus is defined as the aggregate utility of consumers who purchase from the firm. When no consumers misrepresent, aggregate consumer surplus is therefore:

$$CS = \int_{1-D}^{1} u_n d\theta \quad (4)$$

When privacy-sensitive consumers misrepresent, the aggregate consumer surplus includes consumer surplus from non-privacy-sensitive consumers and privacy-sensitive consumers. The aggregate consumer surplus is:

$$CS = g\int_{1-d_m}^{1} u_m d\theta + (1 - g)\int_{1-d_n}^{1} u_n d\theta \quad (5)$$

Social welfare is defined as the sum of firm profit and aggregate consumer surplus:

$$SW = \pi + CS \quad (6)$$

We employ a three-stage Stackelberg game to examine how a data-driven firm determines its information-collection and pricing strategies while consumers may misrepresent information. The firm acts as the leader by choosing information-collection intensity and price, whereas consumers act as followers by deciding whether to purchase and, conditional on purchasing, how accurately to disclose the requested information.

We formulate a three-stage Stackelberg game in which the firm is the leader and consumers are followers. In Stage 1, the firm determines the information-collection intensity y, which determines the amount of consumer information to be collected, the personalized service level supported by that information, and the associated information-processing cost. In Stage 2, the firm sets the product price, p. In Stage 3, consumers observe (y,p). Each consumer decides whether to buy. Conditional on purchasing, privacy-sensitive consumers determine the fraction, α, of information to misrepresent. The firm subsequently processes the collected information and provides personalized service based on the entire information input, y. When consumers disclose truthfully, the collected information accurately reflects

their characteristics. When they misrepresent, the personalized service provided by the firm remains based on y, but its effective alignment with consumers' true preferences depends on $(1-\alpha)y$. We solve the game by backward induction. The resulting strategies constitute a subgame-perfect equilibrium.

The feasibility conditions supporting the equilibria are presented after the equilibria under different scenarios have been derived.

4. Equilibrium Analysis

Section 4 solves the game by backward induction. We first characterize consumers' information-disclosure and purchase decisions because these responses determine the firm's demand, pricing, and information-collection incentives. We then derive the equilibrium outcomes under truthful disclosure and strategic misrepresentation, denoted by superscripts "B" (Scenario B) and "F" (Scenario F), respectively, and compare the equilibrium prices, demands, profits, consumer surplus, and social welfare to show the impact of misrepresentation on the firm and consumers. These results provide the foundation for analyzing the firm's optimal information-collection intensity in Section 5.

4.1. Consumers' Information-Disclosure and Purchase Decisions

Based on the timing sequence of the game, we first analyze consumers' information-disclosure and purchase decisions. Consumers make these decisions to maximize their utilities. Since only privacy-sensitive consumers may misrepresent, they need to decide whether to misrepresent and what fraction of their personal information to misrepresent. Based on Equation (1), we derive privacy-sensitive consumers' optimal decisions by differentiating Equation (1) with respect to the misrepresentation fraction, and we have $\frac{\partial u_m}{\partial \alpha} = y(2y-1)V - 2y^2(V+c_m)\alpha$, $\frac{\partial^2 u_m}{\partial \alpha^2} = -2y^2(V+c_m) < 0$. Then, we have

Proposition 1. *A privacy-sensitive consumer does not misrepresent when* $y \leq \frac{1}{2}$. *When* $y > \frac{1}{2}$, *the privacy-sensitive consumer strategically misrepresents the fraction* $\alpha^*(y) = \frac{(2y-1)V}{2y(V+c_m)}$.

Proposition 1 shows the optimal misrepresentation strategy of a privacy-sensitive consumer. When the information-collection intensity is lower than the threshold, a privacy-sensitive consumer always discloses personal information truthfully to maximize his utility, but misrepresents false information if the information-collection intensity exceeds the threshold.

The threshold behavior of a privacy-sensitive consumer in Proposition 1 can be explained by privacy calculus theory. Misrepresentation reduces privacy concerns and may increase the consumer's utility, but it also weakens the match between personalized service and the consumer's true preferences, which also entails a misrepresentation cost. When the amount of information required by the firm is lower than $\frac{1}{2}$, misrepresentation will reduce the proportion of information consistent with the consumer's true preferences, create service–preference misalignment, and incur a direct cost for the consumer. The consumer therefore discloses all requested information truthfully. When the amount of information required by the firm exceeds the threshold, misrepresentation reduces the amount of true personal information disclosed and alleviates privacy concerns. Although the firm continues to provide personalized service based on the collected information, y, part of that service is generated from misrepresented information and may therefore deviate from the consumer's actual preferences. The optimal misrepresentation fraction balances the privacy benefit against this service deviation and the direct misrepresentation cost.

Based on Lemma 1, we conduct a comparative-static analysis of the privacy-sensitive consumer's utility. Substituting the optimal misrepresentation fraction, $\alpha^*(y)$, into the

privacy-sensitive consumer's utility function in Equation (1) and comparing it with the utility of a privacy-sensitive consumer who discloses personal information truthfully shows that misrepresentation increases the privacy-sensitive consumer's utility. When the amount of information required by the firm exceeds the threshold, a privacy-sensitive consumer discloses more personal information than they prefer if they do not misrepresent. In this case, the privacy risk associated with additional true personal information exceeds its incremental personalized service benefit. A small increase in the misrepresentation fraction therefore improves a privacy-sensitive consumer's utility by reducing information exposure, although it simultaneously reduces the value of personalized service and incurs a misrepresentation cost. The optimal misrepresentation fraction balances these opposing effects. Because the resulting utility gain remains positive after both the loss of personalized service value and the misrepresentation cost have been deducted, strategic misrepresentation represents a rational privacy-protective response rather than arbitrary deceptive behavior.

The above results suggest that firms should not equate greater information collection with more valuable consumer information. Once the information-collection intensity induces strategic misrepresentation, collecting more consumer information may increase the volume of consumer data while reducing data accuracy. Firms should jointly evaluate consumer information quantity, accuracy, consumer participation, and information-processing costs when formulating their information-collection strategies. When consumers' true personal information is particularly important for the firm, limiting unnecessary collection and providing transparent or granular disclosure choices may preserve both consumer participation and data reliability.

Lemma 1. $\frac{d\alpha^*(y)}{dV} > 0$, $\frac{d\alpha^*(y)}{dc_m} < 0$, $\frac{d\alpha^*(y)}{dy} > 0$, $\frac{d\alpha^*(y)}{db} = \frac{d\alpha^*(y)}{dc_d} = \frac{d\alpha^*(y)}{dg} = 0$.

Lemma 1 shows that privacy-sensitive consumers misrepresent more information when the value of data-enabled personalized service, V or the information-collection intensity y increases. Conversely, they misrepresent less when the unit misrepresentation cost c_m increases. Moreover, the equilibrium misrepresentation fraction $\alpha^*(y)$ is locally invariant to the unit profit of true personal information b, the unit information-processing cost c_d, and the share of privacy-sensitive consumers g.

When the firm's information-collection intensity exceeds the threshold, privacy-sensitive consumers misrepresent. A higher value of data-enabled personalized service magnifies the utility consequence of disclosing an amount of true information beyond the consumer's preference. The consumer consequently has a stronger incentive to disclose less true information. That is, a higher value of data-enabled personalized service strengthens the consumer's utility response to the effective use of true personal information. A higher information-collection intensity similarly increases the amount of collected information and strengthens the incentive to misrepresent. By contrast, a higher unit misrepresentation cost reduces the consumer's perceived utility, leading the consumer to provide more true personal information. The unit profit from true information, information-processing cost, and the proportion of privacy-sensitive consumers do not influence the individual consumer's utility function. Although these parameters affect the firm's pricing, demand, and profit, they do not change the consumer's optimal misrepresentation fraction conditional on purchase.

In particular, a larger privacy-sensitive segment increases the number of potential consumers who misrepresent without changing the misrepresentation fraction of each such consumer. Firms should therefore evaluate both individual misrepresentation behavior and market composition when assessing the quality of collected information. Moreover, increasing information-collection intensity may simultaneously increase information vol-

ume and reduce reporting accuracy, so greater information-collection intensity does not necessarily generate more usable true information.

4.2. Equilibrium Analysis Under Scenario B

When consumers do not misrepresent, all of the firm's collected consumer information is true. Following the timing sequence of the game and using backward induction, we first identify the consumers who will buy from the firm. Consumers only buy from the firm when their utility satisfies $u_n(\theta) \geq 0$, and the marginal consumer whose utility equals 0 satisfies $u_n(\theta_0) = 0$. We have $\theta_0 = p^B - y(1-y)V$. Consumers whose intrinsic valuation for the product is less than θ_0 do not buy from the firm. Hence, the firm's market demand is $D_n = 1 - \theta_0$. Since both types of consumers disclose personal information truthfully, the utilities of the privacy-sensitive and non-privacy-sensitive consumers are the same and are shown as Equation (2). Hence, the firm's profit function is $\pi_B = (p^B + by - c_d y)(1 - \theta_0)$. The firm maximizes its profit by setting its price. We can derive the equilibrium price, demand, and profit of the firm as follows.

Proposition 2. *Under Scenario B, the equilibrium strategy is* $p^{B*} = \frac{1+(V-b+c_d)y-Vy^2}{2}$, $D^{B*} = \frac{1+(V+b-c_d)y-Vy^2}{2}$ *and* $\pi^{B*} = \frac{[1+y(1-y)V+(b-c_d)y]^2}{4}$. *Aggregate consumer surplus and social welfare are* $CS^{B*} = \frac{[1+y(1-y)V+(b-c_d)y]^2}{8}$, *and* $SW^{B*} = \frac{3[1+y(1-y)V+(b-c_d)y]^2}{8}$.

Proposition 2 establishes the equilibrium outcomes under Scenario B. To clarify how the underlying model parameters shape the equilibria, we next examine their comparative-static effects. We first consider the unit value of data-enabled personalized service V, the unit profit of true personal information b, and the unit information-processing cost c_d while holding information-collection intensity constant. We then examine the impact of information-collection intensity y separately because it affects both consumers' information-related utility and the firm's information-related return.

Lemma 2. *Under Scenario B, (1)* $\frac{dp^{B*}}{dV} > 0$, $\frac{dD^{B*}}{dV} > 0$, $\frac{d\pi^{B*}}{dV} > 0$, $\frac{dCS^{B*}}{dV} > 0$, $\frac{dSW^{B*}}{dV} > 0$; *(2)* $\frac{dp^{B*}}{db} < 0$, $\frac{dD^{B*}}{db} > 0$, $\frac{d\pi^{B*}}{db} > 0$, $\frac{dCS^{B*}}{db} > 0$, $\frac{dSW^{B*}}{db} > 0$; *(3)* $\frac{dp^{B*}}{dc_d} > 0$, $\frac{dD^{B*}}{dc_d} < 0$, $\frac{d\pi^{B*}}{dc_d} < 0$, $\frac{dCS^{B*}}{dc_d} < 0$, $\frac{dSW^{B*}}{dc_d} < 0$.

Lemma 2 shows that a higher unit value of data-enabled personalized service increases the equilibrium price, demand, firm's profit, consumer surplus and social welfare; a higher unit profit of true personal information decreases the equilibrium price, but increases demand, the firm's profit, consumer surplus and social welfare; a higher unit information-processing cost increases the equilibrium price, but decreases demand, the firm's profit, consumer surplus and social welfare.

Consistent with privacy calculus theory, a higher value of data-enabled personalized service strengthens the benefit consumers obtain from truthful information disclosure. This increases their willingness to pay and expands market participation. The firm captures part of the additional consumer value through a higher price, while the remaining value increases consumer surplus. Firm profit and social welfare therefore also improve. The unit profit of true personal information generates a data-monetization effect. Because the firm obtains greater information-related profit from each purchasing consumer, it relies less on the product price and optimally lowers the price to stimulate demand. The resulting market expansion benefits both the firm and consumers, indicating that the economic use of true personal information can create value rather than merely redistribute surplus. Finally, a higher unit information-processing cost reduces the firm's marginal profit from each consumer and creates a cost pass-through effect. The firm responds by raising the price,

which suppresses demand and ultimately reduces the firm's profit, consumer surplus, and social welfare. From a managerial perspective, firms should focus on improving the service value and economic usefulness of true personal information while controlling information-processing costs. These measures can improve profitability and consumer welfare without requiring a higher collection intensity.

Lemma 3. *Under Scenario B, (1) if* $y < \frac{V-b+c_d}{2V}$, $\frac{dp^{B*}}{dy} > 0$, *otherwise,* $\frac{dp^{B*}}{dy} < 0$; *(2) if* $y < \frac{V+b-c_d}{2V}$, $\frac{dD^{B*}}{dy} > 0$, $\frac{d\pi^{B*}}{dy} > 0$, $\frac{dCS^{B*}}{dy} > 0$, $\frac{dSW^{B*}}{dy} > 0$; *otherwise,* $\frac{dD^{B*}}{dy} < 0$, $\frac{d\pi^{B*}}{dy} < 0$, $\frac{dCS^{B*}}{dy} < 0$, $\frac{dSW^{B*}}{dy} < 0$.

Lemma 3 indicates that at a low collection intensity, a higher information-collection intensity increases the equilibrium price, demand, firm's profit, consumer surplus, and social welfare. At an intermediate collection intensity, a higher information-collection intensity lowers the price but continues to increase demand, the firm's profit, consumer surplus, and social welfare. At a high collection intensity, a higher information-collection intensity reduces all equilibrium outcomes.

The outcomes in Lemma 3 result from the interaction between the personalization–privacy effect and the information-return effect. The personalization–privacy effect captures how more consumer information changes consumer utility. At a low information-collection intensity, more consumer information enables the firm to provide better-matched personalized services, and the resulting personalized service value exceeds the associated privacy risks. As the information-collection intensity increases, however, the marginal improvement in personalized service value diminishes while privacy risks become more salient. Additional collection may therefore eventually reduce consumers' willingness to pay and market participation. The information-return effect operates through the firm's profit structure. Under Scenario B, a higher information-collection intensity provides the firm with more true personal information but also increases its information-processing cost. When the unit profit from true information exceeds the unit information-processing cost, collecting more consumer information increases the firm's information-related return. The firm can then rely less on the product price and lower the price to attract more consumers. When the information-processing cost is relatively high, this price-subsidization effect is weakened or reversed.

These two effects influence the equilibrium price differently. The personalization–privacy effect may support a higher price by increasing consumers' willingness to pay, whereas the information-return effect may lower the price by providing the firm with an alternative source of profit. At an intermediate information-collection intensity, the price-subsidization effect can reduce the price while demand, firm profit, consumer surplus, and social welfare increase. At a high collection intensity, however, the decline in consumer utility dominates the additional information-related return, causing the equilibrium price, demand, firm's profit, consumer surplus, and social welfare to decrease. Thus, firms should improve the usefulness of true personal information and control information-processing costs rather than simply expanding the amount of consumer information collected.

4.3. Equilibrium Analysis Under Scenario F

Consumers are concerned about the use of the personal information they disclose, and they may misrepresent to mitigate potential privacy risks. Using the expected utility function in Equation (1) and the firm's demand function in Equation (3), we follow the timing sequence of the game and employ backward induction to derive the equilibrium solutions. Since non-privacy-sensitive consumers do not misrepresent, we focus on privacy-

sensitive consumers in this section. Based on Proposition 1, under Scenario F, for $y > \frac{1}{2}$, privacy-sensitive consumers misrepresent with a fraction $\alpha^* = \frac{(2y-1)V}{2y(V+c_m)}$.

We first derive the demand from non-privacy-sensitive consumers. Based on Equation (2), the demand from non-privacy-sensitive consumers is $d_n = 1 - p^F + y(1-y)V$. Then, we derive the demand from privacy-sensitive consumers. Based on Equation (1), these privacy-sensitive consumers buy from the firm when their utility satisfies $u_m(\theta) \geq 0$; that is, consumers whose intrinsic valuation over the product satisfies $\theta \geq \theta_1 = p^F - y(1-y)V - \frac{(2y-1)^2V^2}{4(V+c_m)}$. Hence, the demand from privacy-sensitive consumers is $d_m = 1 - p^F + y(1-y)V + \frac{(2y-1)^2V^2}{4(V+c_m)}$.

Substituting d_n and d_m into the firm's profit function in Equation (3) and applying the first-order condition, we derive the firm's equilibrium price, demand, and profit as follows.

Proposition 3. *Under Scenario F,* $p^{F*} = \frac{1}{2}\left\{1 + y(1-y)V - (b-c_d)y + \frac{gV(2y-1)[2b+(2y-1)V]}{4(V+c_m)}\right\}$, $D^{F*} = \frac{1}{2}\left\{1 + y(1-y)V + (b-c_d)y + \frac{gV(2y-1)[(2y-1)V-2b]}{4(V+c_m)}\right\}$, $\pi^{F*} = \frac{1}{4}\left\{1 + y(1-y)V + (b-c_d)y + \frac{gV(2y-1)[(2y-1)V-2b]}{4(V+c_m)}\right\}^2 - \frac{g(1-g)b(2y-1)^3V^3}{8(V+c_m)^2}$, $CS^{F*} = \frac{1}{8}\left\{1 + y(1-y)V + (b-c_d)y + \frac{gV(2y-1)[(2y-1)V-2b]}{4(V+c_m)}\right\}^2 + \frac{g(1-g)(2y-1)^4V^4}{32(V+c_m)^2}$, $SW^{F*} = \frac{3}{8}\left\{1 + y(1-y)V + (b-c_d)y + \frac{gV(2y-1)[(2y-1)V-2b]}{4(V+c_m)}\right\}^2 + \frac{g(1-g)(2y-1)^3V^3[(2y-1)V-4b]}{32(V+c_m)^2}$.

Proposition 3 shows the equilibrium outcomes under Scenario F. We therefore examine how the equilibrium outcomes change with the value of data-enabled personalized service V, the unit profit of true personal information b, the unit information-processing cost c_d, the unit misrepresentation cost c_m, the proportion of privacy-sensitive consumers g, and the information-collection intensity y.

Lemma 4. *Under Scenario F, (1)* $\frac{dp^{F*}}{dV} > 0$; *if* $b < \frac{4y(1-y)(V+c_m)^2 + g(2y-1)^2V(V+2c_m)}{2g(2y-1)c_m}$, $\frac{dD^{F*}}{dV} > 0$, *otherwise,* $\frac{dD^{F*}}{dV} < 0$; *if* $c_d < c_{d1}$, $\frac{d\pi^{F*}}{dV} > 0$, *otherwise,* $\frac{d\pi^{F*}}{dV} < 0$; *if* $c_d > c_{d2}$, $\frac{dCS^{F*}}{dV} > 0$, *otherwise,* $\frac{dCS^{F*}}{dV} < 0$; *if* $c_d < c_{d3}$, $\frac{dSW^{F*}}{dV} > 0$, *otherwise,* $\frac{dSW^{F*}}{dV} < 0$. *(2)* $\frac{dp^{F*}}{db} < 0$, $\frac{dD^{F*}}{db} > 0$, $\frac{d\pi^{F*}}{db} > 0$, $\frac{dCS^{F*}}{db} > 0$, $\frac{dSW^{F*}}{db} > 0$. *(3)* $\frac{dp^{F*}}{dc_d} > 0$, $\frac{dD^{F*}}{dc_d} < 0$, $\frac{d\pi^{F*}}{dc_d} < 0$, $\frac{dCS^{F*}}{dc_d} < 0$, $\frac{dSW^{F*}}{dc_d} < 0$. *where* $c_{d1} = \frac{1+by+y(1-y)V}{y} + \frac{gV(2y-1)}{y(V+c_m)}\left[\frac{(2y-1)V-2b}{4} - \frac{(1-g)b(2y-1)^2V(V+3c_m)}{\Omega}\right]$, $c_{d2} = \frac{1+by+y(1-y)V}{y} + \frac{gV(2y-1)}{y(V+c_m)}\left[\frac{(2y-1)V-2b}{4} + \frac{(1-g)(2y-1)^3V^2(V+2c_m)}{\Omega}\right]$, $c_{d3} = \frac{1+by+y(1-y)V}{y} + \frac{gV(2y-1)}{y(V+c_m)}\left[\frac{(2y-1)V-2b}{4} + \frac{(1-g)(2y-1)^2V[(2y-1)V(V+2c_m)-2b(V+3c_m)]}{3\Omega}\right]$, $\Omega = 4y(1-y)(V+c_m)^2 + g(2y-1)[(2y-1)V(V+2c_m) - 2bc_m]$.

Lemma 4 shows that the value of data-enabled personalized service affects the equilibrium outcomes differently when privacy-sensitive consumers can strategically misrepresent. A higher value of data-enabled personalized service increases consumers' willingness to pay and therefore raises the equilibrium price. However, as established in Lemma 1, it also induces privacy-sensitive consumers to misrepresent a larger fraction of their information, reducing the volume of true personal information and the firm's information-related return. Consequently, whether demand, firm profit, consumer surplus, and social welfare increase depends on whether the additional consumer benefit outweighs the higher price and the loss caused by less true personal information.

The effects of the unit profit of true personal information and unit information-processing cost follow the same basic mechanisms as in Lemma 2. A higher value of

true information lowers the price and improves demand, profit, consumer surplus, and social welfare, whereas a higher processing cost produces the opposite effects. These parameters do not change individual reporting behavior because they influence the firm's profit rather than consumer utility.

Lemma 4 therefore indicates that increasing the value of data-enabled personalized service does not necessarily improve market and welfare outcomes. Firms should improve the value obtained from true personal information or reduce information-processing costs, which produce more predictable benefits, although neither measure directly improves the amount of collected true personal information.

Lemma 5. *Under Scenario F, (1)* $\frac{dp^{F*}}{dc_m} < 0$; *if* $b > \frac{(2y-1)V}{2}$, $\frac{dD^{F*}}{dc_m} > 0$, *otherwise,* $\frac{dD^{F*}}{dc_m} < 0$; *if* $b > \frac{(2y-1)V}{2}$ *and* $c_m > c_{m1}$ *or* $b \leq \max\left[0, \frac{(2y-1)V}{2}\right]$ *and* $c_m < c_{m1}$, $\frac{d\pi^{F*}}{dc_m} > 0$, *otherwise,* $\frac{d\pi^{F*}}{dc_m} < 0$; *if* $b > \frac{(2y-1)V}{2}$ *and* $c_m > c_{m2}$ *or* $b \leq \max\left[0, \frac{(2y-1)V}{2}\right]$ *and* $c_m < c_{m2}$, $\frac{dCS^{F*}}{dc_m} > 0$, *otherwise,* $\frac{dCS^{F*}}{dc_m} < 0$; *if* $b > \frac{(2y-1)V}{2}$ *and* $c_m > c_{m3}$ *or* $b \leq \max\left[0, \frac{(2y-1)V}{2}\right]$ *and* $c_m < c_{m3}$, $\frac{dSW^{F*}}{dc_m} > 0$, *otherwise,* $\frac{dSW^{F*}}{dc_m} < 0$; *(2)* $\frac{dp^{F*}}{dg} > 0$; *if* $b < \max\left[0, \frac{(2y-1)V}{2}\right]$, $\frac{dD^{F*}}{dg} > 0$, *otherwise,* $\frac{dD^{F*}}{dg} < 0$; *if* $g > g_1$, $\frac{d\pi^{F*}}{dg} > 0$, *otherwise,* $\frac{d\pi^{F*}}{dg} < 0$; *if* $b > \frac{3(2y-1)V}{2}$ *and* $g > g_2$ *or* $b \leq \max\left[0, \frac{(2y-1)V}{2}\right]$ *and* $g < g_2$, $\frac{dCS^{F*}}{dg} > 0$, *otherwise,* $\frac{dCS^{F*}}{dg} < 0$; *if* $b > \frac{(2y-1)V}{6}$ *and* $g > g_3$ *or* $b \leq \max\left[0, \frac{(2y-1)V}{6}\right]$ *and* $g < g_3$, $\frac{dSW^{F*}}{dg} > 0$, *otherwise,* $\frac{dSW^{F*}}{dg} < 0$.

where $c_{m1} = \frac{g(2y-1)V[2b-(2y-1)V]}{4[1+y(1-y)V+(b-c_d)y]} - \frac{2(1-g)b(2y-1)^2V^2}{[2b-(2y-1)V][1+y(1-y)V+(b-c_d)y]} - V$, $c_{m2} = \frac{g(2y-1)V[2b-(2y-1)V]}{4[1+y(1-y)V+(b-c_d)y]} + \frac{(1-g)(2y-1)^3V^3}{[2b-(2y-1)V][1+y(1-y)V+(b-c_d)y]} - V$, $c_{m3} = \frac{g(2y-1)V[2b-(2y-1)V]}{4[1+y(1-y)V+(b-c_d)y]} - \frac{(1-g)(2y-1)^2V^2[4b-(2y-1)V]}{3[2b-(2y-1)V][1+y(1-y)V+(b-c_d)y]} - V$, $g_1 = \frac{4b(2y-1)V}{[2b+(2y-1)V]^2} + \frac{4[2b-(2y-1)V](V+c_m)[1+y(1-y)V+(b-c_d)y]}{(2y-1)V[2b+(2y-1)V]^2}$, $g_2 = \frac{2(2y-1)^2V^2}{[2b+(2y-1)V][3(2y-1)V-2b]} - \frac{4[2b-(2y-1)V](V+c_m)[1+y(1-y)V+(b-c_d)y]}{(2y-1)V[2b+(2y-1)V][3(2y-1)V-2b]}$, $g_3 = \frac{2(2y-1)V[4b-(2y-1)V]}{[2b+(2y-1)V][6b-(2y-1)V]} + \frac{12[2b-(2y-1)V](V+c_m)[1+y(1-y)V+(b-c_d)y]}{(2y-1)V[2b+(2y-1)V][6b-(2y-1)V]}$.

Lemma 5 shows that the unit misrepresentation cost and the proportion of privacy-sensitive consumers affect equilibrium outcomes differently under different conditions. A higher unit misrepresentation cost induces privacy-sensitive consumers to disclose more true personal information, thereby increasing the firm's profit from true information. However, it also reduces these consumers' optimized utility because misrepresentation becomes more costly. The firm consequently lowers its price. Whether demand increases or not depends on whether the price reduction, supported by the improved value of collected information, is sufficient to offset the utility loss of privacy-sensitive consumers. Firm profit, consumer surplus, and social welfare therefore depend on the relative effects of a greater volume of true personal information, lower prices, and reduced consumer utility.

An increase in the proportion of privacy-sensitive consumers does not change the fraction of personal information misrepresented by each such consumer, but it increases the number of consumers who misrepresent. These consumers obtain higher optimized utility from disclosing personal information, while the firm receives a smaller proportion of true personal information. The higher consumer willingness to pay and the lower return from true personal information both induce the firm to raise its price. Demand increases only when the utility improvement from strategic disclosure outweighs the effect of the higher price. Firm profit, consumer surplus, and social welfare therefore vary with the relative importance of consumer utility and the unit profit of true personal information.

These results imply that neither a higher misrepresentation cost nor a larger privacy-sensitive segment always benefits the firm. Firms should jointly consider the quality of collected personal information, consumer participation, and the composition of the

consumer market, rather than treating improved data quality or a larger privacy-sensitive market as independently desirable.

Lemma 6. *Under Scenario F, if* $c_d > \frac{[b+(2y-1)V][(1-g)V+c_m]}{V+c_m}$, $\frac{dp^{F*}}{dy} > 0$, *otherwise,* $\frac{dp^{F*}}{dy} < 0$; *if* $b > (2y-1)V$ *and* $c_d < \frac{[b-(2y-1)V][(1-g)V+c_m]}{V+c_m}$ *or* $b \leq \max[0,(2y-1)V]$ *and* $c_d > \frac{[b-(2y-1)V][(1-g)V+c_m]}{V+c_m}$, $\frac{dD^{F*}}{dy} > 0$, *otherwise,* $\frac{dD^{F*}}{dy} < 0$; *if* $c_d < \frac{A+B-\sqrt{(A-B)^2+6yg(1-g)b(2y-1)^2V^3}}{2y(V+c_m)}$, $\frac{d\pi^{F*}}{dy} > 0$, *otherwise,* $\frac{d\pi^{F*}}{dy} < 0$; *if* $c_d < \frac{A+B-\sqrt{(A-B)^2-4yg(1-g)b(2y-1)^3V^4}}{2y(V+c_m)}$ *or* $c_d > \frac{A+B+\sqrt{(A-B)^2-4yg(1-g)b(2y-1)^3V^4}}{2y(V+c_m)}$, $\frac{dCS^{F*}}{dy} > 0$, *otherwise,* $\frac{dCS^{F*}}{dy} < 0$; *if* $c_d < \frac{A+B-\sqrt{(A-B)^2-\frac{4}{3}yg(1-g)(2y-1)^2V^3[(2y-1)V-3b]}}{2y(V+c_m)}$ *or* $c_d > \frac{A+B+\sqrt{(A-B)^2-\frac{4}{3}yg(1-g)(2y-1)^2V^3[(2y-1)V-3b]}}{2y(V+c_m)}$, $\frac{dSW^{F*}}{dy} > 0$, *otherwise,* $\frac{dSW^{F*}}{dy} < 0$.

where $A = (V+c_m)\left[1+y(1-y)V+by+\frac{gV(2y-1)[(2y-1)V-2b]}{4(V+c_m)}\right.$, $B = y[b-(2y-1)V][(1-g)V+c_m]$.

Lemma 6 shows that a greater information-collection intensity does not always increase the equilibrium outcomes. When the unit information-processing cost is relatively high, the additional cost of collection exceeds the firm's profit from the additional true personal information. The firm consequently raises its price, which reduces consumer participation. When the information-processing cost is sufficiently low, the additional return from true personal information allows the firm to lower its price. Demand increases only when this price reduction is sufficient to offset the decline in consumer information-related utility caused by a greater information-collection intensity.

The effects of information-collection intensity on firm profit, consumer surplus, and social welfare are consequently conditional. Firm profit increases when the additional return from true personal information and the resulting market participation outweigh the processing cost and the loss caused by consumer misrepresentation. Consumer surplus depends on whether the price adjustment compensates consumers for the reduction in information-related utility, whereas social welfare additionally reflects the corresponding change in firm profit. Lemma 6 therefore indicates that collecting more personal information is not necessarily beneficial even when the firm can extract value from the collected true information. The firm should determine information-collection intensity by jointly considering processing costs, the profit from true personal information, consumer misrepresentation, and market participation.

4.4. Equilibrium Feasibility and Boundary Cases

The closed-form solutions in Propositions 2 and 3 are derived for an interior market. Under Scenario B, the equilibrium characterized in Proposition 1 satisfies $0 < D^{B*} < 1$ and $p^{B*} > 0$ if and only if: $-1 < y(1-y)V + (b-c_d)y < 1$. The lower bound ensures positive equilibrium demand, whereas the upper bound rules out full market coverage.

Under Scenario F, consider the region $y > \frac{1}{2}$, in which privacy-sensitive consumers choose to misrepresent. Using the equilibrium solutions in Proposition 2, the purchase probabilities of the two consumer types in Proposition 2 satisfy $0 < d_n < d_m < 1$ if and only if: $0 < y(1-y)V + (b-c_d)y - \frac{g(2y-1)V[(2y-1)V+2b]}{4(V+c_m)} < 2 - \frac{(2y-1)^2V^2}{2(V+c_m)}$. The left inequality strictly ensures $d_n > 0$, whereas the right inequality equivalently ensures $d_m < 1$. These conditions ensure that $p^{F*} > 0$. Thus, these restrictions are jointly necessary and sufficient for the type-specific demands in Proposition 2 to constitute a valid equilibrium.

4.5. Comparison Results

When the above boundary conditions are satisfied, we further compare the equilibrium outcomes under Scenario B and Scenario F at the same information-collection intensity. Since no consumers misrepresent when $y \leq \frac{1}{2}$, our comparison focuses on $y > \frac{1}{2}$.

Lemma 7. *(1)* $p^{F^*} > p^{B^*}$*; (2) if* $y \leq \max\left[0, \frac{1}{2} + \frac{b}{V}\right]$, $D^{F^*} > D^{B^*}$*; otherwise,* $D^{F^*} < D^{B^*}$.

Lemma 7 shows that misrepresentation always increases the equilibrium price, but it may not decrease the equilibrium demand. Specifically, when the information-collection intensity is lower than a threshold, misrepresentation increases the equilibrium demand; otherwise, it decreases the equilibrium demand.

Under Scenario F, privacy-sensitive consumers obtain higher utility through misrepresentation. This increases their willingness to pay and allows the firm to charge a higher price. At the same time, misrepresentation reduces the proportion of true personal information collected by the firm. Because the firm obtains less value from personal information while incurring the processing cost for all the collected information, it relies more heavily on product profit. Hence, the firm charges a higher price under Scenario F. When the unit profit of true personal information is below a threshold, the increase in privacy-sensitive consumers' utility is sufficient to offset the impact of a higher price, and aggregate demand increases. When the unit profit of true personal information exceeds this threshold, the firm responds more strongly to the loss of true personal information by raising its price, and the resulting reduction in market participation dominates the increase in privacy-sensitive consumers' utility. The equilibrium demand therefore decreases.

Lemma 8. *if* $g > g_4$, $\pi^{F^*} > \pi^{B^*}$*; otherwise,* $\pi^{F^*} < \pi^{B^*}$.
where $g_4 = \frac{8b(2y-1)^2V^2 - 8(V+c_m)[1+y(1-y)V+(b-c_d)y][(2y-1)V-2b]}{(2y-1)V[(2y-1)V+2b]^2}$.

Lemma 8 shows that the higher equilibrium price under Scenario F does not necessarily result in higher firm profit. Under Scenario F, a privacy-sensitive consumer obtains higher utility through misrepresentation. A larger proportion of privacy-sensitive consumers therefore increases the number of consumers with a higher willingness to pay, allowing the firm to charge a higher price. However, it also increases the amount of personal information that is misrepresented and reduces the firm's return from true personal information.

When the proportion of privacy-sensitive consumers exceeds a threshold, the higher price and the resulting change in demand generate sufficient product profit to compensate for the lower value of the personal information disclosed by privacy-sensitive consumers. Firm profit is therefore higher under Scenario F. When the proportion is below the threshold, too few consumers obtain the additional utility associated with misrepresentation to support a sufficiently large increase in price and demand. The reduction in the firm's return from true personal information then dominates, making Scenario B more profitable.

Lemma 9. *(1) if* $b \leq \max\left[0, \frac{(2y-1)V}{2}\right]$ *and* $g < 2g_2$ *or* $b > \frac{3(2y-1)V}{2}$ *and* $g > 2g_2$, $CS^{F^*} > CS^{B^*}$*; otherwise,* $CS^{F^*} < CS^{B^*}$. *(2) if* $b \leq \max\left[0, \frac{(2y-1)V}{6}\right]$ *and* $g < 2g_3$ *or* $b > \frac{(2y-1)V}{6}$ *and* $g > 2g_3$, $SW^{F^*} > SW^{B^*}$*; otherwise,* $SW^{F^*} < SW^{B^*}$.

Lemma 9 shows that the effects of consumer misrepresentation on consumer surplus and social welfare depend jointly on the unit profit of true personal information and the proportion of privacy-sensitive consumers.

For consumer surplus, when the unit profit of true personal information is below the threshold, Scenario F generates higher consumer surplus only when the proportion of

privacy-sensitive consumers is below the corresponding threshold. In this region, the utility obtained from strategically disclosing personal information is sufficient to compensate for the higher equilibrium price. As the proportion of privacy-sensitive consumers increases, however, the firm raises its price, which also affects non-privacy-sensitive consumers. Consumer surplus may therefore become lower under Scenario F. When the unit profit of true personal information exceeds the threshold, Scenario F improves consumer surplus only when the proportion of privacy-sensitive consumers is sufficiently large. In this case, a large proportion of consumers must obtain the additional utility from misrepresentation to compensate for the higher price.

The social welfare comparison follows a similar structure but uses a different threshold because social welfare includes both consumer surplus and firm's profit. When the unit profit of true personal information is relatively low, misrepresentation increases social welfare only when the proportion of privacy-sensitive consumers is below the corresponding threshold. When the unit profit of true personal information is relatively high, a sufficiently large proportion of privacy-sensitive consumers is required for the increase in consumer utility and market participation to compensate for the reduction in profit from true personal information.

Proposition 4. *When* $b > \frac{3(2y-1)V}{2}$ *and* $g > \widetilde{g}$, *consumer misrepresentation generates a firm–consumer win–win outcome and higher social welfare.*

$$\text{where } \widetilde{g} = \begin{cases} g_4, \ c_m \leq \frac{(2y-1)[2b-(2y-1)V]-8[1+y(1-y)V+(b-c_d)y]}{8[1+y(1-y)V+(b-c_d)y]}V \\ 2g_2, \ c_m > \frac{(2y-1)[2b-(2y-1)V]-8[1+y(1-y)V+(b-c_d)y]}{8[1+y(1-y)V+(b-c_d)y]}V \end{cases}.$$

Proposition 4 provides a suggestion for the firm's information-collection decision. The firm should estimate the value of true personal information and the proportion of privacy-sensitive consumers before selecting an information-collection intensity. When both conditions in Proposition 4 hold, the firm may retain an information-collection intensity that induces consumer misrepresentation and set its price according to consumers' anticipated personal-information disclosure decisions. When either condition fails, the firm should not regard consumer misrepresentation as mutually beneficial and should consider reducing information-collection intensity to the level at which consumers disclose their personal information truthfully.

5. Extensions

The analysis above holds information-collection intensity constant to isolate the effects of strategic misrepresentation on price, demand, firm's profit, consumer surplus, and social welfare. This section relaxes two restrictions of the baseline analysis. Section 5.1 endogenizes information-collection intensity and characterizes the firm's first-stage decision when it anticipates consumers' personal-information disclosure decisions. Section 5.2 considers an alternative information-related consumer utility function to examine the robustness of the consumer misrepresentation threshold in Proposition 1.

5.1. Equilibrium Analysis of the Firm's Endogenous Information-Collection Strategy

Section 4 compares Scenarios B and F at a common information-collection intensity to isolate the effect of strategic misrepresentation from that of information-collection intensity. In the first stage, the firm chooses the information-collection intensity before setting the price and anticipates consumers' subsequent disclosure and purchase decisions. The choice of information-collection intensity determines the amount of information collected and processed, the personalized service level supported by that information, and the processing cost. Consumer misrepresentation does not change these direct consequences of

collected consumer information, but it reduces the proportion of collected information that reflects consumers' true preferences, thereby weakening service–preference alignment and reducing the firm's information-related profit. The firm therefore compares its optimized profit across the truthful disclosure and misrepresentation regions, which determines whether its optimal collection intensity lies below, at, or above the behavioral threshold.

Because privacy-sensitive consumers truthfully disclose their personal information when $y \leq \frac{1}{2}$ and misrepresent when $y > \frac{1}{2}$, the firm's optimized profit is piecewise. In the region without misrepresentation, the profit-maximizing collection intensity is $y^{B*} = \min\left\{\frac{1}{2}, \max\left[0, \frac{V+b-c_d}{2V}\right]\right\}$. Hence, if $b < c_d$, the firm's optimal information-collection intensity is below $\frac{1}{2}$; it equals zero when $c_d \geq V + b$; otherwise, the firm's optimal information-collection intensity is $\frac{1}{2}$.

When the firm's information-collection intensity $y > \frac{1}{2}$, privacy-sensitive consumers misrepresent. Maximizing the firm's profit function in Equation (3) yields the following condition for the optimal information-collection intensity:

$$\{4(V+c_m)[1+y(1-y)V+(b-c_d)y]+gV(2y-1)[(2y-1)V-2b]\}\{[b-(2y-1)V][(1-g)V+c_m]-c_d(V+c_m)\}=6g(1-g)bV^3(2y-1)^2 \quad (7)$$

Under the interior-equilibrium conditions, Equation (7) has at most one economically admissible solution, $\overline{y^*}$, in $y \in \left(\frac{1}{2}, 1\right)$. If the firm's marginal profit remains nonnegative at $y^* = 1$, the firm chooses $y^* = 1$.

Combining the above analysis gives the firm's optimal information-collection intensity:

$$y^* = \begin{cases} \max\left\{0, \frac{V+b-c_d}{2V}\right\}, & b < c_d \\ \frac{1}{2}, & 0 \leq b - c_d < \frac{gV}{V+c_m} \\ \min\left[\overline{y^*}, 1\right], & b - c_d \geq \frac{gV}{V+c_m} \end{cases} \quad (8)$$

The firm's optimal information-collection intensity in Equation (8) shows that when the unit profit of true personal information is lower than the unit information-processing cost, the firm's optimal information-collection intensity is below the behavioral threshold $\frac{1}{2}$. When true personal information generates a nonnegative marginal profit but this profit is insufficient to compensate for the reduction in the accuracy of the personal information disclosed by privacy-sensitive consumers, the firm's optimal information-collection intensity is the behavioral threshold. The firm's optimal information-collection intensity exceeds the threshold only when the marginal profit from true personal information is sufficiently large. Therefore, the behavioral threshold determines when consumers begin to misrepresent personal information, but it does not necessarily determine the firm's optimal collection intensity.

5.2. Robustness Check of the Consumer Misrepresentation Threshold

In Section 4, we derive the behavioral threshold of information-collection intensity $y = \frac{1}{2}$ with a normalized quadratic information-related profit function. Although this specification provides a tractable representation of the decreasing marginal profit of personalized service, its normalization may determine the threshold $\frac{1}{2}$. To confirm that our core insights are driven by fundamental consumer behavior rather than functional form, we consider an alternative specification that isolates the existence of this behavioral threshold from its specific in Proposition 1. We adopt the superscript "N" to denote the extension case.

We assume that if privacy-sensitive consumers misrepresent, the utility function of a privacy-sensitive consumer is

$$u_m^N = \theta + V\left\{\ln[1+(1-\alpha)y] - \frac{2}{3}(1-\alpha)y\right\} - p - c_m(\alpha y)^2 \quad (9)$$

Correspondingly, the utility function of non-privacy-sensitive consumers is:

$$u_n^N = \theta + V\left[\ln(1+y) - \frac{2}{3}y\right] - p \quad (10)$$

In the extension model, the coefficient $\frac{2}{3}$ is a normalization rather than an additional model parameter. It balances the logarithmic function of personalization benefit against the negative impact of privacy concern from the application of true consumer information and preserves an interior behavioral threshold on $y \in [0,1]$.

Since, when $y > \frac{1}{2}$, privacy-sensitive consumers misrepresent, we have $\frac{\partial u_m^N}{\partial \alpha} = yV\left[\frac{2}{3} - \frac{1}{1+(1-\alpha)y}\right] - 2c_m\alpha y^2 > 0$, $\frac{\partial^2 u_m^N}{\partial \alpha^2} = -\frac{Vy^2}{[1+(1-\alpha)y]^2} - 2c_m y^2 < 0$. Hence, a unique optimum exists.

Proposition 5. *Under the logarithmic information-related utility, the privacy-sensitive consumers disclose truthfully when $y \le 1/2$. When $y > 1/2$, the privacy-sensitive consumers strategically misrepresent the fraction $\alpha^{N*}(y) = \frac{3c_m(1+y)+V-\sqrt{[3c_m(1+y)+V]^2-6c_mV(2y-1)}}{6c_m y}$.*

We next resolve the pricing game and compare the two disclosure scenarios under this alternative specification. The optimized utility gain that a privacy-sensitive consumer obtains from misrepresentation relative to truthful disclosure is $\left\{\ln\left[\frac{1+(1-\alpha_N^*)y}{1+y}\right] + \frac{2\alpha_N^* y}{3}\right\}V - c_m\left(\alpha_N^* y\right)^2 > 0$. The firm's lost return from the inaccurate portion of that consumer's information is $b\alpha_N^* y$.

Based on the timing sequence, with backward induction, we derive the equilibria when consumers do not misrepresent as follows: $p_B^{N*} = \frac{Q-2(b-c_d)y}{2}$, $D_B^{N*} = \frac{Q}{2}$, $\pi_B^{N*} = \frac{Q^2}{4}$, $CS_B^{N*} = \frac{Q^2}{8}$, $SW_B^{N*} = \frac{3Q^2}{8}$. Where $Q = 1 + V\left[\ln(1+y) - \frac{2y}{3}\right] + (b-c_d)y$.

Similarly, we derive the equilibria when consumers misrepresent as follows: $p_F^{N*} = \frac{Q-2(b-c_d)y+g\left(\Phi+Vb\alpha^{N*}y\right)}{2}$, $D_F^{N*} = \frac{Q+g\left(\Phi-Vb\alpha^{N*}y\right)}{2}$, $\pi_F^{N*} = \left(D_F^{N*}\right)^2 - g(1-g)\Phi b\alpha^{N*}y$, $CS_F^{N*} = \frac{\left(D_F^{N*}\right)^2}{2} + \frac{g(1-g)\Phi^2}{2}$, $SW_F^{N*} = \frac{3\left(D_F^{N*}\right)^2}{2} + g(1-g)\left(\frac{\Phi^2}{2} - b\alpha^{N*}y\Phi\right)$. Where $\Phi = V\left\{\ln\left[\frac{1+\left(1-\alpha^{N*}\right)y}{1+y}\right] + \frac{2\alpha^{N*}y}{3}\right\} - c_m\left(\alpha^{N*}y\right)^2$.

Based on the equilibria under two different scenarios, we derive the comparison results of the equilibrium outcomes. Since no consumers misrepresent when $y \le \frac{1}{2}$, our comparison focuses on $y > \frac{1}{2}$.

Lemma 10. *Under the logarithmic information-related utility specification, (1) $p_B^{N*} < p_F^{N*}$. (2) if $b \le \frac{\Phi}{\alpha^{N*}y}$, $D_F^{N*} > D_B^{N*}$; otherwise, $D_F^{N*} < D_B^{N*}$. (3) if $g > \frac{2\left[2\alpha^{N*}y\Phi - Q\left(\Phi - b\alpha^{N*}y\right)\right]}{\left(\Phi+b\alpha^{N*}y\right)^2}$, $\pi_F^{N*} \ge \pi_B^{N*}$; otherwise, $\pi_F^{N*} < \pi_B^{N*}$. (4) if $b > \frac{3\Phi}{\alpha^{N*}y}$ and $g > \frac{2\left[Q\left(\alpha^{N*}y-\Phi\right)-2\Phi^2\right]}{\left(\alpha^{N*}y-3\Phi\right)\left(\alpha^{N*}y+\Phi\right)}$ or $b < \frac{3\Phi}{\alpha^{N*}y}$ and $g < \frac{2\left[Q\left(\Phi-\alpha^{N*}y\right)+2\Phi^2\right]}{\left(3\Phi-\alpha^{N*}y\right)\left(\alpha^{N*}y+\Phi\right)}$, $CS_F^{N*} > CS_B^{N*}$; otherwise, $CS_F^{N*} < CS_B^{N*}$. (5) if $b > \frac{\Phi}{3\alpha^{N*}y}$ and $g > \frac{2\left[3Q\left(\alpha^{N*}y-\Phi\right)-2\Phi^2+4\alpha^{N*}y\Phi\right]}{\left(3\alpha^{N*}y-\Phi\right)\left(\alpha^{N*}y+\Phi\right)}$ or $b < \frac{\Phi}{3\alpha^{N*}y}$ and $g < \frac{2\left[3Q\left(\Phi-\alpha^{N*}y\right)+2\Phi^2-4\alpha^{N*}y\Phi\right]}{\left(\Phi-3\alpha^{N*}y\right)\left(\alpha^{N*}y+\Phi\right)}$, $SW_F^{N*} > SW_B^{N*}$; otherwise, $SW_F^{N*} < SW_B^{N*}$.*

Lemma 10 provides comparison equilibrium solutions. The price comparison result is unambiguous because misrepresentation both raises privacy-sensitive consumers' willingness to pay and reduces the firm's return from true information, causing the firm to rely more heavily on product profit. The comparison demand depends on whether the full optimized consumer utility gain exceeds $b\alpha_N^* y$, the lost value of true information. Profit requires the demand and price gains to compensate for the lower information-related return. Consumer surplus additionally reflects the dispersion in utilities between the two consumer groups, while social welfare combines these consumer-side effects with the firm's information loss.

Based on the comparison results, we can derive that

Proposition 6. *Consumer misrepresentation generates a firm–consumer win-win outcome and higher social welfare when the following conditions hold:* $b > \frac{3\Phi}{\alpha^{N*}y}$ *and* $g > \max\left\{\frac{2\left[Q\left(\alpha^{N*}y-\Phi\right)-2\Phi^2\right]}{\left(\alpha^{N*}y-3\Phi\right)\left(\alpha^{N*}y+\Phi\right)}, \frac{2\left[2\alpha^{N*}y\Phi-Q\left(\Phi-b\alpha^{N*}y\right)\right]}{\left(\Phi+b\alpha^{N*}y\right)^2}\right\}$ *or* $\frac{\Phi}{3\alpha^{N*}y} < b < \frac{3\Phi}{\alpha^{N*}y}$ *and* $\max\left\{\frac{2\left[2\alpha^{N*}y\Phi-Q\left(\Phi-b\alpha^{N*}y\right)\right]}{\left(\Phi+b\alpha^{N*}y\right)^2}, \frac{2\left[3Q\left(\alpha^{N*}y-\Phi\right)-2\Phi^2+4\alpha^{N*}y\Phi\right]}{\left(3\alpha^{N*}y-\Phi\right)\left(\alpha^{N*}y+\Phi\right)}\right\} < g < \frac{2\left[Q\left(\Phi-\alpha^{N*}y\right)+2\Phi^2\right]}{\left(3\Phi-\alpha^{N*}y\right)\left(\alpha^{N*}y+\Phi\right)}$ *or* $b < \frac{\Phi}{3\alpha^{N*}y}$ *and* $\frac{2\left[2\alpha^{N*}y\Phi-Q\left(\Phi-b\alpha^{N*}y\right)\right]}{\left(\Phi+b\alpha^{N*}y\right)^2} < g < \min\left\{\frac{2\left[3Q\left(\Phi-\alpha^{N*}y\right)+2\Phi^2-4\alpha^{N*}y\Phi\right]}{\left(\Phi-3\alpha^{N*}y\right)\left(\alpha^{N*}y+\Phi\right)}, \frac{2\left[Q\left(\Phi-\alpha^{N*}y\right)+2\Phi^2\right]}{\left(3\Phi-\alpha^{N*}y\right)\left(\alpha^{N*}y+\Phi\right)}\right\}$.

Proposition 6 shows that misrepresentation can generate a firm–consumer win–win outcome with higher social welfare under the logarithmic utility specification, but the relevant condition depends on the unit value of true personal information. These results preserve the central qualitative insight of Proposition 4: strategic misrepresentation can benefit the firm and consumers simultaneously, but only within a well-defined parameter region. The exact boundaries differ under the logarithmic specification, indicating that the existence and economic mechanism of the win–win outcome are qualitatively robust.

6. Conclusions

Consumers are increasingly concerned about the use of their personal information, while firms are increasingly dependent on consumer information to conduct online marketing activities, such as providing personalized services and targeted advertisements. To protect themselves, consumers may misrepresent their personal information. This behavior affects the decisions of the firm and consumers. In this paper, we investigate the firm's pricing and information-collection strategies in the presence of consumer misrepresentation and examine the effects of consumer misrepresentation.

We establish a three-stage game model in which a firm sells a product to consumers directly and earns additional profit from consumers' true personal information. Consumers may misrepresent depending on their utilities. Accordingly, we examine the firm's equilibrium strategy under two scenarios: consumers do not misrepresent and consumers misrepresent.

The results show that compared to the scenario where consumers do not misrepresent at the same information-collection intensity, strategic misrepresentation always increases the equilibrium price and can generate a firm–consumer win–win outcome with higher social welfare, but only within a specific parameter region. Second, the firm's optimal information-collection intensity may lie below, be equal to, or exceed the behavioral threshold depending on the relationship between the unit profit of true personal information and the unit information-processing cost. Third, when consumers misrepresent, a higher unit profit of data-enabled personalized service always raises the equilibrium price but may reduce demand, firm profit, consumer surplus, and social welfare by inducing greater misrepresentation and reducing the amount of true personal information obtained

by the firm. Fourth, neither a higher misrepresentation cost nor a larger proportion of privacy-sensitive consumers necessarily improves equilibrium outcomes. Fifth, when consumers do not misrepresent, a higher unit profit of true personal information lowers the equilibrium price and benefits both the firm and consumers, whereas a higher unit information-processing cost produces the opposite outcomes and additional information collection has non-monotonic effects.

Our study has several limitations. First, the model considers a monopolistic firm. Future research could introduce competing firms and examine how competition affects firms' information-collection strategies and consumers' personal-information disclosure decisions. Second, the firm unilaterally determines information-collection intensity in the current model, whereas firms and consumers may negotiate the amount of personal information to be collected; future studies could therefore examine such negotiation and its effects on price, demand, and welfare. Third, the model considers a data-conditioned product: consumers who reject the offer neither purchase the product nor disclose personal information. It therefore does not include an explicit option under which consumers can purchase without disclosing personal information. Future studies could compare the data-conditioned product with a purchase-without-disclosure option and examine how the availability of this option affects firm strategy and consumer choice. Finally, our paper studies the topic theoretically and is not calibrated or validated using observed consumer or firm data. Future empirical research could estimate consumers' responses to information-collection intensity and examine whether the predicted effects of strategic misrepresentation on firm performance hold empirically.

Author Contributions: Conceptualization, Y.Z., W.Z. and S.-e.M.; methodology, Y.Z. and S.-e.M.; formal analysis, Y.Z. and S.-e.M.; investigation, Y.Z. and S.-e.M.; writing—original draft preparation, Y.Z. and W.Z.; writing—review and editing, Y.Z. and W.Z.; supervision, S.-e.M. and W.Z.; funding acquisition, Y.Z., S.-e.M. and W.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Social Science Foundation of China (No. 25BGL123), National Natural Science Foundation of China (No. 72371069), National Key Research and Development Program of China (No. 2023YFC3804901) and Major Project of Philosophy and Social Science Research in Colleges and Universities of Jiangsu Province (No. 2025SJZD036).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in this study are included in the article.

Conflicts of Interest: The authors declare no conflicts of interest.

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