

Regulating Personalized Pricing: A Welfare Analysis Across Different Market Structures

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Abstract. This paper analyzes how two regulatory mechanisms- opt-out and sensitive data restriction- affect consumer surplus, producer surplus, and total surplus under monopoly, differentiated Bertrand competition, and monopolistic competition. The analysis shows that welfare effects depend on market structure and on how regulation affects firms' pricing precision and consumers' participation. Under an opt-out mechanism, consumer surplus may increase as the opt-out rate increases, while it may generate deadweight loss at the same time. Sensitive data restriction reduces the accuracy of personalized pricing. It may improve fairness, but it can also cause consumers to face prices higher than their highest willingness to pay and leave the market. In more competitive markets, the effects on consumer and producer surplus are dependent, as competition already constrains market power. This paper also considers practical limitations, including the default effect and proxy variables. Finally, this paper argues that regulatory choice should depend on the market context: sensitive data restriction may be more suitable for markets relating to fundamental rights, while opt-out may be more suitable in general markets. Unlike studies that examine consumer choice rights and data-use restrictions separately, this paper places both regulatory tools within a uniform welfare framework and compares their effects across different market structures.

Keywords: Personalized pricing, opt-out, sensitive data restriction, welfare analysis, consumer data

1. Introduction

The increasing use of consumer data and algorithmic pricing has made personalized pricing an important issue in digital markets. Personalized pricing allows firms to estimate consumers' willingness to pay by using consumer information and charge different consumers different prices for the same product [1]. Personalized pricing may improve allocative efficiency and benefit some consumers, but it might also redistribute welfare from consumers to firms and reduce total welfare in some circumstances [2].

This leads to an important policy question: how should governments regulate personalized pricing while balancing consumer protection and economic efficiency? This paper focuses on two possible regulatory mechanisms. The first is opt-out, which gives consumers the right to refuse personalized pricing and be charged a uniform price [3]. The second is sensitive data restriction, preventing firms from using sensitive attributes while setting personalized prices [3].

The welfare effects of these regulations may vary depending on different market structures. Therefore, this paper analyzes their effects under the three different market structures: monopoly, oligopoly, and monopolistic competition. The analysis focuses on the change in consumer surplus (CS), producer surplus (PS), and total surplus (TS). This paper considers whether regulation improves consumer welfare, how it affects firms' profits, and whether it creates additional deadweight loss (DWL).

This paper first analyzes the two regulations' welfare effects under different market structures and compares the two approaches. Finally, this paper considers practical limitations, including default behavior under opt-out and proxy variables that might be used in sensitive data restriction. Then it discusses the appropriate policy approach under different market situations. Previous literature on personalized pricing focused on opt-out or data restrictions alone. This paper puts the two regulatory tools into a unified welfare analysis framework and compares their effects under different market structures.

2. Economic definition of the regulatory models

2.1. Baseline: unregulated personalized pricing

In the absence of regulations, firms are assumed to collect sufficient data on consumers' habits and to successfully implement personalized pricing, in which consumers receive differentiated prices set by the firm [2]. However, the outcome of personalized pricing is not uniform across all market structures. It is necessary to distinguish among the three market structures: monopoly, differentiated Bertrand competition, and monopolistic competition. With greater market power and higher barriers to entry and exit, a firm's ability to use consumer information for personalized pricing increases [2]. Empirical evidence shows that relative to uniform pricing, personalized pricing can increase a firm's profit, but its effects on consumers are diverse [4].

A monopoly with accurate information and sufficient market power can implement first-degree (perfect) price discrimination. The firm will set its price to target consumers with different highest willingness to pay, aiming to maximize profits [5]. Therefore, CS is approximately zero, while PS is maximized and equals TS, with TS maximized [6]. Total surplus is socially efficient because there is no DWL and all units for which consumers' willingness to pay exceeds marginal cost are sold.

In oligopoly, this paper adopts a differentiated Bertrand competition framework. This market consists of a few firms producing differentiated products, and their optimal price decisions are interdependent [7]. Each firm j maximizes profits according to equation (1).

$$\pi_j = (p_j - c_j)q_j(p_j, p_{-j}) \quad (1)$$

Where π_j refers to the profit of firm j , p_j refers to firm j 's price, c_j refers to firm j 's marginal cost, and q_j refers to firm j 's demand. A firm's demand depends on its own price and its rivals' prices. In this market structure, with multiple firms competing, perfect price discrimination is usually unattainable. Rivals constrain a firm's market power, as they compete for consumers and limit pricing options [5]. Competition prevents single firms from charging consumers their highest willingness to pay, as consumers can compare prices across shops and switch to competitors [7]. Since products are not perfect substitutes, every firm still has a certain amount of market power and will set prices above the marginal cost ($P > MC$). This markup will reduce equilibrium output relative to the socially optimal level, generating DWL. However, the markup ($P-MC$) and the DWL

generated depend on the degree of product differentiation and number of competing firms [7]. When products are highly substitutable, Bertrand competition will drive prices close to MC, leaving firms with little profit [7]. Conversely, if the degree of product differentiation is high, price increases, CS decreases, and DWL increases.

In monopolistically competitive markets, characterized by differentiated products and low barriers to entry, firms have a certain degree of market power but face competitive pressures [7]. Personalized pricing may allow firms to capture abnormal profits from consumers with strong preferences, but competition limits firms' ability to sustain abnormal profits. Monopolistic competition has a CS greater than 0, and TS is not maximized since prices will not reach the highest willingness to pay. However, PS in this scenario may be close to normal profit levels, as long-run profits are limited.

2.2. Opt-out: expansion of consumer choice set

Consumers are given the option to opt out of personalized pricing. A real legislative proposal is the Algorithmic Pricing Transparency Act of Illinois (HB5756). The bill states, "Upon request, a covered entity shall provide the consumer with a non-personalized baseline price for the goods or services" [3]. This proposal would grant consumers the right to exit algorithmic tracking and be provided with a standard price. Although it is not yet enacted into law, it exemplifies the opt-out approach.

This mechanism segments the market into two distinct pools. The "algorithm pool" contains consumers who allow personalized pricing, and their data continues to be collected and analyzed by firms, receiving tailored prices. The "anonymous pool" contains consumers who choose to opt out, typically those who have greater concern over data privacy or those who believe they will be charged higher prices under personalized pricing. Firms are forbidden to charge prices differently among those who opt out, and they all receive a uniform price. This opt-out mechanism functions on the demand side of the market: the decision-making power is on the consumer's side, who can adjust according to their preferences, rather than imposing a constraint on the firm's use of information.

2.3. Sensitive data restriction: contraction of firms' information set

The Sensitive Data Restriction limits the information firms can use by prohibiting the use of sensitive attributes. The same Illinois HB5756 also stated that race, religion, sexual orientation, immigration status, medical information, or criminal history shall not be used to generate algorithmic pricing [3]. Under this regulation, the permitted information firms can use is restricted to non-sensitive information. This includes, but is not limited to, purchase history, browsing behavior, and geographic location.

This mechanism operates on the supply side of the market. Rather than informing consumers or giving them rights to switch sides, it directly limits the categories of information firms can obtain. This lowers the firm's precision in setting personalized prices and reduces price differences among consumers as it becomes harder to estimate each consumer's highest willingness to pay precisely.

3. Logical reasoning of welfare effects

3.1. Welfare effects of opt-out

3.1.1. Monopoly

Under an unregulated monopoly with personalized pricing, $CS \approx 0$, the firm extracts all surplus. The introduction of opt-out greatly changes this situation. Privacy-sensitive consumers who choose to opt out enter the anonymous pool. Since a uniform price is provided, they start obtaining positive surplus. Consumers who remain in the algorithm pool continue to be charged at their highest willingness to pay and remain at zero CS. The amount of increase in CS depends on the number of consumers who chose to opt out.

The monopolist loses the ability to extract full surplus from consumers who opt out. This creates a direct transfer from producers to consumers, reducing PS. The decrease in PS also depends on the number of consumers who choose to opt out and whether the uniform price attracts new buyers who previously refused to participate.

The DWL generated from the anonymous pool increases with the opt-out share. For consumers who remain in the algorithm pool, the firm extracts full surplus, and no DWL is generated. When consumers exit to the anonymous pool, the monopolist sets a uniform price at marginal revenue (MR) = marginal cost (MC), which creates DWL. When the opt-out rate is low, the anonymous pool is small, so the additional DWL generated is negligible, and TS remains close to the unregulated level. However, when the opt-out rate is high, the DWL expands and reduces TS, as illustrated in Figure 1, where the shift to uniform pricing creates consumer gains but also additional DWL.

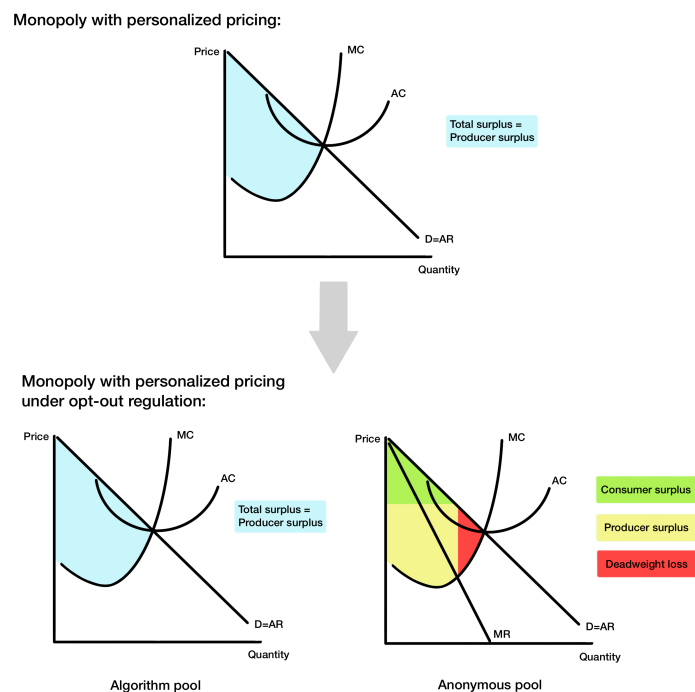


Figure 1. Illustrative welfare effects of opt-out regulation on the representative firm (monopoly)
picture credit: original

3.1.2. Oligopoly

In differentiated Bertrand competition, welfare effects become more uncertain, as the impact of personalized pricing depends on market coverage and firms' reactions [8]. In an oligopolistic market, consumers already retain some positive CS due to competition among firms. Opt-out may generate additional gains for consumers who are charged a uniform price lower than their personalized prices. However, consumers who previously received lower prices may be worse off. The net CS effect therefore depends on the gap between each consumer's personalized price and the anonymous price.

Firms lose profit from consumers who opt out, as they can no longer charge these consumers personalized prices. In addition, firms may have to lower prices in the algorithmic pool to keep consumers from opting out or switching to the business's competitors, which would further compress PS.

The effect on TS is uncertain and depends on the market's specific situation. Oligopolistic competition already prevents it from maximizing TS, and uniform pricing may generate additional DWL on top of the pre-existing DWL. However, the intensified competition in the algorithm pool may reduce the pre-existing DWL. If competition intensifies sufficiently in the algorithm pool, the price reduction may outweigh the additional DWL generated from uniform pricing, leading to an increase in TS relative to the oligopoly before regulation, as illustrated in Figure 2.

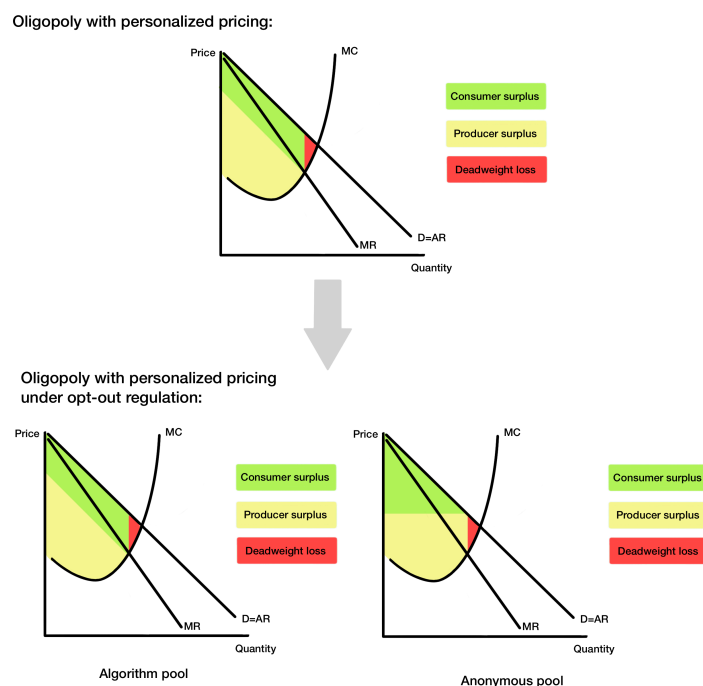


Figure 2. Illustrative welfare effects of opt-out regulation under differentiated Bertrand competition
picture credit: original

3.1.3. Monopolistic competition

Since the competition in this market is intense, it means firms have relatively low market power from the start. Consumers who opt out may gain additional surplus, while those who remain may also gain more surplus due to competition intensity. The extent of CS change depends on the gap

between personalized and uniform prices, the number of opt-out consumers, and the intensity of competition.

When consumers enter the anonymous pool, PS may decrease. In the long run, firms may exit the market if losing data from a portion of consumers reduces profitability. This reduces product diversity, further decreasing PS.

The effect on TS is uncertain. Uniform pricing may exclude some consumers whose highest willingness to pay is between the marginal cost and uniform price, generating additional DWL. However, intensified competition in the algorithm pool may reduce the existing DWL. In addition, the long-run effect of firm exit reduces product variety, causing further welfare loss. The specific effect on TS depends on the interaction of these forces, as illustrated in Figure 3, where additional DWL, stronger competition, and possible long-run losses in product variety jointly affect TS.

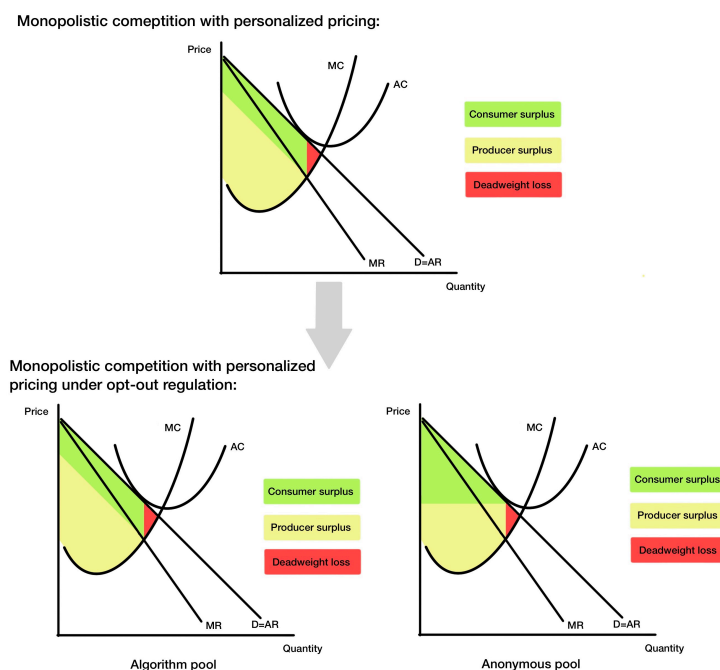


Figure 3. Illustrative welfare effects of opt-out regulation under monopolistic competition picture credit: original

3.2. Welfare effects of sensitive data restriction

3.2.1. Monopoly

Limiting sensitive data reduces the accuracy of the firm's estimation of consumers' willingness to pay. As a result, some consumers may face lower prices, while others may receive prices above their willingness to pay and exit the market. The extent of the increase in CS depends on how the less accurate pricing strategies affect prices and market participation.

By removing valuable information from the firm's database, the restriction reduces the precision of personalized pricing. The firm loses some of the surplus that could be extracted previously, decreasing PS. The effect on PS depends on how extensively the firm relied on sensitive data for setting prices.

Due to lower accuracy of pricing, some consumers may be priced higher than their highest willingness to pay and exit, generating DWL. Other consumers can be priced lower than their

highest willingness to pay. TS decreases relative to the unregulated level, although the exact amount depends on the extent to which pricing errors cause inefficient exclusion, as illustrated in Figure 4.

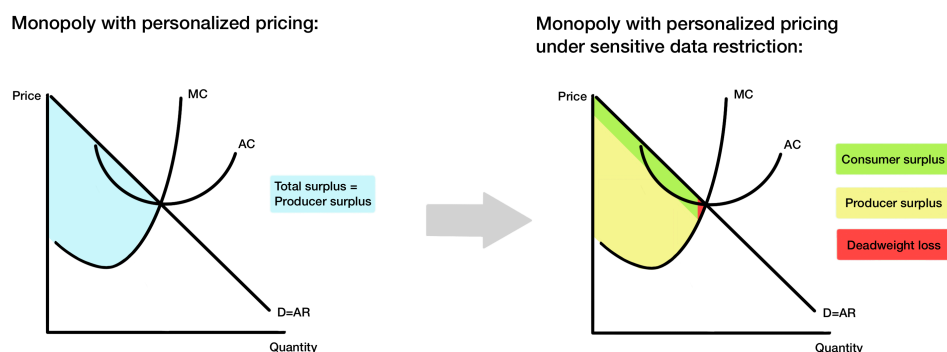


Figure 4. Illustrative welfare effects of sensitive data restriction on the representative firm (monopoly) picture credit: original

3.2.2. Oligopoly

Restriction of sensitive data might weaken the firm's ability to recognize its competitor's consumers, causing it to lose the ability to offer targeted discounts to poach rivals' consumers. This may cause an increase in personalized prices. However, some consumers will benefit from lower prices if firms stop using those data. Additionally, the restriction on data might cause firms to compete more on product quality. Consumers might benefit from improved goods and services in the long-term. Therefore, the effect on CS is uncertain.

The effect on PS is similarly uncertain. If the intensity of competition outweighs the loss brought by lower prediction accuracy, a decrease in PS will happen. Conversely, PS will increase. Its net effect depends on these two effects' relative strength.

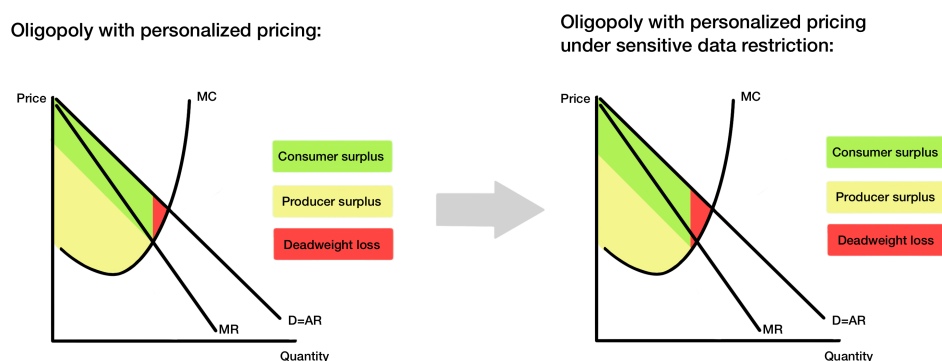


Figure 5. Illustrative welfare effects of sensitive data restriction under differentiated Bertrand competition picture credit: original

If it mainly limits the intensity of competition and the price level is not significantly impacted, TS might decrease due to an increase in price and a decrease in quantity. If it mainly prevents

exploitative pricing while maintaining competition, TS may increase. However, the specific effect on TS depends on the specific changes in CS and PS, as illustrated in Figure 5.

3.2.3. Monopolistic competition

In this market, limitations on sensitive data may also limit a firm's ability to recognize rivals' consumers, increasing prices. However, compared to an oligopoly, a single company's market power is relatively weak, so limiting consumer data might have a relatively small impact on competition. The effect on CS comes mainly from some consumers benefiting from lower prices and others facing higher prices. The net effect depends on the distribution of consumers.

Losing the ability to set prices accurately at the consumer's highest willingness to pay may decrease PS. In the long run, as the market adjusts, firms exiting and entering may push profits toward zero.

Imprecise prices may generate DWL when the resulting price exceeds some consumers' highest willingness to pay. Also, the decrease in profit may lead to some firms exiting the market in the long-run, leading to a decrease in product diversity. The regulation may increase fairness, but it may not necessarily translate into a higher TS in the standard welfare model, as illustrated in Figure 6.

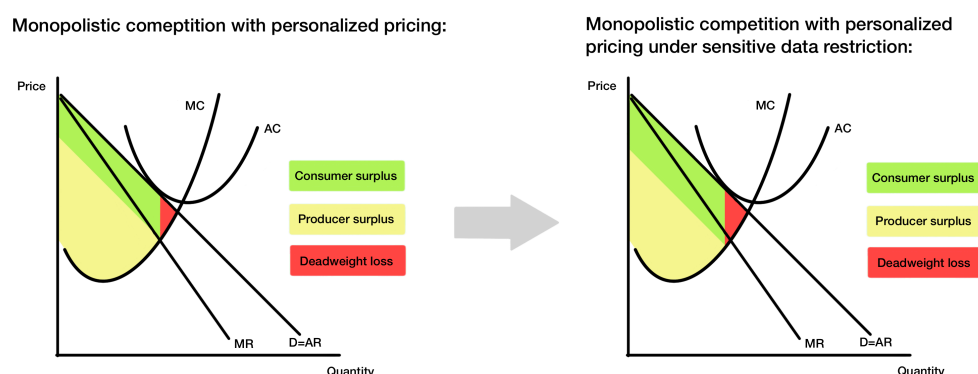


Figure 6. Illustrative welfare effects of sensitive data restriction under monopolistic competitionpicture credit: original

3.3. Comparison of the two models

The main difference between these two regulatory approaches is where they intervene in the personalized pricing process. As shown in Table 1, opt-out operates on the demand side by giving consumers the right to leave the algorithm pool, whereas sensitive data restriction operates on the supply side by limiting the information firms can use. These two methods face different efficiency risks. The specific mechanisms and benefits of the approaches are summarized in Table 1.

Table 1. Mechanism comparison

Dimension	Opt-out	Sensitive Data Restriction
Effect on pricing mechanism	Market splits into two pools: an algorithmic pool with personalized price and an anonymous pool with uniform price.	Firms continue personalized pricing but with reduced precision.

Table 1. (continued)

Mechanism	Demand side choice: Consumers get the right to choose whether to remain in the personalized pool or receive a standard price.	Supply-side information constraint: Directly prohibits firms from using specific categories of data (race, religion, sexual orientation, immigration status, medical information, or criminal history) for pricing.
Direct benefits	Consumers who use the right and are charged lower prices than their highest willingness to pay.	Groups of consumers who were disadvantaged due to the firm's use of their sensitive data.
Main efficiency risk	In the pool of uniform pricing, some consumers may be excluded, reducing allocative precision.	The firm's classification of consumers simplifies, causing exclusion of some consumers, also reducing allocative precision.

The welfare effects also differ significantly in different market structures. As shown in Table 2, opt-out usually increases CS of consumers who opt out, but its impact on PS and TS depends on market structure and the strength of competition. Sensitive data restriction also produces different effects across markets. Table 2 specifically presents the welfare effects of each regulation under each market structure. Neither regulation outweighs the other in all market structures. A suitable regulation depends on whether the policy's priority is to give consumers the right to reject personalized pricing or directly restrict firms' use of some information, and the specific market condition.

Table 2. Welfare comparisons

Regulation and market structure	Effect in CS	Effect in PS	Effect in TS
Opt-out: Monopoly	Increase for consumers who opt out; remains zero for those who stay	Decrease (lose ability to extract full surplus)	Does not increase (the higher the opt-out rate, the greater the welfare loss might be)
Opt-out: Differentiated Bertrand	Uncertain (depends on gap between personalized and uniform price for each consumer)	Decrease (lose profit from opt-out consumers)	Uncertain (uniform pricing generates additional DWL, while intensified competition may reduce DWL)
Opt-out: Monopolistic competition	Increases (consumers gain from uniform pricing and intensified competition)	Decrease (uniform pricing decreases profit, firm exit further erodes PS)	Uncertain (uniform pricing generates DWL, competition reduces DWL)
Sensitive data restriction: Monopoly	Increase (Previously disadvantaged groups may benefit)	Decrease (lose ability to extract full surplus)	Decrease (Unregulated monopoly achieves social optimum; data decrease generates DWL)
Sensitive data restriction: Differentiated Bertrand	Uncertain (poaching discounts disappear, previously disadvantaged consumers gain)	Uncertain (depends on competition and pricing efficiency)	Uncertain (depends on CS and PS's specific changes)
Sensitive data restriction: Monopolistic competition	Uncertain (primarily redistributive between advantaged and disadvantaged consumers)	Uncertain (may move towards normal profit levels in the long run)	Uncertain

4. Mechanism boundaries and realistic reflections

The welfare analysis above is a theoretical framework comparing opt-out regulations and sensitive data restriction. However, the model relies on simplified assumptions about the firm's and consumer's actions, so the results are not perfect universal predictions. In the real world, personalized pricing is a more dynamic process where businesses continuously gather information and consumers strategically respond, and businesses may also adjust their pricing and data-collecting strategies.

4.1. Default effect

The effectiveness of opt-out depends on consumers actively choosing to leave personalized pricing. However, behavioral economics suggests that consumers usually choose the default option. This is known as the "status quo effect", where "consumers have a strong tendency not to change" [9]. Therefore, when personalized pricing is the default option, consumers may remain in the algorithm pool even if opting out can increase their surplus. This effect weakens the welfare improvement predicted in section 3.1. Additionally, an experiment by the Organization for Economic Co-operation and Development (OECD) found that disclosure about personalized pricing only has limited effects on consumers, as many consumers did not recognize or understand the practice [10]. Thus, an opt-in may provide stronger protection, as it requires consumers' permission to enact personalized pricing.

4.2. Proxy variables

The effect of sensitive data restrictions may be weakened by proxy variables. Even though firms may be forbidden to directly use sensitive traits like ethnicity or culture, other variables may contain relevant information. For example, firms can estimate a consumer's cultural background through their surnames and geographic information [11]. Therefore, removing a sensitive category may not completely prevent information related to it from being used. If firms are able to efficiently use proxy variables, welfare effects analyzed in 3.2 may be lower than predicted.

4.3. Policy implications

These limitations suggest that regulation should depend on the type of market. In fields involving fairness and basic rights, such as credit and insurance, restrictions on sensitive data might be more suitable, as discriminative pricing can have significant impacts. For a general goods market, opt-out may be a more suitable regulation, as this allows consumers to choose whether to accept personalized pricing. However, the process of opting out should be simple and easily accessible. The Federal Trade Commission shows that digital interfaces can impact consumers' decisions by setting pre-selected options and difficult cancellation processes [12]. Therefore, when the risk of personalized pricing is high, regulators can instead adopt opt-in, ensuring consumers are informed about the algorithm.

5. Conclusion

This paper analyzed two regulations, opt-out and sensitive data restriction, across monopoly, differentiated Bertrand competition, and monopolistic competition. The analysis shows that neither mechanism has an absolute positive or negative influence on economic welfare, as different firms

have different degrees of market power and different abilities to respond to changes in consumer information. The overall effect depends on the interaction between market power, competition, information, and consumer behavior. Opt-out primarily affects consumers' ability to avoid personalized pricing, while sensitive data restrictions directly limit the information that companies can use when setting prices.

Therefore, the appropriate mechanism should be determined according to the specific situation of a market and the policy goal. For markets involving fundamental rights, the priority should be implementing sensitive data restrictions. As for general goods markets, an opt-out mechanism may be more suitable because it preserves consumers' right to choose whether to allow personalized pricing. However, the effectiveness of an opt-out mechanism also depends on whether consumers actively use their right to opt out. If consumers tend to choose the default option, the potential welfare increase may be limited. Furthermore, restricting data may not completely prevent companies from inferring sensitive data, as they might use proxy variables to predict consumer information, which may weaken the effectiveness of regulation.

In conclusion, personalized pricing cannot be viewed as simply harmful or beneficial. The objective of regulation should be finding a balance between economic efficiency, consumer welfare, market competition, and fairness, rather than simply maximizing a particular welfare indicator. Therefore, effective regulation should consider both the economic impact of different mechanisms and the conditions under which they operate.

References

- [1] de Streel, A., & Jacques, F. (2019). Personalised pricing and EU law. *30th European Conference of the International Telecommunications Society (ITS)*, Helsinki, Finland. Retrieved from <https://www.econstor.eu/bitstream/10419/205221/1/de-Streel-Jacques.pdf>.
- [2] OECD. (2018, October 12). Personalised pricing in the digital era. *OECD*. Retrieved from <https://doi.org/10.1787/db4d9c9c-en>.
- [3] Illinois General Assembly. (2026, May 5). HB5756: Algorithmic pricing transparency act. *Illinois General Assembly*. Retrieved from <https://www.ilga.gov/Legislation/BillStatus/FullText?GAID=18&DocNum=5756&DocTypeID=HB&LegId=0&SessionID=114>.
- [4] Dubé, J.-P., & Misra, S. (2023). Personalized pricing and consumer welfare. *Journal of Political Economy*, 131(1), 131–189.
- [5] Varian, H. R. (2010). *Intermediate microeconomics: A modern approach* (8th ed.). W. W. Norton & Company.
- [6] Xu, R., Zhang, X., Cui, P., Li, B., Shen, Z., & Xu, J. (2022). Regulatory instruments for fair personalized pricing. *Proceedings of the ACM Web Conference 2022*, 4–15.
- [7] Besanko, D. A., & Braeutigam, R. R. (2014). *Microeconomics* (5th ed.). Wiley.
- [8] Rhodes, A., & Zhou, J. (2024). Personalized pricing and competition. *American Economic Review*, 114(7), 2141–2170.
- [9] OECD. (2020, November 27). OECD digital economy outlook 2020. *OECD*.
- [10] OECD. (2021, January 18). The effects of online disclosure about personalised pricing on consumers: Results from a lab experiment in Ireland and Chile. *OECD*.
- [11] Consumer Financial Protection Bureau. (2023, August 8). Using publicly available information to proxy for unidentified race and ethnicity. *Consumer Financial Protection Bureau*. Retrieved from <https://www.consumerfinance.gov/data-research/research-reports/using-publicly-available-information-to-proxy-for-unidentified-race-and-ethnicity/>.
- [12] Federal Trade Commission. (2022, September 15). FTC report shows rise in sophisticated dark patterns designed to trick and trap consumers. *Federal Trade Commission*. Retrieved from <https://www.ftc.gov/news-events/news/press-releases/2022/09/ftc-report-shows-rise-sophisticated-dark-patterns-designed-trick-trap-consumers>.