A Spatial Analysis of Personalized Pricing, Privacy Protection, and Market Competition

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Extended Abstract

This study investigates how personalized pricing and privacy protection jointly influence spatial competition, welfare distribution, and market structure in data-driven oligopolistic markets. As digital technologies have reduced the cost of collecting and tracking consumer data, firms are increasingly able to tailor prices based on consumer characteristics or purchasing histories. At the same time, privacy regulations such as the EU's GDPR have begun to restrict the scope of data use, making the interaction between personalized pricing and privacy protection a central issue in both policy and industry practice.

We develop a spatial competition model featuring one firm with a data or brand advantage and multiple disadvantaged rivals. Only a subset of consumers are subject to personalized pricing, while others face uniform prices. This framework allows us to examine how the relaxation of privacy protection affects spatial competition equilibria, incentives for personalized pricing, social welfare, and the possibility of excess entry. The analysis is expected to reveal nonlinear competitive effects of privacy relaxation. The model will further be extended to allow disadvantaged firms to adopt personalized pricing, to endogenize the degree of personalization, to incorporate consumer privacy choices, network externalities, and elastic demand. The anticipated findings will contribute to the literatures on personalized pricing and spatial competition, highlight the implications of personalized pricing for consumer surplus, industry structure, and social welfare, and provide theoretical and policy insights for data-economy governance.

The rapid development of digital technologies has significantly lowered the cost of collecting, processing, and utilizing consumer data. As a result, personalized pricing where firms tailor prices according to observed consumer characteristics or purchase histories has become increasingly feasible across a broad range of markets. These developments have given rise to a growing economic literature examining how data availability, personalized pricing, and privacy regulation affect competition, welfare, and market structure. This study is also motivated by practical evidence. In recent years, Uber-style data-driven and personalized pricing has expanded beyond ridesharing into everyday consumer markets, including coffee retailing. Delivery platforms such as Uber Eats increasingly tailor prices, delivery fees, and promotional discounts according to user location, purchase history, and time-varying demand, effectively introducing individualized pricing into a high-frequency, low-value consumption setting. Similar practices are evident in coffee chains and digital-first vendors such as Luckin Coffee, where app-based ordering, membership systems, and targeted couponing enable firms to segment consumers and vary effective transaction prices across individuals. As a result, what once appeared to be a simple and transparent retail product has become a natural laboratory for personalized pricing, raising broader concerns about fairness, transparency, and privacy that closely parallel public debates surrounding Uber's dynamic pricing. Coffee markets therefore provide a timely and policy-relevant context

for examining how personalized pricing affects consumer behavior, market outcomes, and regulatory oversight.

Personalized pricing can lead to finer demand segmentation and more precise surplus extraction, potentially increasing firms' profits and expanding market coverage. However, the implications for welfare and competition are ambiguous. For instance, Matsumura and Matsushima (2015) demonstrate that personalized pricing may benefit only the efficient firm, while the less efficient rival suffers, leading to asymmetric adoption of discriminatory pricing. Esteves (2022) and Esteves and Shuai (2022) show that personalized pricing can enhance profitability under sufficiently heterogeneous demand, although consumers may be worse off. Houba, Motchenkova, and Wang (2023) find that personalized pricing remains a dominant strategy even under cost asymmetry, but weaker firms do not gain relative to uniform pricing. Lu and Matsushima (2024) further investigate personalized pricing with multihoming consumers. These studies highlight that personalized pricing affects strategic incentives and market outcomes.

At the same time, privacy protection policies restrict firms' ability to collect and employ personal data, potentially limiting the scope of personalized pricing. The broader literature on privacy economics emphasizes that data may generate both efficiency gains and consumer risks. Acquisti, Taylor and Wagman (2016) argue that data collection improves demand prediction and reduces uncertainty but may distort firm incentives and consumer trust. In digital advertising markets, Goldfarb and Tucker (2011) show that stricter privacy regulation reduces ad effectiveness by constraining behavioral targeting. Taylor and Wagman (2014) and Shy and Stenbacka (2016) further demonstrate that the competitive effects of privacy regulation depend critically on market structure and switching frictions, implying that neither stricter nor weaker privacy protection is universally welfare-improving. More recently, Rhodes and Zhou (2024) analyze personalized pricing under oligopolistic competition and show that data-driven pricing can either intensify or soften competition depending on market coverage, with potentially adverse distributional consequences when only some firms possess data advantages.

Despite these important contributions, much of the existing theoretical analysis relies on duopoly Hotelling models, which limits the ability to examine more general competitive interactions among multiple differentiated firms. In practice, however, many markets, especially digital and platform-based markets, feature asymmetric firms coexisting with numerous smaller rivals, making it essential to adopt a more general competitive structure. To address this gap, the present study develops a spatial spokes model à la Chen and Riordan (2007), Reggiani (2014) and Loginova (2022) to analyze personalized pricing and privacy protection in multi-firm competition. The framework allows one firm to hold a structural advantage—such as brand strength or superior data access—while other firms remain disadvantaged. Personalized pricing is modeled as applying only to nearby or loyal consumers, while uniform pricing governs more distant segments, consistent with behavior-based and data-driven pricing frameworks in prior studies.

Our research focuses on two central questions:

1. How does privacy protection affect firms' incentives and ability to conduct personalized pricing in a spatial market with more than two firms? How do personalized pricing and privacy regulation jointly affect pricing behavior? In particular, we characterize how uniform and personalized prices coevolve across different

regions of the market. Moreover, Privacy protection limits the share of consumers subject to discriminatory pricing. We examine how this interacts with firm asymmetry and market differentiation.

2. What are the implications for consumer welfare, industry profit, and market entry? By allowing free entry of disadvantaged firms, our proposed model also contributes to the literature on excess entry. Our framework highlights how data-driven pricing power modifies the balance between business-stealing and product-diversity effects.

Competition authorities increasingly recognize that access to personal data can create or reinforce market power, while strict privacy protection may reduce efficiency or hinder innovation. By embedding personalized pricing and privacy protection into a unified spatial competition model, this study aims to clarify the trade-offs between consumer surplus, firm profitability, and social welfare, providing theoretical insights to guide regulatory design in data-driven markets.

Following the recent growing literature of personalized pricing such as Matsumura and Matsushima (2015), Esteves and Shuai (2022), Houba, Motchenkova, and Wang (2023) and Lu and Matsushima (2024), this study attempts to build on the theories of spatial competition to examine how personalized pricing and privacy protection reshape market structure and firm strategies. Drawing on my previous works of various spatial competition such as Guo and Lai (2014, 2017, 2022, 2024), together with the pioneering articles of Hotelling (1929), Salop (1979), and d'Aspremont et al. (1979), this study extends traditional spatial models by incorporating data-driven discriminatory pricing into an asymmetric multi-firm competitive environment. In particular, the research develops a theoretical spokes-type spatial framework following Chen and Riordan (2007), Reggiani (2014) and Loginova (2022) to analyze competition between an advantaged firm—endowed with superior data access or brand attachment—and multiple disadvantaged firms. Personalized pricing is allowed to apply selectively to nearby or loyal consumers, while more distant consumers face uniform pricing, thereby linking spatial proximity with pricing discrimination. This structure reflects real-world markets in which consumer data availability varies across firms and segments. The framework enables us to investigate how personalized pricing influences equilibrium prices, firm profitability, consumer surplus, and free-entry market structure under varying degrees of privacy protection.

Model Setting

To study personalized pricing, privacy protection, and spatial competition, we adopt a modified spokes model in the spirit of Chen and Riordan (2007), Reggiani (2014), and Loginova (2022), building on the spatial-competition approaches of Salop (1979), Balasubramanian (1998) and Guo and Lai (2014, 2022). Our analysis also relates to the literature on personalized pricing, including Matsumura and Matsushima (2015), Esteves (2022), Esteves and Shuai (2022), and Houba, Motchenkova, Wang (2023), Lu and Matsushima (2024). In this spokes model, N nodes are connected to a single central point, and each node is located at a distance of 1/2 from the center. One advantaged firm, labelled firm 1 and located at node 1, can invest in collecting consumer data and apply personalized pricing to a subset of nearby customers. The remaining N-1 firms are disadvantaged competitors, located at nodes 2 through N. Those disadvantaged firms may either use personalized pricing for nearby customers or instead charge a uniform price to all customers. Consider a spokes market à la Chen and Riordan (2007). There are N nodes, each representing a distinct product variety, indexed by i=1,…, N. The preference space consists of N spokes of length 1/2, all originating from a single central point. Variety i is located at the extreme end of spoke i. One advantaged firm, labelled firm 1 and located at node 1, is able to collect consumer data and set personalized prices for a subset of nearby consumers. We follow the idea of Rhodes and Zhou (2024) by introducing a dual pricing strategy in which firms charge uniform prices to remote customers while applying personalized pricing to nearby customers. The remaining $N-1$ firms, located at nodes 2 through N, are disadvantaged competitors. These firms may either implement personalized pricing for their nearby consumers or instead charge a uniform price across all consumers.

Consumers located at position $x_j \in [0, 1/2]$ on spoke j purchase at most one unit and obtain net utility

$u(x_j, x_i) = v_i - p_i(x_j) - d(x_j,\ x_i)$, i=1,…, N,

where v_i is the reservation value, $p_i(x_j)$ is the price charged by firm i to a consumer at location x_j, and $d(x_j,$ $x_i)$ denotes the transportation cost. Each firm i is located at the endpoint ($x_i = \frac{1}{2}$) of the i spoke segment. Each firm may set a personalized price $p_i(x_j)$ for a fraction h of its nearby consumers, while charging a uniform price p_i^u to all remaining consumers. The transportation cost is given by $d(x_j,\ x_i) = \mathrm{t}|x_j - x_i| = t\,(\frac{1}{2} - x_j)$ when the consumer and firm are on the same spoke segment, and $d(x_j,\ x_i) = \mathrm{t}|x_j - x_i| = t\,(\frac{1}{2} + x_j)$ when they are located on different spokes. The parameter t is the unit transportation cost and also reflects the degree of product differentiation. To reflect that firm 1 is the advantaged firm, we assume that reservation values satisfy $v_1 > v_2 \geq \cdots \geq v_N$. For simplicity, we further assume that $v_2 = v_3 = \cdots = v_N$ and that the valuation gap satisfies $v_1 - v_2 = \delta$. where δ measures the degree of advantage dispersion across firms. We also assume that this advantage dispersion is not too large, so that the disadvantaged firms remain active in the market.

Compared with much of the existing literature on personalized pricing—such as Matsumura and Matsushima (2015), Esteves (2022), Esteves and Shuai (2022), Houba, Motchenkova, and Wang (2023), and Lu and Matsushima (2024) which mostly relies on a two-firm Hotelling framework, our model is more general because it is based on the spokes model. In fact, when N=2, our setting is degenerated to the standard two-firm Hotelling model. Moreover, our framework emphasizes how the extent of personalized pricing, captured by the parameter h, is affected by privacy protection. Much of the prior literature considers only the binary case in which personalized pricing is either fully available or entirely absent, rather than examining intermediate degrees of personalization. Although Rhodes and Zhou (2024) also study a dual-pricing environment, their analysis achieves socially optimal entry by balancing business-stealing and product-diversity effects, and does not focus on how privacy protection constrains or moderates the scope of personalized pricing.

The marginal consumer who is indifferent between buying from firm 1 (advantaged firm) and firm i (disadvantaged firm) is determined by $\hat{x}_{\mathrm{i}} = \frac{p_i^u - p_1^u + \delta}{2\,t}$. We denote the constant unit production cost for all firms by c. The marginal consumer who is indifferent between purchasing from firm 1 (the advantaged firm) and a disadvantaged firm i is determined by $\hat{x}_i = \frac{p_i^u - p_1^u + \delta}{2\,t}$, where consumers closer to the midpoint are further away from each firm and therefore face uniform pricing. For consumers located close to firm 1, personalized pricing applies. The indifferent consumer between firm 1 and firm 2 satisfies

$$v_1 - (p_1(x) + d(x, x_1)) = v_2 - (c + \ d(x, x2)),$$

which yields the personalized price charged by firm 1 as $p_1(x) = c + \delta + 2\,t\,x$. Similarly, for consumers located near firm 2, if firm 2 is able to use personalized pricing, its pricing rule is determined by

$$v_1 - (c + d(x, x_1)) = v_2 - (p_2(x) + \ d(x, x2)),$$

so that the personalized price is $p_2(x) = c - \delta + 2\,t\,x$.

Then, the profits of firms can be expressed as follows:

$$\pi_1 = \int_{\frac{1}{2}-h\left(\frac{1}{2}+\hat{x}_2\right)}^{\frac{1}{2}} (p_1(x) - c)\, \mathrm{d}x + \int_0^{\frac{1}{2}-h\left(\frac{1}{2}+\hat{x}_2\right)} (p_1^u - c)\, \mathrm{d}x + (N-1) \int_0^{\hat{x}_2} (p_1^u - c)\, \mathrm{d}x, \tag{1}$$

$$\pi_i = \int_{\frac{1}{2}-h(\frac{1}{2}-\hat{x}_i)}^{1/2} (p_i(x) - c)\, \mathrm{d}x + \int_{\hat{x}_i}^{\frac{1}{2}-h(\frac{1}{2}-\hat{x}_i)} (p_i^u - c)\, \mathrm{d}x, \quad i=2,\ldots, N. \tag{2}$$

Equation (1) expresses the profit of firm 1 (the advantaged firm) as the product of its price–cost margins and the corresponding demand segments. The first integral represents the fraction h of consumers located close to firm 1, that is, $x_1 \in [\frac{1}{2} - h\left(\frac{1}{2} + \hat{x}_2\right),\ 1/2]$ for whom firm 1 applies personalized pricing. Herein we restrict on the case where h is not too large ($h < \frac{1}{1+2\hat{x}_2}$) for convenience. The second integral corresponds to the more distant consumers on spoke 1, $x_1 \in [0, \frac{1}{2} - h\left(\frac{1}{2} + \hat{x}_2\right)]$, who are charged the uniform price. Firm 1 also serves consumers on spokes 2 through N located in $x_i \in [0,\ \hat{x}_2]$, who face uniform pricing, as captured by the third term. Equation (2) describes the profit of each disadvantaged firm i=2,…, N. These firms only compete for consumers on their own spoke. The proportion h of consumers located near firm i, $x_2 \in [\frac{1}{2} - h\left(\frac{1}{2} - \hat{x}_2\right),$ $1/2]$ are charged personalized prices, while the more distant consumers $x_2 \in [\hat{x}_i,\ \frac{1}{2} - h\left(\frac{1}{2} - \hat{x}_2\right)]$ face the uniform price.

We also consider the case in which the disadvantaged firms have limited capacity to collect consumer data and therefore cannot engage in personalized pricing. In this setting, these firms are restricted to uniform pricing only. Their profit functions are then given by

$$\pi_i = \int_{\hat{x}_i}^{\frac{1}{2}} (p_i^u - c)\, \mathrm{d}x, \quad i=2,\ldots, N. \tag{3}$$

Consumer surplus (*CS*) can be determined by integrating the utility functions for the different market segments as

$$CS = \int_{\frac{1}{2}-h\left(\frac{1}{2}+\hat{x}_2\right)}^{\frac{1}{2}} (v_1 - p_1(x) - t\left(\frac{1}{2}-x\right))\,\mathrm{d}x + \int_0^{\frac{1}{2}-h\left(\frac{1}{2}+\hat{x}_2\right)} (v_1 - p_i^u - t\left(\frac{1}{2}-x\right))\mathrm{d}x$$

$$+(N-1)\int_{\frac{1}{2}-h(\frac{1}{2}-\hat{x}_2)}^{1/2} (v_2 - p_2(x) - t\left(\frac{1}{2}-x\right))\,\mathrm{d}x + (N-1)\int_{\hat{x}_2}^{\frac{1}{2}-h(\frac{1}{2}-\hat{x}_2)} (v_2 - p_2^u - t\left(\frac{1}{2}-x\right))\,\mathrm{d}x.$$

Consumer surplus therefore represents the total net benefit that consumers obtain from purchasing the products available in the market. When the disadvantaged firms can only set uniform prices, the last two terms above are combined into

$(N-1)\int_{\hat{x}_2}^{\frac{1}{2}} (v_2 - p_2^u - t\left(\frac{1}{2}-x\right))\,\mathrm{d}x.$

Social welfare (*SW*) is then defined as the sum of consumer surplus and the total profits earned by all firms, that is, $SW = CS + (N-1)\pi_2 + \pi_1$.

Equilibrium Analysis on Personalized Pricing and Privacy Protection

By differentiating the profit functions with respect to prices p_i^u, we derive the following equilibrium uniform prices when all firms are able to set personalized prices for nearby consumers:

$$p_1^u = c + \frac{\delta(N-2+(1-h)^3)}{h(N(h^2-3h+3)-2h^3+3h^2-3)} + \frac{t\,(1-h)^2(N-(2h-1)(1-h))}{h(N(h^2-3h+3)-2h^3+3h^2-3)}, \tag{4}$$

$$p_i^u = c - \frac{\delta\left((N-2)(h^2-3h+1)+(1-h)^3\right)}{h\left(N(h^2-3h+3)-2h^3+3h^2-3\right)} + \frac{t\,(1-h)^2(N-(2h-1)(1-h))}{h\left(N(h^2-3h+3)-2h^3+3h^2-3\right)}, \quad i = 2,..,N. \tag{5}$$

When the disadvantaged firms are restricted to charge uniform prices to all consumers and cannot engage in personalized pricing, the equilibrium uniform prices become

$$\tilde{p}_1^u = c + \frac{\delta(h^2-3h-1+N)+t(3h^2-5h+1+N)}{h^2-3h-3+3N}, \tag{6}$$

$$\tilde{p}_i^u = c + \frac{t(2h^2-4h-1+2N)-\delta(N-1)}{h^2-3h-3+3N}, \quad i = 2,..,N. \tag{7}$$

With the above derivation, the impact of privacy protection on equilibrium prices is demonstrated as the following first proposition.

Proposition 1. Consider only the advantaged firm is able to set personalized prices. (a). A reduction in privacy protection (that is, an increase in h) generates a U-shaped effect on equilibrium uniform prices. Specifically, as h increases, the equilibrium uniform prices initially decrease when h is small, but eventually increase when h becomes large. That is, $\frac{\partial \tilde{p}_i^u}{\partial h} < (>) 0$*, i=1,2,..N, when h is small (large), (b). A reduction in privacy* *protection generates a U-shaped relationship between privacy protection and the profit of the advantaged firm, and an inverse-U-shaped relationship for the disadvantaged firms. That is,* $\frac{\partial \pi_1}{\partial h} > (<) 0$ *and* $\frac{\partial \pi_i}{\partial h} < (>) 0$ *i=2,..N, when* h *is small (large), However, A reduction in privacy protection always generates negative impact on total firms' profits.*

Proposition 1 shows that when only the advantaged firm can adopt personalized pricing, weakening privacy protection (i.e., increasing h) does not generate monotonic changes in market outcomes. Instead, uniform prices first fall and then rise, the advantaged firm first gains and then loses, while disadvantaged firms first lose and then partially recover. These nonlinear effects arise because an increase in h simultaneously expands the scope of targeted customers for the advantaged firm and shrinks the set of consumers who are served under uniform pricing. When h is still small, the advantaged firm competes more aggressively for nearby consumers, which forces all firms to reduce their uniform prices. At this stage, the advantaged firm benefits from the additional rent extraction enabled by personalized pricing, whereas disadvantaged firms lose demand and see their profits fall. However, once h becomes sufficiently large, the advantaged firm is already extracting most of the available surplus from its core consumers. A further increase in h mainly reduces the set of marginal consumers who remain subject to uniform pricing. This weakens competition in the uniform-pricing segment and leads firms to raise their uniform prices. As a result, the advantaged firm's profit eventually falls, while the disadvantaged firms recover part of their profitability. Nevertheless, total industry profit always declines, because the competitive pressure induced by personalized pricing more than offsets the later softening in uniform-price competition.

These results also imply that personalized pricing is not always a dominant strategy. As the advantaged firm increases the extent of personalized pricing (a higher h), doing so is profitable only when personalization remains limited. Once personalization reaches intermediate levels, all firms earn lower profits, including the advantaged one. Thus, firms may not always have unilateral incentives to expand personalized pricing, even when they possess superior data advantages.

This result provides some comparing properties of personalized pricing with the existing literature. Much prior work relies on the standard two-firm Hotelling framework such as Matsumura and Matsushima (2015), Esteves (2022), Esteves and Shuai (2022), Houba, Motchenkova, and Wang (2023) and Lu and Matsushima (2024). By contrast, our paper differs in three key respects. First, we adopt the spokes model, which allows for multiple differentiated firms rather than only two. The standard Hotelling duopoly emerges only as the special case where N=2. This richer structure makes it possible to study how personalized pricing increases competition not only between two symmetric rivals, but also across a broader market with one advantaged and many disadvantaged firms. Second, instead of analyzing a binary regime switch, we examine the degree of personalization through the parameter h, which is directly linked to the strength of privacy protection. This enables us to capture continuous policy variation and to uncover the U-shaped and inverse-U-shaped relationships that do not arise in models with only two pricing regimes. Third, our results imply that personalized pricing redistributes surplus in a non-monotonic way: the advantaged firm benefits only up to a point, disadvantaged firms suffer initially but later partially recover, while total industry profit falls throughout.

Next, we turn to the incentives for the advantaged firm to adopt personalized pricing.

Proposition 2: Consider the case in which only the advantaged firm is able to set personalized prices. The incentive for the advantaged firm to expand the scope of personalized pricing, as reflected in $\frac{\partial \pi_1}{\partial h}$*, is increasing in both the number of firms N and the advantage dispersion δ. By contrast, its relationship with the degree of product differentiation t is non-monotonic: the incentive is positively related to t when products are sufficiently close substitutes (i.e., t is small), but becomes negatively related to t once product differentiation is sufficiently large.*

Proposition 2 show how market structure and product differentiation affect the profitability of personalized pricing for the advantaged firm. First, as the number of firms *N* increases, competition over marginal consumers intensifies. Personalized pricing allows the advantaged firm to selectively extract surplus from consumers who are more closely matched with its product, while still pricing competitively to attract marginal consumers. This selective targeting becomes more valuable when there are more competitors, because the scope for business-stealing increases. Second, the incentive to adopt personalization becomes stronger as the advantage dispersion δ widens. A larger δ implies that the advantaged firm enjoys a stronger inherent valuation advantage among its core consumers. Personalized pricing enables the advantaged firm to appropriate more of this valuation gap by charging higher prices to these consumers without necessarily raising prices for marginal ones. The role of product differentiation t is not monotone. When products are highly substitutable (i.e., t is very small), competition over consumers is intense. In this case, personalized pricing is particularly valuable because it enables the advantaged firm to tailor prices and soften head-to-head price competition while still retaining its best-matched consumers. Therefore, the incentive to expand personalization is increasing in t starting from very low levels. However, once products become sufficiently differentiated (i.e., t is not very small), firms already enjoy a considerable degree of local market power. In this environment, the incremental benefit of personalized pricing diminishes, because the advantaged firm can already set relatively high uniform prices without losing many consumers.

Next, we turn to the issue of excess entry. Suppose that disadvantaged firms may freely enter the market by paying a fixed entry cost *F*. For notational simplicity, we normalize the transportation cost parameter to *t*=1, which allows us to express social welfare and the profit of each disadvantaged firm as

$$SW = \frac{(N-1)\delta^2-(N(h^2-h-N)-2h^2+4h+1)\delta}{2(3N+h^2-3h-3)} + \frac{1}{4} - \frac{3N}{8} + \frac{N}{2}(v_1 - c) - (N-1)F, \tag{8}$$

$$\pi_i = \frac{\left(2N-\delta(N-1)+2h^2-4h-1\right)^2}{2\left(3(N-1)+h^2-3h\right)^2} - F,\ i{=}2,\ \ldots N. \tag{9}$$

The social welfare function reflects how welfare depends on the number of firms *N* in the market. It captures the trade-off between the consumer gains from product variety and competition on one hand, and the transportation costs and fixed entry costs on the other. The term $v_1 - c$ represents the basic surplus from consumption, $(N\text{-}1)F$ denotes the aggregate fixed entry cost of disadvantaged firms, and the term $\frac{1}{4} - \frac{3N}{8}$ reflects the welfare losses arising from spatial mismatch and distance costs. Because in the spokes model a larger number of firms implies a finer partition of the market space, we normalize consumer density to $\frac{2}{N}$ (except for the fixed-cost term). This normalization allows us to focus on the effect of privacy protection on the equilibrium market structure.

Proposition 3. Consider the case in which only the advantaged firm is able to set personalized prices. (a) As privacy protection is relaxed (that is, as h increases), the equilibrium number of disadvantaged firms decreases when h is small but increases when h becomes large. (b) The market always exhibits excess entry of disadvantaged firms relative to the socially optimal level.

Proposition 3(a) shows that the relationship between privacy protection and market structure is non-monotonic. When privacy protection is still strong (small h), expanding the scope of personalized pricing strengthens the advantaged firm's competitive advantage. This discourages the entry of disadvantaged firms, since their expected profits fall more rapidly as competition intensifies. However, once privacy protection becomes sufficiently weak (large h), uniform-price competition softens as shown earlier in Proposition 1, allowing disadvantaged firms to recover profitability. At this stage, weaker firms again find entry attractive, and the equilibrium number of disadvantaged firms rises.

Proposition 3(b) shows that, despite these shifts in entry incentives, the market always experiences excess entry relative to the social optimum. Entry creates both positive and negative externalities. Although additional firms increase product variety and reduce consumer transportation costs, they also intensify competition for marginal consumers and impose duplicative fixed costs. Because entering firms do not internalize the social cost of entry, they enter even when the net social contribution of an additional firm is negative. This mechanism generalizes the classical excess-entry result from spatial competition models to an environment with personalized pricing and privacy-dependent targeting.

Extensions

This extension endogenizes the extent of personalized pricing, denoted by parameter h, along two main dimensions. First, firms are allowed to invest in data collection and algorithmic analytics to enhance personalization. In this setting, h becomes a strategic firm-level choice rather than an exogenous condition. Firms incur increasing investment costs reflecting expenditures on data acquisition, machine learning, and data-processing infrastructure. Each firm chooses its preferred level of personalization by balancing the additional profit from targeted consumers against these costs. This framework links technological investment incentives with market structure, competitive asymmetry, and privacy conditions.

Preliminary analysis suggests several systematic patterns. The equilibrium level of personalization rises when consumer preference advantages become more dispersed, because firms can extract more value from their core customers. Personalization also tends to increase as the number of firms grows, since stronger competition in uniform pricing pushes firms toward data-driven targeting strategies. In contrast, personalization declines when products are already highly differentiated, because firms possess local market power and gain less from additional targeting. Second, personalization may also be determined from the demand side through consumers' privacy choices. Under an opt-in regime, consumers decide whether to share personal data in exchange for discounts, improved services, or personalized offers. The equilibrium level of personalization then reflects consumers' willingness to trade privacy for these benefits, allowing analysis of privacy costs, fairness concerns, and regulatory policies.

A further extension incorporates network effects, which are central features of digital platforms. In such environments, the value of a product depends not only on its intrinsic characteristics but also on the size of the firm's customer base. A larger user base increases perceived product value and may attract more advertising revenue. This creates a trade-off between direct consumer pricing and indirect advertising income. The interaction among network effects, advertising incentives, and data-driven targeting influences pricing, entry, and welfare outcomes. Finally, the model allows for elastic demand. Instead of assuming that each consumer buys a fixed quantity, demand becomes responsive to prices. When demand is highly sensitive to price, personalized pricing can expand total output by attracting price-sensitive consumers, increasing participation and potentially improving welfare. When demand is less sensitive, personalization mainly redistributes surplus rather than expanding the market. This extension provides a richer analysis of how personalization, privacy, and demand sensitivity jointly shape competition and welfare.

Conclusions

This study examines how personalized pricing and privacy protection jointly shape spatial competition, welfare distribution, and market structure in data-driven oligopolistic markets. As digital technologies reduce the cost of collecting and processing consumer data, firms increasingly rely on personalized pricing to target individual consumers. At the same time, privacy regulations limit the scope of data use, creating a central policy trade-off between efficiency, competition, and consumer protection.

Using a spatial spokes model with one advantaged firm and multiple disadvantaged rivals, the analysis shows that the effects of privacy relaxation are generally nonlinear. When only the advantaged firm can conduct personalized pricing, a reduction in privacy protection initially intensifies competition. Uniform prices fall because the advantaged firm competes more aggressively for nearby consumers, which benefits consumers but reduces the profits of disadvantaged firms. At this stage, the advantaged firm gains from improved surplus extraction. However, as privacy protection weakens further and personalization becomes extensive, competition in the uniform-pricing segment softens. Uniform prices rise, the advantaged firm's profits eventually decline, and disadvantaged firms partially recover. Despite these shifts, total industry profit falls as privacy protection is relaxed, indicating that personalized pricing intensifies overall competitive pressure.

The model also reveals that personalized pricing is not always a dominant strategy. Although firms with data advantages benefit from personalization when its scope is limited, excessive personalization reduces profits for all firms. This suggests that the incentives to expand data-driven pricing depend on market structure, competitive asymmetry, and product differentiation. In particular, the advantaged firm's incentive to personalize becomes stronger when the number of competitors increases or when its valuation advantage over rivals is larger.

When entry by disadvantaged firms is allowed, the interaction between privacy protection and market structure becomes more complex. The equilibrium number of entrants exhibits a non-monotonic relationship with the extent of personalization. Initially, weaker privacy protection discourages entry because it strengthens the advantaged firm's competitive edge. However, once personalization becomes extensive and uniform-price competition softens, entry becomes more attractive again. Despite these changes, the market consistently exhibits excess entry relative to the social optimum, reflecting the classic trade-off between product variety and duplicative entry costs. The extensions further enrich the framework by allowing firms to invest in data capabilities, incorporating consumer privacy choices, and introducing network effects and elastic demand. These additions highlight how personalization incentives depend on technological investment, consumer privacy preferences, platform scale, and demand responsiveness. In particular, personalized pricing may either expand output or primarily redistribute surplus, depending on demand elasticity and the strength of network externalities.

Keywords: Personalized pricing, privacy protection, spatial competition / spokes model, excess entry, asymmetric competition

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