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Can data openness unlock competition when an incumbent has exclusive data access for personalized pricing? ☆

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A B S T R A C T

This paper examines how an incumbent firm's data investment decisions can impact market structure and competition. In markets with sufficiently low entry costs, using exclusive data for personalized pricing (PP) does not raise any barrier to entry. However, in markets with intermediate entry costs, the risk of competition and consumer harm is significant. Policy intervention is needed to foster competition. The effectiveness of an information-sharing policy depends on whether the incumbent anticipates it. Mandatory information sharing can only promote entry in markets with intermediate to high entry costs if the incumbent does not foresee its imposition. If the incumbent foresees this policy, it will strategically reduce its data acquisition to deter entry, by serving fewer consumers in the early period. This will cause significant harm to consumers and overall welfare. In markets with sufficiently low intermediate entry costs, information-sharing obligations can effectively foster competition and benefit consumers, regardless of the incumbent's anticipation. A ban on price personalization practices could be a better policy option to promote competition, especially in markets with high entry costs or where mandatory information sharing is not effective due to the incumbent strategic behavior.

1. Introduction

> "*As data is power, those already large, often global, businesses which are able to utilize existing data effectively, have advantages in terms of maintaining their existing position and further increasing their market share. This will inevitably pose a barrier to new entrants (without any such data) or even smaller competitors.[...]If other solutions would not work, data openness, could be the necessary tool to create the potential for new companies to enter the market and challenge an otherwise entrenched business.*"
>
> In Unlocking digital competition, UK Report of the Digital Competition Expert Panel (Furman et al., 2019)

In digital markets, access to significant volumes of customers' personal data by large incumbent companies, like Amazon, Walmart, Target, Alibaba, among others, has become a major focus of discussion in the competition and antitrust community. The size of these companies is not a problem *per se*; the idea that "big is not bad" is an established rule of competition policy. However, as these companies accumulate more and more data on users, they are better positioned to employ data-based strategies that can heighten competition and consumer harm concerns.

First, exclusive possession of data, with few or no substitutes, may confer a form of unmatchable advantage to incumbent businesses, making successful rivalry less likely. When new entrants or smaller companies are unable to buy access to the same kind of data as incumbent companies, data can act as an important barrier to entry (OECD, 2020). Second, while greater collection of personal data allows businesses to improve their product offerings, it also provides them with a competitive advantage to implement sophisticated forms of price discrimination strategies, like personalized pricing (henceforth PP).[2] The

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[2] For example, Shiller (2014) estimates the increase in profit if Netflix would introduce personalized prices. According to the author, this would lead to an increase of profit for the company between 0.8% (if it used data on consumer demographics) and 12.2% (if it used the browsing history of its consumers). Dubé and Misra (2023) conducted an experiment on Ziprecruiter, an online recruiting company, comparing the existing uniform price charged by Ziprecruiter, an optimized uniform price, and targeted prices. They find that the firm's profits increase by 65% when moving from the existing price to the optimized price, and increase further by 10% when adopting personalized pricing.

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personalization of prices, as discussed in the OECD (2018) report on "Personalized Pricing in the Digital Era", can enhance efficiency and benefit consumers by encouraging businesses to compete more aggressively for each customer (Thisse and Vives, 1988). However, in certain cases, businesses with significant market power that implement this strategy may cause harm to competition and consumers (Bourreau and De Streel, 2018; OECD, 2018, 2020 and Montes et al., 2019). This becomes especially problematic when personalized pricing is employed by a dominant firm as a means of exclusionary abuse, using its data advantage to target customers who prefer competitors' products with lower prices, with the intention of monopolizing the market.

The accumulation of personal data by businesses has raised concerns about the effects on competition and consumer welfare, and as a result, competition and regulatory bodies around the world have taken steps to address these issues by adapting their regulatory frameworks to the digital economy. Various reports have recommended the establishment of specialized regulatory agencies to address the challenges posed by the digital economy. For instance, the Stigler report proposes the creation of a 'Digital Authority' in the US,[3] while the Furman report recommends the formation of a 'Digital Market Unit' in the UK.[4,5]

The recent 10th Amendment of the German Competition Act, which became effective on January 19, 2021 also addresses abuse of dominance and is intended to further shape and complete the regulatory framework of competition in the data-driven economy (Budzinski et al., 2020). Following the Amendment, irrespective of size, a company is considered to have 'relative market power', if another company is dependent on it for its own business strategies. Access to data is introduced as an important criterion.[6] As a result, there is an increasing call for data openness interventions in digital markets, which are now considered crucial elements of digital competition policy reform agendas.

Data openness interventions, including mandatory information sharing and data portability, have been recommended as essential components of digital competition policy reform agendas by several bodies (e.g., the UK Digital Competition Expert Panel, the US Stigler Committee on Digital Platforms, and the OECD). They argue that data openness can increase competition by reducing barriers to entry associated with data access, especially in markets where individual-level data is valuable. In recent years, the European legislative framework for the digital economy has been expanded and refined extensively, and is still undergoing further fine-tuning. This is visible in the legislative package that was proposed as a part of the European Data Strategy, including notably the proposed *Data Act*[7] and the *Digital Markets Act* (which will enter in to force in May, 2023),[8] and the adopted *Data Governance Act*[9] and *Digital Services Act*.[10]

This paper aims to address the following questions: How does an incumbent company's investment in data affect personalized pricing and the entry of new competitors? What incentives does the incumbent have to sell to more or fewer consumers before new entry takes place? Finally, under what market conditions can mandatory information sharing policies restore competition and prevent consumer harm?

The ability of firms to use consumer data to price discriminate is not a new topic in economics. There is an extensive literature on price discrimination, covering both monopolistic and oligopolistic price markets.[11] The pioneering work of Thisse and Vives (1988), based on the Hotelling model, shows that in competitive static settings, in comparison to uniform pricing (no data benchmark), the disclosure of perfect information about consumers' preferences and the induced perfect price discrimination, can produce different profit and welfare results depending on the firms' available data. When firms are symmetric, and all have data, personalized pricing intensifies price competition, boosts consumer surplus and hurts profits.[12] In contrast, when one firm has exclusive access to data for PP, compared to uniform pricing, profit is higher for the informed firm and lower for the uninformed firm (Montes et al., 2019). In this case, overall consumer surplus is still higher, but welfare falls due to inefficient shopping by those consumers who buy from the more distant firm (excess "transportation costs" in the Hotelling linear city).

While Thisse and Vives (1988) assume that firms have perfect information about all consumers in the market, Montes et al. (2019) consider a scenario where a data broker exogenously owns this information and competing firms must purchase it for price discrimination purposes. This creates the possibility of an asymmetric situation where only one firm has access to personal data, depending on the data broker's decisions.

Our model complements the later works in two ways. Firstly, we endogenize the incumbent firm's data acquisition process, allowing it to choose whether to collect data on all consumers or only a proportion of them. To do so, we introduce a preliminary period where only the incumbent is active in the market (located at 0). Each consumer stays in the market for two periods of consumption, and his/her location is fixed across periods. In period 1, the incumbent has no information about consumers, faces no risk of entry and sets a uniform price. Consumers observe the incumbent's price and decide whether or not to buy the good. After first-period purchase decisions are made, the incumbent learns the exact 'location' of the customers it serves. Hence, in this preliminary period, by selling to more or fewer consumers, the incumbent "*invests in data*", and can later, in period 2, use this information to charge personalized prices and deter entry.[13] Secondly, we look at entry decisions after the incumbent has invested in data for PP. If entry occurs, the new entrant lacks access to data for price discrimination, thus it charges a uniform price (henceforth U). Thus, in the first stage of period 2, after observing the incumbent price decisions and so the proportion of served consumers which belong to the incumbent's database, the entrant decides whether to enter, incurring the fixed entry cost $F \geq 0$, or to stay out of the market. Then, in the second stage of period 2, price decisions are taken. In particular, if the entrant enters, a duopoly results, the incumbent employs PP and the entrant charges a uniform price, i.e. the price regime is (PP,U); otherwise, the incumbent

[3] See Stigler Committee on Digital Platforms, Final Report, September 2019, available at https://www.chicagobooth.edu/research/stigler/news-and-media/committee-on-digital-platforms-final-report.

[4] See Furman et al. (2019), "Unlocking digital competition: Report of the digital competition expert panel", available at https://www.gov.uk/government/publications/unlocking-digital-competition-report-of-the-digital-competition-expert-panel.

[5] This specialized agency will be a mix of a competition authority and a regulator; it will focus on the digital economy and oversee large incumbents (Tirole, 2020).

[6] The refusal to provide access to such data in exchange for an adequate fee may also constitute an abuse (OECD, 2020).

[7] See: https://ec.europa.eu/commission/presscorner/detail/en/ip_22_1113 (accessed at 30 march 2023).

[8] See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32022R1925 (accessed 23 march 2023).

[9] See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52020PC0767 (accessed 26 march 2023).

[10] See http://data.europa.eu/eli/reg/2022/2065/oj (accessed 26 march 2023).

[11] Armstrong (2006) and Stole (2007) provide excellent surveys of the literature.

[12] In static settings, the rationale for the positive effect of competitive price discrimination on profits may lie on firms' asymmetry (e.g. Shaffer and Zhang, 2002; Ghose and Huang, 2009; and Matsumura and Matsushima, 2015), multidimensional product differentiation (Esteves, 2009), imperfect targetability (Chen et al., 2001), consumers' demand heterogeneities (Esteves, 2022) and CES demand/delivered pricing model (Esteves and Shuai, 2022).

[13] It is worth noting that the incumbent firm is subject to the obligation to obtain the consent of individuals for collection of personal data, since this provision is at the heart of the European GDPR. We assume that this condition holds.

remains in a monopoly position with the ability to quote personalized prices, the price regime (PP).

Our model has also connections with the behavior-based price discrimination (BBPD) literature in which firms gather consumer information through the first-period purchase, which they use for price discrimination in the future. In this literature, consumer data collected in period 1 allows firms to distinguish an old customer from a new one (or one who bought from the rival before) and price accordingly (e.g. Chen, 1997; Fudenberg and Tirole, 2000). A common finding in this literature is that firms charge lower prices to new customers than to old customers. BBPD is shown to usually lead to lower profits for firms and welfare losses due to inefficient shopping by those consumers who switch to the more distant seller in the second period. In this vein, a close related paper is Choe et al. (2018). The authors assume that two symmetric firms compete in uniform prices in a first period without any consumer information, then, after having acquired information about their own first-period consumers, firms can offer a personalized price to old customers and a single poaching price to the rival's previous customers. They find that firms are harmed by this possibility, which actually intensifies the negative profit effects identified by Fudenberg and Tirole (2000).

In order to study the effects of data as a barrier to entry, our paper introduces a variation of Choe et al. (2018) by starting with an asymmetric setting (in period 1 only the incumbent firm is active). Endogenizing data acquisition allows us to rely on Fudenberg and Tirole (1984)'s taxonomy of entry-related strategies to explain the incumbent's incentive to sell to more or fewer consumers before any entry can take place. Indeed, we show that if entry costs are sufficiently low ($F \leq \frac{1}{8}$) and consumers' willingness to pay (i.e., v) is low, entry accommodation calls for underinvestment in consumer data—the incumbent adopts the '*puppy dog strategy*' in period 1. As investment in consumer data makes the incumbent tough, under entry accommodation, it prefers to underinvest in data acquisition to look less aggressive in the pricing game (PP,U) of period 2. This is achieved by quoting a higher price in period 1, serving less consumers, and getting perfect information about a lower proportion of customers for PP in period 2. For higher entry costs $\left(F > \frac{1}{8}\right)$, the incumbent can behave as an unconstrained monopolist without fearing entry.

This paper is also related to the strand of the economic literature that have studied the potential use of price discrimination as a foreclosure strategy. Rey and Tirole (2007) provide a comprehensive survey on how price discrimination can be used for both vertical and horizontal foreclosure. A closed paper is Gehrig et al. (2011) which analyzes the effects of price discrimination on entry and welfare. Notwithstanding, there are important differences between their model and ours. They look at BBPD rather than at PP. The potential entrant has no data and faces no fixed cost of entry (i.e., $F = 0$). The authors exogenously assume that the incumbent has the required data for BBPD, thus, they ignore the process of data acquisition. They show that the potential abuse of market dominance imposed by BBPD is exploitation, not exclusion. In contrast, we show that the incumbent ability to use its collected data for PP is an effective tool for consumer welfare *exploitation* and *exclusion* of competitors from the market, particularly when entry costs are not small.

The purpose of this paper is to provide guidance to public agencies on effective policy interventions in markets relatively well represented by the features of our model. We consider a ban on using data for personalized pricing and mandatory information sharing obligations. The paper takes into account factors such as entry costs, consumers' willingness to pay, and the dominant firm's foresight towards policy interventions. Our analysis suggests that markets with entry costs falling between $\frac{1}{8}$ and $\frac{1}{4}$ require policy intervention to prevent harm to competition and consumer welfare. We show that the effectiveness of an information sharing obligation depends on whether the incumbent firm anticipates the intervention, with such policy being more effective in markets with intermediate to high entry costs (between $\frac{1}{8}$ and $\frac{1}{4}$) if the incumbent does not anticipate it. If entry costs are higher (between $\frac{2}{11}$ and $\frac{1}{4}$), a forward-looking incumbent may reduce its data acquisition, serving fewer consumers in the early period in an attempt to make entry less profitable under (PP,PP). This is done to discourage entry into the market, and can result in significant harm to both consumers and overall welfare if an information sharing obligation is imposed.

Therefore, in markets with intermediate to high entry costs, public agencies should consider the strategic responses of incumbents when implementing information sharing policy interventions. If these interventions are insufficient to achieve the desired competitive outcome, public agencies may consider implementing a ban on the use of data for personalized pricing (PP) or simply a ban on PP. Such policies may be particularly important in markets with high entry costs (between $\frac{1}{4} < F \leq \frac{1}{2}$), where even with information sharing, the entry of new competitors may not be feasible. However, it is important to note that while banning personalized pricing can restore competition across a wide range of entry costs, it may be challenging for public agencies to monitor compliance by dominant firms with this requirement.

The paper is structured as follows. In the next section, we present the model used in this study. Section 3 discusses the case of an unconstrained monopoly. We analyze the equilibrium in section 4. In section 5, we examine the effectiveness of an information sharing intervention in promoting competition. The welfare analysis is presented in section 6. In section 7, we discuss policy issues and provide final remarks. The Appendix contains proofs that were omitted from the main text.

2. The model

Consider a Hotelling linear city model where a unit mass of consumers has unit demands and stay in the market for two periods of consumption, $t = 1, 2$. Consumers are uniformly distributed on $[0, 1]$. The position of a specific consumer, denoted as $x \in [0, 1]$, remains constant over time and reflects their relative preference for the incumbent brand (located at 0) and a potential entrant brand (located at 1 in the event of entry). Consumers have a reservation value v for their ideal product. We assume v is sufficiently high, i.e. $v \geq \frac{3}{2}$.[14] While discussing different values of v in the paper, we will refer to values of v in the interval $\frac{3}{2} \leq v \leq 2$ as '*low*' v, and $v > 2$ as '*high*' v.

In period 1, only an incumbent, firm A, is active. It is located at 0 and produces good A at zero marginal costs. A consumer of type $x \in [0, 1]$ incurs a disutility of $-x$ if she/he buys a unit of good A. So, a consumer located at $x \in [0, 1]$ derives utility $v - x - p_A$ when buying from firm A. In the beginning of the game, the incumbent has no means to identify the location of any consumer, thus it sets a single price to all consumers (uniform pricing). Consumers observe the incumbent's price and decide whether or not to buy the good. After first-period purchase decisions have been made, the incumbent learns the exact 'location' of the customers it serves; those located on the interval $[0, x_1]$, with $0 < x_1 \leq 1$. In other words, the incumbent gathers perfect information about the location of each consumer located at $x \in [0, x_1]$. Formally, the incumbent data acquisition is captured by the length of its customer-database $x_1 \in [0, 1]$.

In period 2 there are two stages. In the first stage, after observing the incumbent first-period price and thus its data acquisition x_1, firm B decides whether or not to enter in the market. If it enters, it incurs the entry cost $F \geq 0$ and its location is exogenously fixed at 1; its marginal

[14] We will see that under competition with uniform equilibrium price equal to 1 and $\frac{1}{2}$ of consumers buying from each firm the market is covered so long as the utility of the more distant consumer, located at $\frac{1}{2}$, is nonnegative. This implies: $v - 1 - \frac{1}{2} \geq 0$, from which we get $v \geq \frac{3}{2}$. Additionally, when the incumbent charges a personalized price, while the entrant sets a single price, the consumer of type $x = 0$ buys the good from the incumbent at price $p(x = 0) = \frac{3}{2}$ as long as $v - \frac{3}{2} \geq 0$.

production cost is also null. (If it stays out, it doesn't sell anything but saves the entry cost F.) A consumer of type $x \in [0,1]$ incurs a disutility of $-(1-x)$ if she/he buys a unit of good B. In the second stage, firm A and B (or only firm A, if B stays out) make(s) price decisions simultaneously. The incumbent has exclusive access to the data collected from its own previous clientele, thus it uses this data to set a personalized price (PP) to each identified customer $x \in [0, x_1]$. The remaining consumers, located in the interval $[x_1, 1]$ did not buy from firm A before, so they are unidentified in period 2. The incumbent charges a uniform pricing to consumers in this segment. Because there are no alternative sources of information for the rival firm, it quotes a uniform price to all consumers.

Finally, to simplify notation and the discussion, we assume that the incumbent uses a discount factor $\delta = 1$. To focus on our main question we assume that consumers are naive. Relaxing this naivety assumption in our framework would imply assuming that consumers are highly sophisticated.[15] In particular, apart from anticipating that the incumbent can engage in PP practices, consumers would also have to predict the outcome of entry decisions and the subsequent price offers.[16] It is worth noting that recent studies have shown that consumers have limited awareness and knowledge of personalized pricing (Ofcom, 2020[17] and EU, 2018[18]), and existing regulations may not be sufficient to ensure full transparency and control over personal data. In addition, while regulations such as the European General Data Protection Regulation (GDPR), aim to promote transparency and give consumers more control over their personal data, it is still possible that companies may not fully comply with these regulations. Therefore, assuming that consumers are not fully aware and in control of how their personal data is being used for price discrimination may not be a completely unrealistic assumption at the present time (EU, 2022 study on personalized pricing).[19]

3. Benchmark: unconstrained monopoly

For future reference, in this section we consider two benchmarks in which the incumbent firm is a monopolist in both periods.

3.1. Price discrimination is not permitted

Consider first the case where price discrimination is not permitted in period 2, either because the incumbent has data but cannot make use of it for price discrimination or because data acquisition is blocked, due to technological or legal restrictions or because all consumers hide their types. As a result of that, the incumbent firm charges a uniform price in both periods.

The indifferent consumer between buying its product or not is located at $\overline{x}$ such that $v - \overline{x} - p = 0$. This means that consumers located at $x \leq \overline{x}$ can buy the good, while consumers located at $x > \overline{x}$ stay out of the market (with $\overline{x} = v - p$ and $0 < \overline{x} \leq 1$). Under uniform pricing the incumbent profit per period is $\pi = p(v-p)$, with $v - p \leq 1$. Taking into account that we are assuming that $v \geq \frac{3}{2}$, we can establish the following proposition.

Proposition 1. *If price discrimination is not permitted:*

(i) When consumers' willingness to pay is low (i.e., $\frac{3}{2} \leq v \leq 2$), the monopolist sets the optimal price $\underline{p}_t^u = \frac{v}{2}$ in each period $t = 1, 2$, in period 1 it serves $\underline{x}_1^u = \frac{v}{2}$ consumers (with $\frac{3}{4} \leq \underline{x}_1^u \leq 1$), and its profit per period is $\underline{\pi}_t^u = \frac{v^2}{4}$. The monopolist overall profits are $\underline{\pi}^u = \frac{v^2}{2}$.

(ii) When consumers' willingness to pay is high (i.e. $v > 2$), the monopolist sets the optimal price $\overline{p}_t^u = v - 1$ in each period $t = 1, 2$, in period 1 it serves $\overline{x}_1^u = 1$ consumers and its profit per period is $\overline{\pi}_t^u = (v-1)$. The monopolist overall profits are $\overline{\pi}^u = 2(v-1)$.

Proof. See the Appendix. □

When v is low some consumers are left out of the market in both periods under uniform pricing. Consumer surplus (CS) in each period $t = 1, 2$, is:

$$\underline{CS}_t^u = \int_0^{\frac{v}{2}} \left(v - \underline{p}_t^u - x \right) dx = \frac{v^2}{8}. \tag{1}$$

Overall consumer surplus is $\underline{CS}^u = 2\underline{CS}_t^u = \frac{v^2}{4}$, overall profits are $\underline{\pi}^u = 2\underline{\pi}_t^u = \frac{v^2}{2}$. Thus, overall welfare is $\underline{W}^u = \frac{3}{4}v^2$. In contrast, when v is high, there is full participation. In each period consumer surplus is

$$\overline{CS}_t^u = \int_0^1 \left(v - \overline{p}_t - x \right) dx = \frac{1}{2} \tag{2}$$

Thus, overall consumer surplus is $\overline{CS}^u = 2\overline{CS}_t^u = 1$ and overall profits are $\overline{\pi}^u = 2\overline{\pi}_t^u = 2(v-1)$. Hence, overall welfare is $\overline{W}^u = 2v - 1$.

3.2. Use of data for price discrimination is allowed

Now consider the case where the incumbent firm is able to use data collected from its previous customers to quote personalized prices in period 2. Given the share of x_1 served consumers in period 1, the incumbent is able to identify perfectly each customer's exact location in period 2. Thus, it is able to charge a price $p(x)$ to capture the entire surplus of consumers with $x \in [0, x_1]$. The remaining consumers with $x \in [x_1, 1]$ are not identified, so the incumbent charges all of them the uniform price $\widetilde{p}$.

The optimal second-period price for a recognized consumer located at x is $p(x) = v - x$, with $x \in [0, x_1]$, and with corresponding profits $\int_0^{x_1} p(x)dx = \frac{1}{2}x_1(2v - x_1)$. Look next at the monopolist price decision to the group of anonymous consumers. The non-discrimination price $\widetilde{p}$ is chosen to maximize $(\widetilde{x} - x_1)\widetilde{p}$ with $\widetilde{x} = v - \widetilde{p}$. Thus $\widetilde{p} = \frac{v - x_1}{2}$ and $\widetilde{x} = \frac{v + x_1}{2}$. If $v > 2 - x_1$ (which will be the case in equilibrium) we get $\widetilde{p} = v - 1$ and profits from the segment of anonymous consumers are $(1 - x_1)(v-1)$. Then, if $v > 2 - x_1$ the monopolist second-period profits are:

$$\pi_2^{pp} = \frac{1}{2}x_1(2v - x_1) + (1 - x_1)(v-1).$$

In period 1, the incumbent makes its price decision taking into account the effect of this choice on both period profits. Overall profits are

$$\Pi^{pp} = (v - x_1)x_1 + \frac{1}{2}x_1(2v - x_1) + (1 - x_1)(v-1)$$

From the first-order conditions with respect to x_1, we get that $x_1 = \frac{1}{3}(v+1)$ with $x_1 \leq 1$. Therefore, when $v > 2$ we obtain $\overline{x}_1^{pp} = 1$ and

[15] Although this extension is interesting and worthpursuing, it would introduce additional complications into the model making the answer to our main question less clear-cut. This is left for future research.

[16] When consumers are strategic, the economics literature shows that intertemporal price discrimination could not be optimal for the monopolist (see for instance, Stokey, 1979). Acquisti and Varian (2005) revisit this result in a model where a monopolist has access to a tracking technology and consumers can use an anonymizing technology. They show that using past information about consumers benefits the monopolist either if a large share of consumers is myopic (i.e., they ignore the fact that paying a high price today makes it more likely that they will be offered a high price tomorrow) and/or tracking is also used to provide consumers with personalized (higher-quality) services.

[17] See https://www.ofcom.org.uk/_data/assets/pdf_file/0033/199248/personalised-pricing-discussion.pdf (accessed at April 25, 2023).

[18] See https://commission.europa.eu/system/files/2018-07/synthesis_report_online_personalisation_study_final_0.pdf (accessed April 22, 2023).

[19] See: https://www.europarl.europa.eu/RegData/etudes/STUD/2022/734008/IPOL_STU(2022)734008_EN.pdf.

then the monopolist first-period price is $\overline{p} = v - 1$. When $\frac{3}{2} \leq v \leq 2$, $\underline{x}_1 = \frac{1}{3}(v+1)$ and the first-period price is $\underline{p}_1 = \frac{1}{3}(2v-1)$. Thus, the monopolist first and second-period profits are, respectively:

$$\pi_1^{pp} = \begin{cases} \frac{1}{9}(2v-1)(v+1) & \text{if} \quad \frac{3}{2} \leq v \leq 2 \\ v-1 & \text{if} \quad v > 2 \end{cases}$$

$$\pi_2^{pp} = \begin{cases} \frac{11}{9}v - \frac{13}{18} - \frac{1}{18}v^2 & \text{if} \quad \frac{3}{2} \leq v \leq 2 \\ v - \frac{1}{2} & \text{if} \quad v > 2 \end{cases}$$

The next proposition summarizes our main results for an unconstrained monopolist which is able to collect and use consumer data for PP.

Proposition 2. *When the use of customer data for personalized pricing in period 2 is permitted then:*

(i) When v is low $\left(\frac{3}{2} \leq v \leq 2\right)$, the incumbent first-period price is $\underline{p}_1 = \frac{1}{3}(2v-1)$ and $\underline{x}_1^{pp} = \frac{1}{3}(v+1)$ (with $\frac{5}{6} \leq \underline{x}_1^{pp} \leq 1$). In period 2, identified consumers pay $p(x) = v - x$ for $x \in \left[0, \frac{1}{3}(v+1)\right]$, while anonymous consumers with $x \in \left[\frac{1}{3}(v+1), 1\right]$ pay $\widetilde{p} = v - 1$. The monopolist overall profits are $\underline{\pi}^{pp} = \frac{1}{6}v^2 + \frac{4}{3}v - \frac{5}{6}$.

(ii) When v is high ($v > 2$), the incumbent first-period price is $\overline{p}^1 = v - 1$ with $\overline{x}_1^{pp} = 1$. All consumers are recognized in period 2 and are charged price $p(x) = v - x$, with $x \in [0, 1]$. Overall profits are $\overline{\pi}^{pp} = 2v - \frac{3}{2}$.

Next we compute consumer surplus and social welfare when the incumbent is allowed to use its data for PP. Consider first the case where v is low. Some consumers are left out of the market in period 1, but all of them can buy the good in period 2. In period 1 and 2, consumer surplus is, respectively, equal to $\underline{CS}_1^{pp} = \frac{1}{18}(v+1)^2$ and $\underline{CS}_2^{pp} = \frac{1}{18}(v-2)^2$. Hence, overall consumer surplus, is equal to $\underline{CS}^{pp} = \frac{1}{9}v^2 - \frac{1}{9}v + \frac{5}{18}$. As overall profits are $\underline{\pi}^{pp} = \frac{1}{6}v^2 + \frac{4}{3}v - \frac{5}{6}$, overall social welfare is $\underline{W}^{pp} = \frac{5}{18}v^2 + \frac{11}{9}v - \frac{5}{9}$.

When v is high, all consumers can buy the good in both periods. Consumer surplus in period 1 and 2 is respectively equal to $\overline{CS}_1^{pp} = \frac{1}{2}$ and $\overline{CS}_2^{pp} = 0$, yielding an overall consumer surplus equal to $\overline{CS}^{pp} = \frac{1}{2}$. Since $\overline{\pi}^{pp} = 2v - \frac{3}{2}$, overall welfare is equal to $\overline{W}^{pp} = 2v - 1$.

Corollary 1. *In comparison to the case where price discrimination is not allowed, the ability of the incumbent firm to use its data for PP implies that:*

(i) $\underline{\pi}^{pp} - \underline{\pi}^{u} > 0$; $\underline{CS}^{pp} - \underline{CS}^{u} < 0$ and $\underline{W}^{pp} - \underline{W}^{u} > 0$, when $\frac{3}{2} \leq v \leq 2$.

(ii) $\overline{\pi}^{pp} - \overline{\pi}^{u} > 0$; $\overline{CS}^{pp} - \overline{CS}^{u} < 0$ and $\overline{W}^{pp} - \overline{W}^{u} = 0$, when $v > 2$.

Regardless of v, as expected, the monopoly firm always benefits from the ability to use its data as an input for PP ($\pi^{pp} - \pi^{u} > 0$). When a firm sets personalized prices instead of a uniform price, two opposite effects arise: some consumers with high willingness-to-pay can be worse off (*appropriation effect*), while some consumers with low willingness-to-pay can be better off (*demand expansion effect*). The appropriation effect means that moving from uniform pricing to personalized prices, the monopoly firm increases the price charged to consumers with strong preferences (high willingness-to-pay). (We will see that under competition this might not occur.) These consumers are then worse off with personalized prices. The demand expansion effect arises under personalized pricing because the incumbent firm may serve consumers that it would not serve were it constrained to set uniform pricing. This is the case when v is low: although aggregate consumer surplus falls with PP, the market expansion effect boosts social welfare.[20] When $v > 2$, all consumers can purchase the good in both periods under uniform and personalized pricing. Because the market expansion effect of PP is null, PP only acts to reduce consumer welfare at the benefit of the incumbent's profits.

When a dominant company uses its data for personalized prices, any intervention to avoid consumer harm might be addressed through a combination of complementary policy tools, including competition and antitrust policy, consumer protection and data protection. Regarding antitrust law, a general *per se* prohibition of personalized prices is usually not justified, however, if it can be proved that consumer surplus and welfare falls with personalized prices in a specific case, the practice can be prohibited by the antitrust rules. Following Bourreau and De Streel (2018), in the European Union, Article 102(c) TFEU prohibit specifically abuse of dominant position. In this context, discrimination is defined as "applying dissimilar conditions to equivalent transactions with other trading parties, thereby placing them at a competitive disadvantage". Within competition law, personalized pricing may potentially be assessed under abuse of dominance rules, though there are some limitations to the application of competition law in this area.[21] Antitrust rules are better at condemning *exclusionary* price personalization than regulating *exploitative* price personalization. Indeed, because the appropriation effect outweighs the demand expansion effect, so far our analysis confirms the exploitative effect of PP by a dominant firm. However, the exclusive access to personal data for personalized pricing may help a dominant firm to exclude potential competitors from the relevant market, so it is important to consider the potential *exclusionary effects* of personalized pricing. This issue will be discussed further in the next section.

4. Data acquisition and entry decisions when personalized pricing is permitted

4.1. No discrimination benchmark

For future reference, let us consider the benchmark case where the incumbent firm A is unable to use its data for personalized pricing. In this scenario, if entry occurs in period 2, the pricing game follows the Hotelling model, where both firms charge a uniform price denoted as (U,U). The incumbent's decision on data acquisition in the first period does not affect the prices or entry decisions in the second period. The equilibrium uniform price is $p_i^{u,u} = 1$, $i = A, B$. Given $p_i^{u,u}$ we assume that all consumers receive a nonnegative surplus, i.e., all consumers are willing to buy the good. The incumbent firm, A, serves all consumers to the left of $\frac{1}{2}$, while the entrant firm, B, serves all consumers to the right of $\frac{1}{2}$. The consumer located at $x = \frac{1}{2}$ purchases the good if and only if $v - p_i^{u,u} - \frac{1}{2} \geq 0$, which is equivalent to $v \geq \frac{3}{2}$. This condition ensures that the market is fully covered under competition. Each firm's second period prices are $\pi_A^{u,u} = \frac{1}{2}$; $\pi_B^{u,u} = \frac{1}{2} - F$. As a result, firm B enters the market as long as $F \leq \frac{1}{2}$. Under this scenario, consumer surplus in period 2 is equal to $CS_2^{u,u} = v - \frac{5}{4}$. In period 1, the incumbent firm behaves according to Proposition 1, choosing $x_1 = \frac{v}{2}$ when v is low, and $x_1 = 1$ when v is high. Consequently, when v is low $\pi_A^{u,u} = \frac{v^2}{4} + \frac{1}{2}$, $\pi_B = \frac{1}{2} - F$; $CS^{u,u} = \frac{1}{8}v^2 + v - \frac{5}{4}$ and $W^{u,u} = \frac{3}{8}v^2 + v - \frac{1}{4} - F$. When v is high, $\pi_A^{u,u} = v - \frac{1}{2}$; $\pi_B^{u,u} = \frac{1}{2} - F$; $CS^{u,u} = v - \frac{3}{4}$ and $W^{u,u} = 2v - \frac{3}{4} - F$.

[20] This output expansion effect and its implications for economic welfare was first formalized by Varian (1985) in his pioneering American Economic Review article.

[21] The OECD (2018) states that this limitation arises because (i) rules on abuse of dominance only apply to firms that have substantial market power, which are in fact the circumstances under which personalized pricing can cause more consumer harm; (ii) in several jurisdictions, exploitative abuses are either not prohibited by competition law, or rarely investigated in practice; (iii) it is often unclear whether competition rules against discrimination apply to business-to-consumer relationships.

4.2. Second-stage of period 2: price decisions

Now let's consider a scenario where the incumbent has no restrictions on using its own proprietary data for personalized pricing. As usual, we solve the game working backwards from the second-stage of period 2. Consider first the case where firm B enters and incurs the entry cost F. The incumbent can set individual prices, $p(x)$, to each consumer x that belongs to its database $[0, x_1]$ based on the information it has acquired. On the other hand, the entrant has no alternative sources of information and can only set a single price. As previously mentioned, we refer to this pricing regime as (PP,U). In the first period, the incumbent acquires information on the consumers in the market up to x_1. Depending on the extent of this information acquisition, the incumbent can gather perfect information about all consumers in the market (if $x_1 = 1$) or only about a portion of the market (if $x_1 < 1$). Hence, in period 2, the incumbent charges a personalized price, $p_A^{pp,u}(x)$, to identify consumers with $x \in [0, x_1]$ and a non-discrimination price, $p_A^{pp,u}$, to new (anonymous) customers, with $x \in [x_1, 1]$. Meanwhile, the entrant sets a uniform price, $p_B^{pp,u}$.

Look first at a consumer located at interval $[x_1, 1]$. The indifferent consumer between buying from A and B is located at $\widetilde{x}$ given by:

$$\widetilde{x} = \frac{1}{2} + \frac{p_B^{pp,u} - p_A^{pp,u}}{2} \text{ with } x_1 \le \widetilde{x} \le 1.$$

Consider now the consumer with $x \in [0, x_1]$ who bought from firm A in the first period. In period 2, the consumer's outside option is not zero, but the utility associated with buying from B at the uniform $p_B^{pp,u}$. Hence, to induce the consumer to continue buying from firm A in the second period, the personalized price $p_A^{pp,u}(x)$ charged by A in period 2 must be such that the consumer is indifferent between buying from A and B, which happens when $p_A^{pp,u}(x) = p_B^{pp,u} + (1 - 2x)$.

Firm A's marginal cost is its best offer to a distant consumer, such as the one located at $\widehat{x}_A^0$. In other words, $p_A^{pp,u}(\widehat{x}_A^0) = 0$. At this price, the distant consumer is indifferent between buying from firm A and firm B, as long as $0 + \widehat{x}_A^0 = p_B^{pp,u} + (1 - \widehat{x}_A^0)$. This equation yields $\widehat{x}_A^o = \frac{1+p_B^{pp,u}}{2}$, indicating that firm A can serve all old consumers located to the left of $\widehat{x}_A^o$. Depending on x_1, firm A's profits from both previous customers (superscript o) and new customers (superscript n) are as follows:

$$\pi_A^o = \int_0^{\min\left\{\widehat{x}_A^o, x_1\right\}} p_A(x)dx \text{ and } \pi_A^n = p_A^{pp,u} \max\left\{\widetilde{x} - x_1, 0\right\}. \tag{3}$$

Firm B's profits are

$$\pi_B = \max\left\{x_1 - \widehat{x}_A^o, 0\right\} p_B^{pp,u} + p_B^{pp,u} \min\left\{1 - x_1, 1 - \widetilde{x}\right\}. \tag{4}$$

Let's consider the following cases. First, suppose that $x_1 > \widehat{x}_A^o$. When this is the case, we get $\frac{1+p_B^{pp,u}}{2} < x_1$. Therefore from $\widetilde{x} = \frac{1+p_B^{pp,u}}{2} - \frac{p_A^{pp,u}}{2}$ we can infer that $\widetilde{x} - x_1 < 0$. This suggests that firm A is unable to attract any consumers from the pool of anonymous new customers. Thus when $\widehat{x}_A^o < x_1$, firm A and B profits, are respectively:

$$\pi_A^o = \int_0^{\frac{1+p_B^{pp,u}}{2}} p_A(x)dx \text{ and } \pi_A^n = 0$$

$$\pi_B = \left(x_1 - \frac{1 + p_B^{pp,u}}{2}\right) p_B^{pp,u} + p_B^{pp,u}\left(1 - x_1\right)$$

If we take the derivative of π_B with respect to $p_B^{pp,u}$ we obtain $p_B^{pp,u} = \frac{1}{2}$. This, in turn, implies that $\widehat{x}_A^0 = \frac{3}{4}$. As a result, firm A serves all consumers located at the left of $\frac{3}{4}$, and firm B serves the remaining customers. Therefore, $p_A^{pp,u}(x) = \frac{3}{2} - 2x$ if $x \le \frac{3}{4}$; while $p_A^{pp,u}(x) = 0$ if $x \ge \frac{3}{4}$.

Second, let's consider the case where $x_1 \le \widehat{x}_A^0$, and $\widehat{x}_A^o = \frac{1+p_B^{pp,u}}{2}$. If x_1 is not sufficiently high, then firm A will attract at most x_1 at $p_A^{pp,u}(x)$. However, in this scenario, firm A can still attract a fraction of new (anonymous) customers as long as $\widetilde{x} > x_1$, with $\widetilde{x} = \frac{1}{2} + \frac{p_B^{pp,u} - p_A^{pp,u}}{2}$. The profits of firms A and B are, respectively given by:

$$\pi_A^o = \int_0^{x_1} p_A^{pp,u}(x)dx \text{ and } \pi_A^n = p_A^{pp,u}\left(\widetilde{x} - x_1\right) \text{ with } \widetilde{x} \ge x_1,$$

$$\pi_B = p_B\left(1 - \widetilde{x}\right).$$

The following proposition summarizes the equilibrium price decisions in the case of entry.

Proposition 3. *When firm B enters and personalized pricing is permitted, in equilibrium:*

(i) If the group of firm A's identified customers is sufficiently high, i.e. if $\frac{3}{4} \le x_1 \le 1$*:*

$$p_A^{pp,u}(x) = \begin{cases} \frac{3}{2} - 2x & \text{if} \quad x \le \frac{3}{4} \\ 0 & \text{if} \quad x \ge \frac{3}{4} \end{cases} \quad \text{and} \quad p_B^{pp,u} = \frac{1}{2}, \tag{5}$$

firms A and B profits are respectively equal to

$$\pi_A^{pp,u} = \frac{9}{16} \quad \text{and} \quad \pi_B^{pp,u} = \frac{1}{8} - F. \tag{6}$$

(ii) If the group of firm A's identified customers is not too high, i.e. if $x_1 \le \frac{3}{4}$*:*

$$p_A^{pp,u}(x) = \begin{cases} 2(1 - x - \frac{1}{3}x_1) & \text{if} \quad x \le 1 - \frac{1}{3}x_1 \\ 0 & \text{if} \quad x \ge 1 - \frac{1}{3}x_1 \end{cases}, \quad p_A^{pp,u} = 1 - \frac{4}{3}x_1$$

$$\text{and} \quad p_B^{pp,u} = 1 - \frac{2}{3}x_1 \tag{7}$$

each firm profit is

$$\pi_A^{pp,u} = \frac{1}{2} + \frac{1}{9}x_1\left(6 - 7x_1\right), \tag{8}$$

$$\pi_B^{pp,u} = \frac{1}{2} - \frac{2}{9}x_1\left(3 - x_1\right) - F. \tag{9}$$

Proof. See the Appendix. □

Proposition 3 offers valuable insights into the connection between personal data acquisition by an incumbent and competitive interaction in the event of entry. Firstly, it demonstrates that the informed firm obtains higher profits with PP than with UP $\left(\pi_A^{pp,u} - \pi_A^{u,u} > 0\right)$, whereas the opposite is true for the uninformed firm $\left(\pi_B^{pp,u} - \pi_B^{u,u} < 0\right)$. Additionally, it illustrates that the incumbent informed firm earns more profits than the uninformed entrant $\left(\pi_A^{pp,u} > \pi_B^{pp,u}\right)$. It is worth noting that the literature has already demonstrated the profit advantage of the informed firm (e.g., Liu and Serfes, 2004; Montes et al., 2019). However, Proposition 3 emphasizes the crucial connection between the incumbent's data acquisition choices before any entry occurs and the role of exclusive data access in shaping market structure and/or competitive interaction between firms in period 2.

Remark 1. Increasing the incumbent's data acquisition (higher x_1) intensifies price competition in the event of entry under (PP, U).

This outcome is highly intuitive. As the incumbent's proportion of identified customers (x_1) rises, the entrant is compelled to engage in fiercer competition across both the broader portion of firm A's identified customers and the shrinking segment of unidentified ones. Since prices are strategic complements, this leads to the incumbent charging lower prices to both identified and anonymous customers.

Before proceeding, it is also worthwhile to compare our equilibrium second-period prices in the event of entry (PP,U) with their corresponding counterparts under (U,U), in which both firms charge $p^{u,u}=1$. Consider first the case where the incumbent initial data acquisition is not too high, i.e., $x_1<\frac{3}{4}$. Proposition 3 reveals that a segment of customers will face higher prices under (PP,U), while others will face lower prices. Specifically, customers with strong preferences for the incumbent, located in the interval $\left[0,\frac{1}{2}-\frac{1}{3}x_1\right[$ will repurchase from A at a price greater than 1. All other customers will pay lower prices under (PP,U) compared to (U,U). Now, let us suppose that $x_1\geq\frac{3}{4}$. Consumers with preferences within $\left[0,\frac{1}{4}\right[$ will purchase from the incumbent at a price higher than 1, while those with preferences in the interval $\left[\frac{1}{4},\frac{3}{4}\right]$ will buy from the incumbent at a price lower than 1 (the customer located at $x=\frac{3}{4}$ benefits the most as it pays 0). Consumers located at $\left[\frac{3}{4},1\right]$ will purchase from B at a price of $\frac{1}{2}$.

Regarding the impact of the incumbent's data acquisition on both firms' profits, we can conclude that any first-period "investment in consumer data" such that $x_1>\frac{3}{4}$ has no additional effect on the incumbent and entrant second-period profits. In fact, each firm's second-period profits are constant for every $x_1\geq\frac{3}{4}$. In contrast, if $x_1<\frac{3}{4}$, we can conclude that $\frac{\partial\pi_B}{\partial x_1}<0$ for any x_1, and $\frac{\partial\pi_A}{\partial x_1}<0$ so long as $x_1>\frac{3}{7}$. Therefore, if the incumbent's share of informed consumers is higher than $\frac{3}{7}$ (which will be the case), further increases in the list of the incumbent's identified customers reduces both firms' second-period profits in the event of entry. This explains why the entry accommodation strategy requires underinvestment in consumer data, known as the "*puppy dog strategy*", where the incumbent seeks to appear small and harmless to provoke a favorable response from the entrant.

4.3. First-stage of period 2: entry decisions

We now turn to stage 1 of period 2, where after observing the incumbent's information acquisition x_1, the entrant decides whether to enter the market or not. If firm B decides to enter incurring the entry cost F, the firms set prices simultaneously at stage 2. We have seen that if price discrimination were not permitted, under (U,U), the entrant's profits are $\pi_B^{u,u}=\frac{1}{2}-F$. Thus:

Remark 2. If price discrimination were not permitted in period 2, firm B would decide to enter as long as $F\leq\frac{1}{2}$; otherwise it would prefer to stay out of the market.

In contrast, when the incumbent firm can use its data for PP, the entrant's profits in case of entry are:

$$\pi_B^{pp,u}=\begin{cases}\frac{1}{8}-F & \text{if} \quad x_1\geq\frac{3}{4}\\ \frac{1}{2}-\frac{2}{9}x_1\left(3-x_1\right)-F & \text{if} \quad x_1<\frac{3}{4}\end{cases} \tag{10}$$

Otherwise, if the entrant decides to stay out of the market, its profits are null. Therefore, if $x_1\leq\frac{3}{4}$, the entrant enters the market if and only if $F\leq\frac{1}{2}-\frac{2}{9}x_1\left(3-x_1\right)$, otherwise it stays out of the market. If $x_1\geq\frac{3}{4}$, the entrant enters the market if and only if $F\leq\frac{1}{8}$, otherwise it stays out of the market. This suggests that, regardless of the level of data acquisition by the incumbent firm, the entrant decides to enter the market if the entry cost F is sufficiently low, i.e., $F<\frac{1}{8}$. However, for higher entry costs, the entrant's decision might be contingent on the incumbent's investment in data acquisition for personalized pricing.

4.4. Period 1: information acquisition decisions

As previously mentioned, at the beginning of the game, the incumbent lacks data on consumers, and thus it sets a uniform price. However, once consumers make their purchasing decisions, the incumbent can obtain perfect information about the preferences of the consumers it served, which are located in the interval $\left[0,x_1\right]$. This data is then used in period 2 to price discriminate and influence entry. Consequently, the incumbent takes into account that its initial pricing decision determines the share of served customers and, thus, the size of its database. This, in turn, will impact its future pricing behavior and the profits the entrant can achieve upon entry. By serving more consumers today (i.e., increasing x_1), the incumbent can expand its list of perfectly identified customers and commit to playing more aggressively in the future in the event of entry. Based on the level of entry costs, we can consider the following possibilities.

Remark 3 *(Blockaded entry).* If $F>\frac{1}{8}$ the incumbent firm has no incentive to worry about entry and can act as an unconstrained monopolist.

Entry is considered blocked if it is not profitable even when the incumbent behaves as an unconstrained monopolist. According to Proposition 2, when personal data can be used as an input for price personalization, an unconstrained monopolist chooses $\underline{x}_1^{pp}\geq\frac{5}{6}>\frac{3}{4}$ when v is low (i.e., $\frac{3}{2}\leq v\leq 2$) and $\overline{x}_1^{pp}=1$ when $v>2$. Since an unconstrained monopolist always creates a database with a size above $\frac{3}{4}$, entry will not be profitable for any entry cost above $\frac{1}{8}$. As a result, the incumbents' advantage in using consumer data for PP is strong enough to leave the entrant out of the market for any entry cost above $\frac{1}{8}$. In other words, the incumbent will have no incentive to create a larger customer database to deter entry. Consequently, entry deterrence does not occur in equilibrium. However, in Section 5, we will discuss how entry deterrence may arise in equilibrium if the incumbent firm anticipates an information sharing obligation.

Remark 4 *(Entry is inevitable).* When $F\leq\frac{1}{8}$ the entrant always finds it profitable to enter the market. In this scenario the incumbent adjusts its data acquisition behavior to accommodate entry.

Considering Proposition 3, we can conclude that if firm B enters and the incumbent's initial data acquisition lies within the interval of $x_1\in\left[\frac{3}{4},1\right]$, then the incumbent's second-period profit becomes a constant value of $\frac{9}{16}$. On the other hand, its first-period profit can be expressed as p_1x_1 with $x_1=v-p_1$. Alternatively, we can also express the first-period profit as $\left(v-x_1\right)x_1$. As a result, in the beginning of the game, the incumbent aims to maximize its overall profit $\overline{\Pi}_A^{pp,u}$ by choosing the optimal value for x_1, where

$$\overline{\Pi}_A^{pp,u}=\left(v-x_1\right)x_1+\frac{9}{16}. \tag{11}$$

When $v>2$ the incumbent optimal choice in period 1 is to set $p_1=v-1$ and $x_1=1$.

Consider now the case where the incumbent can only collect data on consumers located at $x\in\left[0,x_1\right]$ with $x_1<\frac{3}{4}$. Proposition 3 demonstrates that when firm B enters, the incumbent's second-period profit is $\frac{1}{2}+\frac{1}{9}x_1\left(6-7x_1\right)$, while its first-period profit is $\left(v-p_1\right)p_1$. Therefore, in the beginning of the game, the incumbent maximizes its overall profits $\underline{\Pi}_A^{pp,u}$ by selecting the optimal value of p_1 (or equivalently, x_1), with:

$$\underline{\Pi}_A^{pp,u}=\left(v-x_1\right)x_1+\left(\frac{1}{2}+\frac{1}{9}x_1\left(6-7x_1\right)\right). \tag{12}$$

The first-order condition (FOC) with respect to x_1 yields $x_1=\frac{9}{32}v+\frac{3}{16}$. Using this, we can obtain the next proposition straightforwardly.

Proposition 4. *When the incumbent firm can use data collected from its first-period customers as an input for PP in the second-period, and the entry cost is sufficiently low* ($F\leq\frac{1}{8}$) *then in the SPNE:*

(i) If $v > 2$, the incumbent optimal decision is to cover the whole market in period 1, by charging $\overline{p}_1^{EA} = v - 1$ and $\overline{x}_1^{EA} = 1$. Firm B enters and both firms' second-period prices are:

$$\overline{p}_A^{pp,u}(x) = \begin{cases} \frac{3}{2} - 2x & if \quad x \leq \frac{3}{4} \\ 0 & if \quad x \geq \frac{3}{4} \end{cases} \quad and \quad \overline{p}_B^{pp,u} = \frac{1}{2}, \tag{13}$$

Overall profits for each firm are:

$$\overline{\Pi}_A^{pp,u} = v - \frac{7}{16} \quad and \quad \overline{\pi}_B^{pp,u} = \frac{1}{8} - F. \tag{14}$$

(ii) If $\frac{3}{2} \leq v \leq 2$, the incumbent optimal decision under entry accommodation is to charge $\underline{p}_1^{EA} = \frac{1}{32}(23v - 6)$ and serve all customers located at $\left[0, \underline{x}_1^{EA}\right]$ with $\underline{x}_1^{EA} = \frac{9}{32}v + \frac{3}{16}$ and $\frac{39}{64} \leq \underline{x}_1^{EA} \leq \frac{3}{4}$. Firm B enters and second-period prices are:

$$\underline{p}_A^{pp,u}(x) = \begin{cases} \frac{3}{16}(10 - v) - 2x & if \quad x \leq \frac{3}{32}(10 - v) \\ 0 & if \quad x \geq \frac{3}{32}(10 - v) \end{cases}, \tag{15}$$

$$\underline{p}_A^{pp,u} = \frac{3}{8}(2 - v) \quad and \quad \underline{p}_B^{pp,u} = \frac{1}{16}(14 - 3v), \tag{16}$$

each firm overall profits are:

$$\underline{\Pi}_A^{pp,u} = \frac{9}{64}v^2 + \frac{3}{16}v + \frac{9}{16}, \tag{17}$$

$$\underline{\pi}_B^{pp,u} = \frac{9}{512}v^2 - \frac{21}{128}v + \frac{49}{128} - F. \tag{18}$$

In order to prove the expression obtained for overall equilibrium profits defined above we simply need to substitute x_1 by $\underline{x}_1^{EA}$ into equations (9), (11) and (12).

It is important to note that $\underline{x}_1^{EA}$ increases with v. Specifically, when $v = \frac{3}{2}$, $\underline{x}_1^{EA} = \frac{39}{64} \simeq 0.61$, and when $v = 2$, $\underline{x}_1^{EA} = \frac{3}{4}$. Therefore, under entry accommodation and $\frac{3}{2} \leq v \leq 2$, the incumbent chooses to gather data on consumers located in the interval $\left[0, \underline{x}_1^{EA}\right]$ where $\underline{x}_1^{EA} \in \left[\frac{39}{64}, \frac{3}{4}\right]$. Consumers located in the interval $\left[0, \underline{x}_1^{EA}\right]$ purchase from firm A at the personalized price $\underline{p}_A^{pp,u}(x)$, while consumers located in the interval $\left[\underline{x}_1^{EA}, \widetilde{x}\right]$ purchase from firm A at a price of $\underline{p}_A^{pp,u}$. Consumers located in the interval $\left[\widetilde{x}, 1\right]$ purchase from firm B at price of $\underline{p}_B^{pp,u}$. Here $\widetilde{x} = \frac{3}{32}(v + 6)$. Consequently, when v is low, the second-period profits of firms A and B are, respectively:

$$\underline{\pi}_{A2}^{pp,u} = -\frac{63}{1024}v^2 + \frac{27}{256}v + \frac{153}{256} \tag{19}$$

$$\underline{\pi}_B^{pp,u} = \frac{9}{512}v^2 - \frac{21}{128}v + \frac{49}{128} - F. \tag{20}$$

Proposition 4 highlights that when consumers' willingness to pay is sufficiently high (i.e., $v > 2$), the incumbent serves the entire market, behaving as a monopolist with no threat of entry. If entry does occur, in the second period, the incumbent cannot fully exploit the information it has collected because it is unable to sell to customers located in the interval $\left[\frac{3}{4}, 1\right]$. More interesting results arise when v is low.

Remark 5. When consumers' willingness to pay is low (i.e., $\frac{3}{2} \leq v \leq 2$), entry accommodation calls for underinvestment in consumer data acquisition–the incumbent adopts the 'puppy dog strategy' in period 1.

The proof of this result is straightforward. We only need to compare the incumbent information acquisition under entry accommodation $\underline{x}_1^{EA}$ with its decision when acting as an unconstrained (or myopic) incumbent, given by $x_1^M = \frac{1}{3}(v + 1)$. Note that x_1^M is an increasing function of v. When $v = \frac{3}{2}$ then $x_1^M = \frac{5}{6} \simeq 0.83$, when $v = 2$, $x_1^M = 1$. It follows directly that $\underline{x}_1^{EA} - x_1^M < 0$. Therefore, under entry accommodation, as investment in consumer data makes the incumbent look more aggressive, it prefers to underinvest in data acquisition to appear less aggressive in the pricing game of period 2. This is achieved by quoting a higher price in period 1 ($\underline{p}_1^{EA} > \underline{p}_M^{pp}$), serving fewer consumers in that period, and obtaining perfect information about a lower proportion of customers. By doing so, when entry is inevitable, the incumbent prices less aggressively under (PP,U).

Proposition 5. *When $\frac{3}{2} \leq v \leq 2$, overall consumer surplus and welfare is, respectively equal to $\underline{CS}^{pp,u} = \frac{153}{2048}v^2 + \frac{563}{512}v - \frac{623}{512}$ and $\underline{W}^{pp,u} = \frac{477}{2048}v^2 + \frac{575}{512}v - \frac{139}{512} - F$. When $v > 2$, overall consumer surplus and welfare equals $\overline{CS}^{pp,u} = v - \frac{1}{2}$ and $\overline{W}^{pp,u} = 2v - \frac{13}{16} - F$.*

Proof. See the Appendix. □

Personalized Prices and abuse of dominance: Abuse of dominance are any anti-competitive business practices, in which a dominant firm may engage in order to maintain or increase its position in the market. In most jurisdictions, qualifying a conduct as an abuse of dominance requires three fundamental conditions to be met: (1) the offender must be dominant in the relevant market; (2) the conduct must fit a generally accepted category of abuse; and (3) the conduct must be shown to have anti-competitive effects that are not counter-balanced by efficiencies. Firstly, the fact that provisions on abuse of dominance only apply to dominant firms is consistent with the idea that, for a firm to be able to unilaterally harm the competitive process, it must have a degree of market power in the relevant market. Secondly, as dominance is in itself not unlawful, but only its abuse, it is necessary to identify an anti-competitive conduct in order to establish an infringement. Competition authorities can only establish an infringement if they identify an anti-competitive behavior belonging to one of the two following categories of abuse: exclusionary and exploitative. Following Akman (2009) " '[E]xclusionary' abuses refer to those practices of a dominant firm which seek to harm the competitive position of its competitors or to exclude them from the market, whereas 'exploitative' abuses can be defined as attempts by a dominant firm to use the opportunities provided by its market strength in order to harm customers directly."

Our analysis indicates that under certain circumstances, it may be possible to qualify personalized pricing as an *exclusionary* abuse. This is particularly true when a dominant firm uses its data advantage to target customers who prefer competitors' products with lower prices, with the aim of foreclosing the market. By employing such tactics, the incumbent is able to maintain its dominant position, resulting in serious harm to both competition and consumer welfare. In conclusion, in markets relatively well represented by the features of this model, policy intervention is needed to promote competition and prevent consumer harm. While banning personalized pricing can restore competition at a wide range of entry costs, it can be challenging for public agencies to monitor whether a dominant firm is complying with this requirement. The dominant firm may use tactics such as setting a uniform listed price for their product while secretly providing targeted discounts to consumers based on their willingness to pay, making it difficult to detect any anti-competitive behavior.

Building on the existing discourse surrounding data openness and information sharing policies, the following section aims to examine the market conditions under which such policy interventions can effectively unlock competition and ultimately benefit consumers.

5. Information sharing

In the rapidly growing digital economy, data has been referred to as the 'new gold'. A company that can increase the volume and quality of its data more quickly than its competitors not only gains a competitive advantage in different dimensions (e.g. pricing, advertising, innovation, etc.) but also strengthens its market position. The lack of alternative

data sources available to new competitors, combined with a dominant market position of a data holder[22] and its potential to abuse this position in order to limit competition, has been previously discussed as a significant risk to both competition and consumer welfare.

While competition law has been a crucial aspect of European economic policy and legislation for decades, its application to the digital economy and digital data is not always straightforward. The main provisions of competition law can be found directly in the Treaty on the Functioning of the European Union (TFEU) itself (mainly in Articles 101 and 102). The application of these rules to the digital economy and to digital data, which are also within the EU's competencies as a part of the (digital) single market, is however not always easy.

As mentioned in the Introduction, numerous studies conducted by competition authorities and expert panels have emphasized the significance of data openness policy interventions, including the Digital Competition Expert Panel in the UK (2019) and the Stigler Committee on Digital Platforms in the US (2019). These studies argue that information sharing can foster competition by enabling new market entrants to attract users more easily and potentially reduce barriers to entry associated with data access, particularly in markets where individual-level data holds value. In addition, the European legislative framework has been expanded and refined extensively, and is still undergoing further fine-tuning. This is visible in the legislative package that was proposed as a part of the European Data Strategy, including notably the proposed *Data Act* and the *Digital Markets Act*[23] (which will enter in to force in May, 2023), and the adopted *Data Governance Act* and *Digital Services Act*.

On 23 February 2022 the European Commission published its proposal for a regulation on harmonized rules on fair access to and use of data (The 'Data Act Proposal').[24] The Data Act aims to stimulate business-to-business (B2B) data sharing in full respect of European rules (e.g. GDPR).[25,26] It covers the following main contexts[27]: (i) mandatory access to data (generated by connected devices, held by those that are subject to data sharing obligations by law) by consumers, businesses and public authorities; (ii) data sharing when small and medium-sized enterprises (SMEs) are involved; and (iii) data processing services.[28] Chapter III of the Data Act Proposal establishes detailed rules for the terms and conditions for data holders to make data available if they are required to do so not only under the Data Act but also under any other subsequently adopted EU or member state legislation.[29]

While the future data-sharing legislation across the EU is still in the proposal stage and under discussion, it is crucial to understand how an obligation to share information can impact the incumbents' data acquisition, market entry decisions, and consumer welfare.

In line with this, in this section we consider a hypothetical scenario where a public agency imposes a mandatory information-sharing remedy after the incumbent has made its data acquisition decision and just before entry decisions are made. In this case, if the entrant enters the market it bears the entry cost F and gains access to the rival's information. Under information sharing both firms can set personalized prices $\widehat{p}_i^{pp,pp}(x)$ for consumers located at $x \in [0, x_1]$, and a uniform price $\widehat{p}_i$ for the group of anonymous consumers, $i = A, B$, located at $x \in [x_1, 1]$. The two segments are independent.

As previously discussed, the risk of competition harm in our model is particularly significant in markets with intermediate to high entry costs, where $\frac{1}{8} < F \leq \frac{1}{4}$. Therefore, public intervention is particularly crucial in markets with entry costs within this range. The following proposition summarizes the equilibrium prices of both firms if entry occurs under information sharing and both firms employ personalized prices. Suppose $x_1 > \frac{1}{2}$, which will be the case in equilibrium.

Proposition 6. *Suppose the incumbent shares its information about consumers located at $[0, x_1]$ with the entrant. In equilibrium, each firm's equilibrium price schedule is:*

(i) When $\frac{1}{2} \leq x_1 \leq \frac{3}{4}$, firms A and B quote personalized prices for consumers located $x \in [0, x_1]$:

$$\widehat{p}_A^{pp,pp}(x) = \begin{cases} 1-2x & if \quad x \leq \frac{1}{2} \\ 0 & if \quad x \geq \frac{1}{2} \end{cases}, \quad and$$
$$\widehat{p}_B^{pp,pp}(x) = \begin{cases} 2x-1 & if \quad x \geq \frac{1}{2} \\ 0 & if \quad x \leq \frac{1}{2} \end{cases}, \tag{21}$$

while both firms charge a uniform price for consumers located at $[x_1, 1]$:

$$\widehat{p}_A = 1 - \frac{4}{3}x_1 \quad and \quad \widehat{p}_B = 1 - \frac{2}{3}x_1. \tag{22}$$

The profits for each firm are:

$$\widehat{\pi}_A^2 = \frac{8}{9}x_1^2 - \frac{4}{3}x_1 + \frac{3}{4} \quad and \quad \widehat{\pi}_B = \frac{11}{9}x_1^2 - \frac{5}{3}x_1 + \frac{3}{4} - F.$$

(ii) When $\frac{3}{4} < x_1 \leq 1$, the personalized price schedules for consumers located at $x \in [0, x_1]$ are the same as in (i). The uniform price for consumers located at $[x_1, 1]$ is $\widehat{p}_A = 0$ and $\widehat{p}_B = 2x_1 - 1$. The profits for each firm are:

$$\widehat{\pi}_A^2 = \frac{1}{4} \quad and \quad \widehat{\pi}_B = x_1(2 - x_1) - \frac{3}{4} - F.$$

Proof. See the Appendix. □

As a consequence, we can establish the following result.

Remark 6. If $x_1 \leq \frac{3}{4}$, the entrant enters the market so long as $F \leq \frac{11}{9}x_1^2 - \frac{5}{3}x_1 + \frac{3}{4}$, otherwise it prefers to stay out. If $x_1 \geq \frac{3}{4}$, the entrant enters the market if $F \leq x_1(2 - x_1) - \frac{3}{4}$, otherwise it stays out. With information sharing entry is blockaded as long as $F > \frac{1}{4}$.

[22] According to the Data Act Proposal, "Data holders," are enterprises having a "right or obligation" or the "ability" to make data available to data recipients in the EU. The exact scope of the "data holder" definition is unclear, but it is intended to be very broad. This suggests that a dominant firm that has been accumulating data can be referred as a data holder.

[23] In particular, article 6 (i) of the Digital Markets Act concerns data sharing between dominant platforms and business users.

[24] See: https://www.ibanet.org/the-data-act-new-EU-rules-for-data-sharing#_edn2.

[25] The new rules will apply to a wide variety of actors: manufacturers and providers of connected products and services placed on the market in the EU; users of such products and services (both individuals and legal persons); data holder making data available to data recipients in the EU; data recipients in the EU to whom data are made available; public sector bodies and EU institutions, agencies or bodies; and providers of data processing services offered in the EU. Micro, small and medium-sized companies are exempted from some obligations.

[26] Notwithstanding competition and consumer protection agencies often share similar objectives—to maximize consumer welfare or a broader measure of total welfare—the two can conflict with each other (Jin and Wagman, 2021). While data openness will tackle the key barrier to entry in digital markets, promoting competition, it can harm consumer privacy.

[27] The First Presidency compromise text for the Data Act, was presented by the Czech Presidency of the Council of the European Union in July 2022.

[28] The document provides additional clarification on the types of data covered, which includes, among others, any private sector data subject to statutory data sharing obligations.

[29] Specifically, data holder companies must make the data available to third parties in a fair, reasonable, and non-discriminatory manner and with transparency. They may charge a reasonable fee as compensation for data access, covering the necessary costs of data reproduction, dissemination via electronic means, and storage, but not data collection or production. In case of micro, small of medium-sized enterprises, they cannot exceed the direct costs incurred for making the data available. The exact scope of these obligations will depend on the scope of future data-sharing legislation across the EU.

In the following sections, we will discuss two cases. In the first case, the incumbent does not anticipate a policy intervention for data sharing. Therefore, at the beginning of the game, it invests in data acquisition as if such an intervention would never happen. In the second case, the incumbent anticipates this intervention, which allows us to examine the impact of information-sharing obligations on the incumbent's initial data acquisition decisions.

5.1. Incumbent does not anticipate data sharing obligations

Since data-sharing legislation in the EU is still in the proposal stage and subject to discussion, it is reasonable to assume that many incumbent firms have been accumulating data without anticipating any future data-sharing obligations. Therefore, it is relevant to explore the scenario where incumbent firms take a myopic approach and invest in data as if no intervention will occur. In this section, we make this assumption.

As we are discussing policy intervention in markets where entry costs are between $\frac{1}{8}$ and $\frac{1}{4}$, from our previous analysis, we know from our previous analysis that if $F > \frac{1}{8}$, the incumbent acts as an unconstrained monopolist, gathering perfect information about consumers located on the interval $\left[0, x_1^{pp}\right]$, with $\underline{x}_1^{pp} = \frac{1}{3}(v+1)$ if $\frac{3}{2} \leq v \leq 2$, while $\overline{x}_1^{pp} = 1$ if $v > 2$. Let us denote an incumbent who is myopic with regard to an information-sharing remedy as "m".

Remark 7. If the incumbent does not anticipate an information sharing obligation, its data acquisition in period 1 is denoted as x_1^m, which is given by $x_1^m = \frac{1}{3}(v+1)$ if v is low; and $x_1^m = 1$ if v is high.

When v is high, and after policy intervention, firm B decides to enter. Both firms then have perfect information about the location of all consumers in the market. According to Proposition 6, the pricing game in stage 2 of period 2 is similar to Thisse and Vives (1988), which means that each firm's equilibrium profits are $\widehat{\pi}_A^{pp,pp} = \frac{1}{4}$ and $\widehat{\pi}_B^{pp,pp} = \frac{1}{4} - F$, with $F \leq \frac{1}{4}$. In the case where $\frac{3}{2} \leq v \leq 2$ and $x_1^m = \frac{1}{3}(v+1)$, it follows that $\frac{5}{6} \leq x_1^m \leq 1$. Under information sharing, both firms will have perfect information about consumers located on the interval $\left[0, x_1^m\right]$, but no information about the remaining consumers, who are located on the interval $\left[x_1^m, 1\right]$. Using Proposition 6 and the fact that $x_1^m > \frac{3}{4}$, we obtain each firm's second-period profits: $\widehat{\pi}_A^{pp,pp} = \frac{1}{4}$ and $\widehat{\pi}_B^{pp,pp} = \frac{4}{9}v - \frac{1}{9}v^2 - \frac{7}{36} - F$.

As a result of a mandatory information sharing, the incumbent firm experiences a decrease in profits, while the entrant sees an increase in profits compared to the scenario where information is not shared (PP, U). This implies that if information sharing is not mandatory, the incumbent firm may have a stronger incentive to withhold access to its customers' data, even if offered a reasonable fee in exchange. Analyzing firm B's entry decision in the context of an unanticipated information sharing intervention by the incumbent yields the following result.

Proposition 7. *If the incumbent does not anticipate an information sharing obligation, the entrant decides to enter so long as $F \leq \widehat{F}$ with $\widehat{F} = \frac{4}{9}v - \frac{1}{9}v^2 - \frac{7}{36}$, when $\frac{3}{2} \leq v \leq 2$; and $\widehat{F} = \frac{1}{4}$ when $v \geq 2$.*

This result demonstrates that mandatory information sharing can be an effective policy tool for promoting competition in markets where the incumbent is not anticipating such an intervention. Specifically, it increases the likelihood of entry in markets with entry costs falling in the range $F \in \left]\frac{1}{8}, \widehat{F}\right]$, with $\widehat{F} \in \left[\frac{2}{9}, \frac{1}{4}\right]$ for $\frac{3}{2} \leq v \leq 2$; and $\widehat{F} = \frac{1}{4}$ for $v \geq 2$.[30]

[30] If for instance $v = \frac{3}{2}$, $\overline{F} = \frac{2}{9} \simeq 0.222$. While entry would be blocked with no policy intervention, mandatory data sharing makes it inevitable as long as $F \leq 0.222$. When $v > 2$, entry occurs as long as $F \leq 0.25$.

In markets where consumers' reservation value is high, the likelihood of entry is higher.

Let IS denote information sharing. As the incumbent is myopic with regard to any policy intervention it acts as an unconstrained monopolist in the beginning of the game. The next proposition summarizes the main findings in terms of profits, consumer surplus and welfare.

Proposition 8. *Suppose the incumbent does not anticipate the imposition of an information sharing obligation. When $\frac{3}{2} \leq v \leq 2$, $\underline{\pi}_A^{IS,m} = \frac{2}{9}v^2 + \frac{1}{9}v + \frac{5}{36}$; $\underline{\pi}_B^{IS,m} = \frac{4}{9}v - \frac{1}{9}v^2 - \frac{7}{36} - F$; $\underline{CS}^{IS,m} = \frac{1}{6}v^2 + \frac{2}{3}v - \frac{1}{4}$ and $\underline{W}^{IS,m} = \frac{5}{18}v^2 + \frac{11}{9}v - \frac{11}{36} - F$. When $v > 2$, $\overline{CS}^{IS,m} = v - \frac{1}{4}$; $\overline{\pi}_A^{IS,m} = v - \frac{3}{4}$; $\overline{\pi}_B^{IS,m} = \frac{1}{4} - F$; thus $\overline{W}^{IS,m} = 2v - F - \frac{3}{4}$.*

Proof. See the Appendix. □

5.2. Incumbent anticipates information sharing obligations

In this section it is assumed that in the beginning of the game the incumbent anticipates being required to share the data it collects about x_1 customers with a potential entrant in the next period. This analysis is important because data-sharing policies are expected to become more prevalent in many countries, particularly in the digital sector, where large companies gather substantial amounts of user data. If a new regulation or policy mandates data-sharing with new entrants, it is crucial to evaluate *how* this remedy could impact the incumbent's data collection and thereby, the room for competition with the entrant.

Again we look at markets with entry costs between $\frac{1}{8}$ and $\frac{1}{4}$, where information sharing policies are particularly important to promote competition and prevent consumer harm. In this range, entry depends on the incumbent's initial data acquisition choice. Since the incumbent behaves strategically, it can either choose to *accommodate* entry by selecting $x_1^{s,a}$ or it can *deter entry by choosing* $x_1^{s,d}$. We refer to the strategic incumbent as s. Based on Proposition 6 and Remark 6, we can establish the following Proposition.

Proposition 9. *When the incumbent firm anticipates information sharing obligations, the following equilibrium acquisition decisions are observed:*

(i) For small entry costs falling within the range of $\frac{1}{8} < F \leq \frac{2}{11}$, the incumbent prefers to accommodate entry by choosing $x_1^{s,a} = \frac{v}{2}$ when $\frac{3}{2} \leq v \leq 2$ (with $\frac{3}{4} \leq x_1^{s,a} \leq 1$), and $x_1^{s,a} = 1$ when $v \geq 2$.

(ii) For intermediate entry costs that satisfy $\frac{2}{11} < F < \frac{3}{16}$, the incumbent chooses to deter entry by reducing its data acquisition to $x_1^{s,d} = \frac{15}{22} + \frac{3}{11}\sqrt{11F-2}$, where $x_1^{s,d} < \frac{3}{4}$ for every v (with $x_1^{s,d} < x_1^{s,a}$).

(iii) For higher entry costs, within the range of $\frac{3}{16} \leq F \leq \frac{1}{4}$, regardless of v, the incumbent chooses to deter entry by reducing its data acquisition to $x_1^{s,d} = \frac{3}{4}$ (with $x_1^{s,d} < x_1^{s,a}$).

Proof. See the Appendix. □

Let us compare the data acquisition decisions made by a myopic and a strategic incumbent. Consider first the range of entry costs that satisfy the condition $\frac{1}{8} < F \leq \frac{2}{11}$. A strategic incumbent takes into account that its second-period profits under (PP,PP) are constant for every $x_1 > \frac{3}{4}$. Thus, under entry accommodation it chooses x_1 to maximize its first-period profits. Specifically, it selects $x_1^{s,a} = \frac{v}{2}$ when v is low and $x_1^{s,a} = 1$ when v is high. As a result, compared to the myopic scenario, a strategic incumbent *reduces* its acquisition data in period 1 ($x_1^{s,a} < x_1^m$) when v is low. However, both types of incumbents decide to serve the whole market in period 1 when v is high (i.e., $x_1^{s,a} = x_1^m = 1$).

When entry costs are intermediate to high, specifically falling within the range of $\frac{2}{11} < F \leq \frac{1}{4}$, a strategic incumbent would choose to deter entry by setting its data acquisition $x_1^{s,d}$ below $\frac{3}{4}$. Proposition 9 shows

that for $\frac{2}{11} < F < \frac{3}{16}$, $x_1^{s,d} = \frac{15}{22} + \frac{3}{11}\sqrt{11F-2}$, while for $\frac{3}{16} \leq F \leq \frac{1}{4}$, $x_1^{s,d} = \frac{3}{4}$ for every value of v. In contrast, a myopic incumbent would choose $x_1^m > \frac{3}{4}$ for every $\frac{3}{2} \leq v < 2$ and $x_1^m = 1$ for $v > 2$.

Compared to the myopic case, a strategic incumbent reduces its data acquisition under entry deterrence by selecting a value of $x_1^{s,d}$ below $\frac{3}{4}$, thereby lowering the profitability of the entrant under (PP,PP). It is also important to note that unlike situations without policy intervention or where the incumbent does not anticipate information sharing, a strategic incumbent no longer serves the entire market in period 1 under entry deterrence when the value of v is high. This means that in addition to the negative impact on entry, the anticipation of this policy will also exclude some consumers from the market in period 1, leading to significant adverse effects on consumer surplus and overall welfare.

Overall, in this scenario, the effectiveness of mandatory data sharing policies in promoting entry is limited to situations where entry costs are low, specifically when $\frac{1}{8} \leq F \leq \frac{2}{11}$. This suggests that while mandatory data sharing policies have the potential to promote competition for the benefit of consumers, they may not be effective in all situations, particularly in markets with intermediate to high entry costs, where incumbents anticipate their implementation and act strategically. The next proposition summarizes the main findings in terms of profits, consumer surplus and welfare.

Proposition 10. *If the incumbent anticipates an information sharing obligation:*

(i) When entry costs are sufficiently low (i.e., $\frac{1}{8} < F \leq \frac{2}{11}$) and v is low, the incumbent accommodates by choosing $x_1^a = \frac{v}{2}$. In this case, $\underline{\pi}_A^{IS,a} = \frac{1}{4}\left(v^2+1\right)$; $\underline{\pi}_B^{IS,a} = \frac{1}{4}(v-1)(3-v) - F$; $\underline{CS}^{IS,a} = \frac{7}{24}\left(8v - v^2 - 6\right)$, and $\underline{W}^{IS,a} = \frac{1}{24}v(80-7v) - \frac{9}{4} - F$. When v is high, the incumbent accommodates entry by choosing $x_1^a = 1$, thus $\overline{\pi}_A^{IS,a} = v - \frac{3}{4}$; $\overline{\pi}_B^{IS,a} = \frac{1}{4} - F$, $\overline{CS}^{IS,a} = v - \frac{1}{4}$ and $\overline{W}^{IS,a} = 2v - \frac{3}{4} - F$.

(ii) For intermediate entry costs that satisfy $\frac{2}{11} < F \leq \frac{1}{4}$, the incumbent chooses to deter entry by choosing to serve x_1^d consumers in period 1. When $\frac{2}{11} < F \leq \frac{3}{16}$, $x_1^d = \frac{15}{22} + \frac{3}{11}\sqrt{11F-2} < \frac{3}{4}$. Therefore, $\pi_A^{IS,d} = \frac{37}{22}v - \frac{27}{22}F + \frac{3}{11}v\sqrt{11F-2} - \frac{69}{242}\sqrt{11F-2} - \frac{767}{968}$; $\pi_B^{IS,d} = 0$; $CS^{IS,d} = \frac{9}{11}F + \frac{12}{121}\sqrt{11F-2} + \frac{65}{484}$ and $W^{IS,d} = \frac{37}{22}v - \frac{9}{22}F + \frac{3}{11}v\sqrt{11F-2} - \frac{45}{242}\sqrt{11F-2} - \frac{637}{968}$. When $\frac{3}{16} < F \leq \frac{1}{4}$, we obtain $x_1^d = \frac{3}{4}$, thus $\pi_A^{IS,d} = \frac{7}{4}v - \frac{35}{32}$, $\pi_B^{IS,d} = 0$, $CS^{IS,d} = \frac{5}{16}$ and $W^{IS,d} = \frac{7}{4}v - \frac{25}{32}$.

Proof. See the Appendix. □

6. Welfare issues

This section analyzes the profits (π_i, $i = A, B$), consumer surplus (CS) and social welfare (W) based on our previous analysis and the precise expressions for profits, consumer surplus, and welfare presented above. To facilitate the discussion, we will consider two numerical examples. Table 1 presents our main results for the case where v is low (i.e., $v = 1.8$). Table 2 presents our main results for the case where v is high (i.e., $v = 3$). Proposition 11 summarizes the welfare results when there is no policy intervention.

Proposition 11. *If there is no policy intervention:*

(i) In markets with low entry costs ($F \leq \frac{1}{8}$) and with low reservation values $\left(\frac{3}{2} \leq v \leq 2\right)$, in comparison to monopoly, entry significantly boosts consumer surplus but reduces social welfare due to the incumbent's underinvestment in consumer data, which leaves more consumers out of the market in period 1. When v is sufficiently high ($v > 2$), entry boosts consumer surplus and overall welfare.

(ii) In markets where entry is blocked due to high entry costs $\left(F > \frac{1}{8}\right)$, the use of data by a monopoly firm for price discrimination harms consumers at the benefit of profits, when compared to a ban on personalized pricing. However, if consumers' reservation value is low, monopoly price discrimination can boost social welfare due to the demand expansion effect.

Proof. Since the expressions for profits, consumer surplus, and welfare are already provided above, proving the proposition is straightforward.

The following proposition summarizes the main consumer and welfare results under two types of policy intervention: a ban on price discrimination and a mandatory information sharing remedy.

Proposition 12. *With policy intervention:*

(i) When $\frac{1}{4} < F \leq \frac{1}{2}$, a policy of banning the use of data for price discrimination restores competition in the market, resulting in an increase in consumer surplus and welfare compared to the monopoly case. In this case, a mandatory information sharing does not promote competition.

(ii) If the incumbent does not anticipate a mandatory information sharing obligation, then granting the entrant access to data for price discrimination restores competition for entry costs $\frac{1}{8} < F \leq \frac{1}{4}$. As a result, consumer surplus and aggregate welfare increase at the expense of profits. Moreover, the gains in consumer welfare are greater under an information sharing policy than under a ban on price discrimination.

(iii) If the incumbent anticipates an information sharing obligation and entry costs are sufficiently low ($\frac{1}{8} < F \leq \frac{2}{11}$), it prefers to accommodate entry. In this case, the information sharing remedy restores competition at the benefit of consumer surplus and aggregate welfare.

(iv) If the incumbent anticipates an information sharing obligation and entry costs are intermediate to high ($\frac{2}{11} < F \leq \frac{1}{4}$), it prefers to deter entry. This remedy does not promote competition and can lead to a decrease in consumer surplus and welfare, even when compared to a monopoly scenario with no policy intervention.

Proof. Since the expressions for consumer surplus and welfare are already provided above, proving the proposition is straightforward. □

Propositions 11 and 12 provide valuable insights to policymakers regarding the potential effects of two policy interventions, namely, (i) banning the use of data for price discrimination, and (ii) mandating information sharing, in specific market scenarios where a dominant firm has exclusive access to consumer data for price personalization. In the following discussion we prioritize consumer welfare as the appropriate perspective to guide competition policy. We distinguish between markets where the incumbent's exclusive access to data does not block entry and markets where the incumbent's data advantage can raise a barrier to entry.

Exclusive data access raises no barrier to entry

When entry costs are sufficiently small ($0 \leq F \leq 1/8$), the presence of competition from the new entrant benefits consumers in comparison to a monopoly market. Proposition 11 highlights that consumers as a whole are better off under (PP,U) than under (U,U). Based on our previous computations it is easy to conclude that $CS^{pp,u} - CS^{u,u} > 0$ for any $v \geq \frac{3}{2}$. (The reverse happens to social welfare $W^{pp,u} - W^{u,u} < 0$ for any $v \geq \frac{3}{2}$.) As explained before, PP benefits some consumers, while leaves others worse off. When the incumbent is not allowed to use its data for PP, in case of entry, the price regime is (U,U) and both firms charge $p^{u,u} = 1$. When v is low and entry is inevitable, entry accommodation leads the incumbent to 'underinvest in data acquisition' (i.e., $\underline{x}_1^{EA} \leq \frac{3}{4}$). Proposition 3 shows that a subset of customers will pay higher prices under (PP,U), while others will pay lower prices. Specifically, customers with high willingness to pay for the incumbent, located in the interval $\left[0, \frac{1}{2} - \frac{1}{3}\underline{x}_1^{EA}\right[$ purchase again from the incumbent in period 2 at a price higher than 1. All other consumers pay lower prices under (PP,U) than under (U,U). When v is high then $\underline{x}_1^{EA} \geq \frac{3}{4}$. In period 2, consumers located on the interval $\left[0, \frac{1}{4}\right[$ purchase the good from the incumbent at a

Table 1
$v = 1.8$.

Pricing	π_A	π_B	CS	W
U	1.62	0	0.81	2.43
PP	2.107	0	0.438	2.544
(U,U) if $F \leq \frac{1}{2}$	1.31	$0.5 - F$	0.955	$2.765 - F$
(PP,U) if $F \leq \frac{1}{8}$	1.356	$0.144 - F$	1.005	$2.505 - F$
Information sharing obligation is not anticipated				
(PP,PP) if $\frac{1}{8} \leq F \leq \widehat{F} \leq \frac{1}{4}$	1.059	$0.246 - F$	1.490	$2.795 - F$
PP if $F > \widehat{F}$	2.107	0	0.438	2.544
Information sharing obligation is anticipated				
(PP,PP) if $\frac{1}{8} \leq F \leq \frac{2}{11}$	1.06	$0.24 - F$	1.505	$2.805 - F$
PP if $\frac{2}{11} < F \leq \frac{3}{16}$	$2.23 - 1.23F$ $+0.21\sqrt{11F-2}$	0	$\frac{9}{11}F + \frac{65}{484}$ $+\frac{12}{121}\sqrt{11F-2}$	$2.37 - 0.41F$ $+0.30\sqrt{11F-2}$
PP if $\frac{3}{16} < F \leq \frac{1}{4}$	2.06	0	0.313	2.369

Table 2
$v = 3$.

Pricing	π_A	π_B	CS	W
U	4.0	0	1	5.0
PP	4.5	0	0.5	5.0
(U,U) if $F \leq \frac{1}{2}$	2.5	$0.5 - F$	2.25	$5.25 - F$
(PP,U) if $F \leq \frac{1}{8}$	2.56	$0.125 - F$	2.5	$5.19 - F$
Information sharing obligation is not anticipated				
(PP,PP) if $\frac{1}{8} \leq F \leq \frac{1}{4}$	2.25	$0.25 - F$	2.75	$5.25 - F$
PP if $F > \frac{1}{4}$	4.5	0	0.5	5.0
Information sharing obligation is anticipated				
(PP,PP) if $\frac{1}{8} \leq F \leq \frac{2}{11}$	2.25	$0.25 - F$	2.75	$5.25 - F$
PP if $\frac{2}{11} < F \leq \frac{3}{16}$	$4.25 - 1.23F$ $+0.53\sqrt{11F-2}$	0	$\frac{9}{11}F + \frac{65}{484}$ $+\frac{12}{121}\sqrt{11F-2}$	$4.39 - 0.41F$ $+0.63\sqrt{11F-2}$
PP if $\frac{3}{16} < F \leq \frac{1}{4}$	4.16	0	0.31	4.47

price higher than 1, while those in the interval $\left[\frac{1}{4}, \frac{3}{4}\right]$ buy from the incumbent at a price lower than 1. Consumers located at $\left[\frac{3}{4}, 1\right]$ buy from B at price $\frac{1}{2}$.

Thus, although it is true that PP favors some consumers while leaves others worse-off, the analysis of the effects should be based on consumer welfare as a whole, and not on the harm imposed on a subgroup of individuals. This suggests that, apart from other concerns related to privacy and fairness issues, which are beyond the scope of this model, competition authorities who prioritize the promotion of consumer welfare may find no compelling reasons to prohibit an incumbent from using data for PP when entry is inevitable.[31] Nevertheless, it is important to stress that even in situations where there is no risk of exclusion of competitors, a policy of mandatory information sharing that promotes (PP,PP) can still be an effective tool for increasing consumer surplus and reducing the risk of exploitation, compared to a situation where no information sharing policy is in place (PP,U). This is particularly relevant in competitive markets where the Data Act and the GDPR can help improve consumer welfare by enabling data portability through the 'right to data portability'.

Exclusive data access raises a barrier to entry

As mentioned earlier, markets with intermediate entry costs, specifically $\frac{1}{8} < F \leq \frac{1}{2}$, are the most relevant for policy intervention. In what follows we will focus our discussion on these markets. If the use of data for PP is not permitted, the competitor would always decide to enter. However, if the use of data for PP is allowed, the incumbent's data advantage can act to exclude rivals from the market.

Our analysis highlights that in the absence of any policy intervention, the incumbent's data acquisition, aimed at future price personalization, in the early stage would significantly raise a barrier to entry, causing considerable harm to both consumer and social welfare ($CS^{pp} - CS^{pp,pp} < 0$ and $W^{pp} - W^{pp,pp} < 0$). In this scenario, Firm B would choose not to enter the market, and Firm A would maintain its monopoly position, leading to the capture of all consumer surplus. In this scenario the potential abuse associated with exclusive access to data for PP by a dominant firm is *exploitation* with *exclusion*.[32]

A ban on personalized pricing would restore competition at (U,U) for entry costs lower than $\frac{1}{2}$, benefiting consumers and overall welfare. An information sharing obligation promoting data openness is another potential policy intervention that could increase competition in markets where entry costs are lower than $\frac{1}{4}$. When all competing firms have access to the same piece of information for PP, the intensity of competition increases, with a positive impact on consumer welfare (which would reach its maximum value at (PP,PP)) and on social surplus. However, in this case, it is important to consider whether incumbent anticipates this remedy or not.

Let us consider first the scenario where the dominant firm does not anticipate any information sharing obligation. Our analysis indicates

[31] In contrast, competition authorities that give more weight to social welfare may find personalized pricing to be harmful, and so they might be open to consider policy restrictions on the use of data for pricing by an incumbent dominant firm. This trade-off between consumer surplus and total welfare is very specific to personalized pricing (the same happens in merger review), not being commonly observed in other types of abuse that generally affect consumer welfare and social welfare in a similar way.

[32] While exploitative abuses are contemplated by competition law, in EU member States, in other countries such as the United States, they are not covered by antitrust law, which means there is little chance that personalized pricing will be prosecuted as an exploitative abuse. However, exclusionary abuses, particularly whenever companies lower their prices for some of the competitors' customers with the aim of foreclosing the market are covered in EU member states and United States.

that entry becomes profitable for entry costs in the range $\frac{1}{8} < F \leq \widehat{F}$, with $\widehat{F} \leq \frac{1}{4}$, suggesting that competition is restored and consumer welfare is improved: $CS^{pp,pp} > CS^{p,u} > CS^{u,u}$. It is worth noting that, in terms of consumer welfare, a mandatory information sharing remedy that promotes competitive personalized pricing is more beneficial than a ban on personalized pricing. A ban on PP should be considered in markets with high enough entry costs ($\frac{1}{4} < F \leq \frac{1}{2}$), where competition can only be restored and consumer harm prevented if personalized pricing is not permitted.

When the dominant firm anticipates the remedy of information sharing and adjusts its data acquisition strategy in period 1, policy makers should take into account market-specific factors such as the level of entry costs and consumers' willingness to pay. Proposition 12, part (iii) suggests that, regardless of v, an information sharing remedy is an effective tool to foster competition in the market and boost consumer welfare as long as entry costs are sufficiently low. However, in markets with intermediate to high entry costs, the dominant firm may choose to reduce its data acquisition to deter entry. Therefore, an information sharing policy in such markets could have significant adverse effects on consumer surplus and welfare. For instance, in markets where consumers have a high willingness to pay and entry costs fall within the range of $\frac{2}{11} < F \leq \frac{1}{4}$, a monopolist decides to serve all consumers without policy intervention. However, if an information sharing policy is anticipated, the incumbent may strategically limit its market reach in the first period to discourage entry, resulting in a reduction in consumer surplus and welfare if the policy is implemented. In such markets, a policy that restricts the use of data for personalized pricing could potentially lead to a better outcome.

In conclusion, it is of utmost importance for policy makers to conduct a thorough evaluation of market conditions prior to implementing an information sharing remedy in markets with intermediate to high entry costs where data is an input for price personalization. Our model highlights the importance of considering factors such as consumers' willingness to pay, the level of entry costs, and the incumbent's foresight to ensure that the remedy has a positive impact on consumer welfare. Only by doing so can they make informed decisions that promote competition and improve consumer welfare.

7. Policy issues and final remarks

The rise of digital markets has led to the emergence of new challenges for competition policy. One of these challenges is the role of data as a driver of market power and barrier to entry for new firms. In markets where data plays a critical role, incumbents may have significant advantages over new entrants, such as proprietary access to valuable data and the ability to engage in personalization pricing (PP), which may lead to lower consumer welfare.

To address these challenges, public agencies and regulators around the world are exploring various policy tools to promote competition in digital markets. One of these tools is mandatory information sharing policies, which require incumbents to share their data with potential competitors. In line with this, as previously mentioned, the European legislative framework has undergone extensive expansion and refinement in recent years, with ongoing adjustments. These policies explicitly acknowledge that "*Europe aims to capture the benefits of better use of data, including greater productivity and competitive markets*." Although these initiatives do not alter EU competition legislation, they establish a complementary legal framework that affects how a lack of competition can be addressed in digital markets.

This manuscript sheds light on the crucial issue of personalized pricing by dominant firms that have exclusive access to consumer data. The paper highlights how such incumbents can use their data advantage to engage in price discrimination, potentially resulting in consumer harm and exclusion of new entrants. To address these risks, policymakers have various interventions at their disposal, such as a ban on personalized pricing or mandatory data sharing. Our analysis offers insights into the effectiveness of these interventions, taking into account the specific characteristics of each market.

Our model emphasizes that policy intervention is particularly important in markets where entry costs are not too small (above $\frac{1}{8}$), as the risk of harm to competition and consumer welfare is significant. Our analysis reveals that the efficacy of information sharing obligations depends on the incumbent's anticipation of the intervention. If the incumbent does not anticipate the obligation, mandating information sharing can stimulate entry in markets with intermediate to high entry costs (between $\frac{1}{8}$ and $\widehat{F}$, with $\widehat{F} \leq \frac{1}{4}$). However, if the incumbent foresees the imposition of this remedy, the same outcome is unlikely to occur in this range of entry costs. On the other hand, in markets with entry costs between $\frac{1}{8}$ and $\frac{2}{11}$, an information-sharing obligation can boost competition and benefit consumers, regardless of the incumbent's anticipation. When entry costs are high enough (between $\frac{2}{11}$ and $\frac{1}{4}$), a forward-looking incumbent can adjust its data acquisition strategy to deter entry, leading to significant harm to consumer and overall welfare if an information sharing obligation is imposed. Hence, public agencies must consider the incumbent's strategic response while implementing information sharing obligations, especially in markets with higher entry costs.

In markets where a mandatory information sharing policy would not achieve the desired competitive outcome, public agencies may consider implementing a ban on the use of data for PP or simply a ban on PP. This policy is especially crucial in markets with sufficiently high entry costs ($\frac{1}{4} < F \leq \frac{1}{2}$), because even with information sharing, the entry of new competitors would not be feasible. However, it is worth noting that while banning personalized pricing can restore competition at a wide range of entry costs, it can be challenging for public agencies to monitor whether a dominant firm is complying with this requirement.

Finally, it is worth highlighting the potential benefits of promoting consumer-led tools to enhance competition. The GDPR and the Data Act grant consumers control over their personal data, and the right to data portability enables individuals to receive personal data they have provided to a company and request that it be transmitted directly to a competitor. This implies that, in the context of our model, consumers could play a crucial role in influencing access to data, the scope of personalized pricing, and overall competition. However, it is unlikely that this will happen in the near future due to several reasons.[33] Firstly, consumers may not have enough knowledge or understanding of how data collection affects pricing and competition, and they may not be aware of the benefits of sharing their personal data with competitors, especially with companies that are not yet established in the market. Secondly, even if some consumers do request data mobility, others may not do so because they are not aware of this option or they lack trust and understanding to take advantage of personal data mobility, or it may simply be too time-consuming. Although the GDPR primarily focuses on data protection and privacy issues rather than competition, we believe that personal data mobility will play an essential pro-competitive role in data-driven markets in the future. To make this happen, regulators need to ensure that consumers have sufficient knowledge, trust, and understanding to benefit from personal data mobility.

Therefore, the crucial role of data as a potential barrier to competition highlights the need for competition and regulatory bodies worldwide to take action and improve the regulatory frameworks for the digital economy. The focus should be on competition, with consumer welfare as the key standard for measuring success. While mandatory data sharing can be an essential tool to promote the entry of new businesses and avoid consumer harm in *certain* digital markets, any such approach must also ensure that robust privacy safeguards are in place to respect users' privacy rights and expectations. Ultimately, any pol-

[33] An interesting paper considering how an opt-in regime of privacy regulation, limits the scope for online price discrimination and affects product quality and consumer surplus is Conti and Reverberi (2021).

icy intervention should aim to produce better outcomes for consumers, facilitate the entry and growth of new companies, and encourage innovation among existing firms. Future research could explore the linkages between antitrust policy and privacy protection regulation and consider the effects of consumer awareness and consent regarding the use of data for price personalization.

8. Appendix

This appendix collects the proofs that were omitted from the main text.

Proof of Proposition 1. Under a monopoly setting the indifferent consumer between buying the product or not is located at $\overline{x}$ such that $v-\overline{x}-p=0$. Thus, consumers located at $x\leq\overline{x}$ can buy the good, while consumers located at $x>\overline{x}$ stay out of the market (with $\overline{x}=v-p$ and $0<\overline{x}\leq 1$). Under uniform pricing the incumbent profit per period is $\pi=p(v-p)$, with $v-p\leq 1$. From the FOC with respect to p we obtain $p^u=\frac{v}{2}$ and $x_1=\frac{v}{2}$. This solution holds as long as $x_1\leq 1$ which implies that v is sufficiently low, i.e. $v\leq 2$. If $v>2$ we have a corner solution and so $x_1=1$, the monopolist optimal price is $p=v-1$. Overall profits are just equal to 2π. □

Proof of Proposition 3. Consider first the case where $\widehat{x}_A^o<x_1$, with $\widehat{x}_A^o=\frac{1+p_B^{pp,u}}{2}$. In this situation

$$\pi_A=\int_0^{\frac{1+p_B^{pp,u}}{2}}p_A(x)dx \quad\text{and}\quad \pi_B=\left(x_1-\frac{1+p_B^{pp,u}}{2}\right)p_B^{pp,u}+p_B^{pp,u}\left(1-x_1\right)-F$$

From the derivative of π_B with respect to $p_B^{pp,u}$ we obtain $p_B^{pp,u}=\frac{1}{2}$, thus $\widehat{x}_A^0=\frac{3}{4}$. Firm A serves all consumers located at the left of $\frac{3}{4}$, and firm B serves the remaining ones. Firm A's PP schedule is:

$$p_A^{p,u}(x)=\begin{cases}\frac{3}{2}-2x & if \quad x\leq\frac{3}{4}\\ 0 & if \quad x\geq\frac{3}{4}\end{cases}. \tag{23}$$

Therefore, for $x_1\in\left[\frac{3}{4},1\right]$ firm A and B's profit is, respectively:

$$\pi_A=\int_0^{\frac{3}{4}}p_A^{p,u}(x)dx=\frac{9}{16} \quad\text{and}\quad \pi_B=\frac{1}{4}p_B^{pp,u}-F=\frac{1}{8}-F.$$

Secondly, suppose that $x_1\leq\widehat{x}_A^0$, with $\widehat{x}_A^o=\frac{1+p_B^{pp,u}}{2}$. If x_1 is not sufficiently high, then at $p_A^{p,u}(x)$ firm A will at most attract x_1 consumers. However, in this case, it can attract a fraction of new (anonymous) consumers as long as $\widetilde{x}>x_1$, with $\widetilde{x}=\frac{1}{2}+\frac{p_B^{pp,u}-p_A^{pp,u}}{2}$. Firm A and B profits are, respectively:

$$\pi_A^o=\int_0^{x_1}p_A^{pp,u}(x)dx;\ \ \pi_A^n=p_A^{pp,u}\left(\widetilde{x}-x_1\right)\ \text{ with }\widetilde{x}\geq x_1\ \text{ and }\ \pi_B=p_B\left(1-\widetilde{x}\right)$$

Thus, $\pi_A^o=\int_0^{x_1}p_A^{pp,u}(x)dx$; $\pi_A^n=p_A^{pp,u}\left(\frac{1}{2}+\frac{p_B^{pp,u}-p_A^{pp,u}}{2}-x_1\right)$ and $\pi_B=p_B\left(1-\left(\frac{1}{2}+\frac{p_B^{pp,u}-p_A^{pp,u}}{2}\right)\right)$. From the FOC we obtain

$$p_A^{pp,u}=1-\frac{4}{3}x_1;\ \ p_B^{pp,u}=1-\frac{2}{3}x_1\ \text{ and }\ \widetilde{x}=\frac{1}{3}x_1+\frac{1}{2}.$$

From, $p_A^{pp,u}(x)=p_B^{pp,u}+(1-2x)$, we obtain $p_A^{pp,u}(x)=2\left(1-x-\frac{1}{3}x_1\right)$, which is nonnegative as long as $x\leq 1-\frac{1}{3}x_1$.

Note that $\widetilde{x}\geq x_1$ implies $x_1\leq\frac{3}{4}$. Therefore, as long as $x_1\leq\frac{3}{4}$, firm A profits from its previous own customers and new customers are:

$$\pi_A^o=\int_0^{x_1}p_A(x)dx=\frac{1}{3}x_1\left(6-5x_1\right)\ \text{ and }\ \pi_A^n=\frac{1}{2}+\frac{8}{9}x_1^2-\frac{4}{3}x_1.$$

Firm A and B overall second-period profits are:

$$\pi_A^{pp,u}=\pi_A^o+\pi_A^n=\frac{1}{2}-\frac{7}{9}x_1^2+\frac{2}{3}x_1\quad\text{and}\quad\pi_B^{pp,u}=\frac{2}{9}x_1^2-\frac{2}{3}x_1+\frac{1}{2}-F.\ \square$$

Proof of Proposition 5. Prove first part (i). When $\frac{3}{2}\leq v\leq 2$, in period 2 social welfare is given by

$$\underline{W}_2^{pp,u}=\int_0^{\widetilde{x}}(v-x)dx+\int_{\widetilde{x}}^1(v-(1-x))\,dx=\frac{253}{256}v-\frac{9}{1024}v^2-\frac{65}{256}-F,$$

while consumer surplus can be expressed as $\underline{CS}_2^{pp,u}=\underline{W}_2^{pp,u}-\underline{\pi}_{A2}^{pp,u}-\underline{\pi}_B^{pp,u}$. This yields:

$$\underline{CS}_2^{pp,u}=\frac{9}{256}v^2+\frac{67}{64}v-\frac{79}{64}.$$

Doing the same for period 1:

$$\underline{W}_1^{pp,u}=\int_0^{\underline{x}_1^{EA}}(v-x)dx=\frac{495}{2048}v^2+\frac{69}{512}v-\frac{9}{512},$$

$$\underline{\pi}_{A1}^{pp,u}=\underline{p}_1^{EA}\underline{x}_1^{EA}=\frac{207}{1024}v^2+\frac{21}{256}v-\frac{9}{256},$$

$$\underline{CS}_1^{pp,u}=\frac{81}{2048}v^2+\frac{27}{512}v+\frac{9}{512}.$$

Therefore, when $\frac{3}{2}\leq v\leq 2$, overall consumer surplus and welfare is:

$$\underline{W}^{pp,u}=\frac{477}{2048}v^2+\frac{575}{512}v-\frac{139}{512}-F,$$

$$\underline{CS}^{pp,u}=\frac{153}{2048}v^2+\frac{563}{512}v-\frac{623}{512}.$$

Prove next part (ii) and suppose that $v>2$. Social welfare in period 1 and 2 is respectively equal to:

$$\overline{W}_2^{pp,u}=\int_0^{\frac{3}{4}}(v-x)\,dx+\int_{\frac{3}{4}}^1(v-(1-x))dx-F=v-\frac{5}{16}-F,$$

$$\overline{W}_1^{pp,u}=\int_0^1(v-x)dx=v-\frac{1}{2}.$$

Overall welfare is $\overline{W}^{pp,u}=2v-\frac{13}{16}-F$. Consumer surplus in period 1 and 2 is, respectively $\overline{CS}_2^{pp,u}=v-1$ and $\overline{CS}_1^{pp,u}=\frac{1}{2}$ Therefore overall consumer surplus is $\overline{CS}^{pp,u}=v-\frac{1}{2}$. □

Proof of Proposition 6. When $x_1\leq\frac{3}{4}$, the incumbent has perfect information about only a proportion of consumers, those who bought its product in period 1, located on the interval $[0,x_1]$; while it has no information about the remaining consumers, located on the interval $[x_1,1]$. Under information sharing both firms can set a personalized pricing $p_i^{pp,pp}(x)$ to the consumer $x\in[0,x_1]$, and a uniform price $\widehat{p}_i$ to the group of anonymous consumers with $x\in[x_1,1]$, $i=A,B$. Each firm price schedule under (PP,PP) for consumers located at $x\in[0,x_1]$ is:

$$p_A^{pp,pp}(x)=\begin{cases}1-2x & if \quad x\leq\frac{1}{2}\\ 0 & if \quad x>\frac{1}{2}\end{cases},$$

$$p_B^{pp,pp}(x)=\begin{cases}2x-1 & if \quad x\geq\frac{1}{2}\\ 0 & if \quad x<\frac{1}{2}\end{cases}.$$

Consider consumers locate at $[x_1,1]$. The indifferent consumer is located at $\widetilde{x}$ given by $\widetilde{x}=\frac{1}{2}+\frac{\widehat{p}_B-\widehat{p}_A}{2}$. If $\widetilde{x}=x_1$ no consumer buys from A and all consumers buy from B. If $x_1<\widetilde{x}$ then $(\widetilde{x}-x_1)$ consumers

buy from A and $(1-\widetilde{x})$ buy from B. Thus firm A and B profits are, respectively equal to:

$$\pi_A = \max\left\{\widehat{p}_A\left(\widetilde{x}-x_1\right),0\right\}$$

$$\pi_B = \begin{cases} \widehat{p}_B\left(1-\widetilde{x}\right) & if \quad x_1 < \widetilde{x} \\ \widehat{p}_B\left(1-x_1\right) & if \quad x_1 > \widetilde{x} \end{cases}$$

Firm A has a clear disadvantage in this group of consumers, who have strong preferences for firm B. Because it is a dominated strategy for firm A to quote a price below the marginal cost, which in this case is equal to zero, the best price it is willing to charge to the more distant consumer is $\widehat{p}_A = 0$. This would be the case when $x_1 > \frac{3}{4}$. However we are assuming that $x_1 < \frac{3}{4}$. In this case, firm A would be able to serve some consumers in the interval $[x_1, 1]$. It is straightforward to obtain $\widehat{p}_A = 1 - \frac{4}{3}x_1$, $\widehat{p}_B = 1 - \frac{2}{3}x_1$. Note that $\widehat{p}_A \geq 0$ as long as $x_1 \leq \frac{3}{4}$. This yields $\widetilde{x} = \frac{1}{3}x_1 + \frac{1}{2}$. If $x_1 \geq \frac{1}{2}$ firm A profits in the group of consumers located at $[0, x_1]$ is equal $\frac{1}{4}$ for every x_1. However its profits in the group of anonymous consumers is

$$\widehat{\pi}_A = \left(1-\frac{4}{3}x_1\right)\left(\frac{1}{3}x_1 + \frac{1}{2} - x_1\right) = \frac{8}{9}x_1^2 - \frac{4}{3}x_1 + \frac{1}{2}.$$

In this case, firm A overall second-period profit would be $\pi_A^2 = x_1^2 - \frac{4}{3}x_1 + \frac{3}{4}$. Regarding firm B, when $x_1 \geq \frac{1}{2}$, at (PP,PP) it serves all consumers located at the $\left[\frac{1}{2}, x_1\right]$. Profit from this group of consumers is:

$$\pi_B^{pp,pp} = \int_{\frac{1}{2}}^{x_1} (2x-1)dx = x_1^2 - x_1 + \frac{1}{4}.$$

Regarding the consumers located at $[x_1, 1]$ its profit equals:

$$\widehat{\pi}_B = \left(1-\frac{1}{3}x_1 - \frac{1}{2}\right)\left(1-\frac{2}{3}x_1\right) = \frac{2}{9}x_1^2 - \frac{2}{3}x_1 + \frac{1}{2}$$

In this case, firm B overall second-period profit would be $\pi_B^2 = \frac{11}{9}x_1^2 - \frac{5}{3}x_1 + \frac{3}{4} - F$.

When $x_1 > \frac{3}{4}$, firm A only serves consumers located at the left of $\frac{1}{2}$, while firm B serves all consumers at the right of $\frac{1}{2}$ in period 2. As $\widehat{p}_A = 0$, we obtain $\widehat{p}_B = 2x_1 - 1$. Profits are $\pi_A^2 = \frac{1}{4}$ and

$$\pi_B^2 = \int_{\frac{1}{2}}^{x_1} (2x-1)dx + (1-x_1)(2x_1-1) - F = 2x_1 - x_1^2 - \frac{3}{4} - F. \quad \square$$

Proof of Proposition 8. Consider first the determination of consumer surplus and overall welfare in case of a mandatory information sharing in period 2. When $v > 2$, in period 2, consumer surplus and welfare under (PP,PP) are respectively equal to:

$$\overline{CS}_2^{pp,pp} = \int_0^{\frac{1}{2}} \left[v - \overline{p}_A^{pp,pp}(x) - x\right] dx + \int_{\frac{1}{2}}^{1} \left[v - \overline{p}_B^{pp,pp}(x) - (1-x)\right] dx = v - \frac{3}{4}$$

$$\overline{W}_2^{pp,pp} = \overline{CS}_2^{pp,pp} + \overline{\pi}_A^{pp,pp} + \overline{\pi}_B^{pp,pp} = v - F - \frac{1}{4}.$$

If $\frac{3}{2} \leq v \leq 2$, in period 2 we obtain:

$$\underline{CS}_2^{pp,pp} = \int_0^{\frac{1}{2}} \left[v - \underline{p}_A^{pp,pp}(x) - x\right] dx + \int_{\frac{1}{2}}^{x_1^m} \left[v - \underline{p}_B^{pp,pp}(x) - (1-x)\right] dx$$

$$+ \int_{x_1^m}^{1} \left[v - \underline{p}_B^{pp,pp} - (1-x)\right] dx = \frac{1}{9}v^2 + \frac{5}{9}v - \frac{11}{36},$$

and $\underline{W}_2^{pp,pp} = \underline{CS}_2^{pp,pp} + \underline{\pi}_A^{pp,pp} + \underline{\pi}_B^{pp,pp} = v - F - \frac{1}{4}$. Consider next period 1. When v is high, all consumers buy the good, thus $\overline{CS}_1^{pp} = \frac{1}{2}$. When v is low, some consumers are left out of the market in period 1, $\underline{CS}_1 = \frac{1}{18}(v+1)^2$. Therefore, when v is high, overall consumer surplus is $\overline{CS}^{IS,m} = v - \frac{1}{4}$. When v is low, overall consumer surplus equals $\underline{CS}^{IS,m} = \frac{1}{6}v^2 + \frac{2}{3}v - \frac{1}{4}$. The myopic incumbent profits in period 1 are

$$\pi_1^m = \begin{cases} \frac{1}{9}(2v-1)(v+1) & if \quad \frac{3}{2} \leq v \leq 2 \\ v-1 & if \quad v > 2 \end{cases}.$$

Therefore, when v is low the incumbent overall profits are $\underline{\pi}_A^{IS,m} = \frac{1}{9}(2v-1)(v+1) + \frac{1}{4} = \frac{2}{9}v^2 + \frac{1}{9}v + \frac{5}{36}$, while firm B's profits are $\underline{\pi}_B^{IS,m} = \frac{4}{9}v - \frac{1}{9}v^2 - \frac{7}{36} - F$. Overall welfare is $\underline{W}^{IS,m} = \frac{5}{18}v^2 + \frac{11}{9}v - \frac{11}{36} - F$. If v is high, $\overline{\pi}_A^{IS,m} = v - \frac{3}{4}$ and $\overline{\pi}_B^{IS,m} = \frac{1}{4} - F$. Thus, overall welfare is $\overline{W}^{IS,m} = 2v - F - \frac{3}{4}$. $\square$

Proof of Proposition 9. Consider first the case where the incumbent accommodates entry (the superscript a is used for accommodation) and collects data on consumers located at $x \in [0, x_1^a]$ with $x_1^a < \frac{3}{4}$. In the beginning of the game, the incumbent maximizes its overall profits $\widehat{\pi}_A^a$ by selecting the optimal value of p_1 (or equivalently, x_1), with

$$\widehat{\pi}_A^a = \left(v - x_1\right)x_1 + \left(\frac{8}{9}x_1^2 - \frac{4}{3}x_1 + \frac{3}{4}\right)$$

The FOC with respect to x_1 yields $x_1^a = \frac{9}{2}v - 6$. However, $x_1^a \geq \frac{3}{4}$ for $v > \frac{3}{2}$, which is not possible given our assumptions. When $x_1 > \frac{3}{4}$, we obtain $\widehat{\pi}_A^a = \left(v - x_1\right)x_1 + \frac{1}{4}$. In this case, under entry accommodation, the incumbent chooses $x_1^a = \frac{v}{2}$. When $\frac{3}{2} \leq v \leq 2$ it is always the case that $\frac{3}{4} \leq x_1^a \leq 1$. When $v \geq 2$, it follows that $x_1^a = 1$. As result under entry accommodation $x_1^a = \frac{v}{2} \geq \frac{3}{4}$ and $\widehat{\pi}_A^a = \frac{1}{4}\left(v^2+1\right)$.

Consider next entry deterrence (superscript d). If $x_1 \leq \frac{3}{4}$, the incumbent cannot deter entry as long as $\frac{1}{8} < F < \frac{2}{11}$. In contrast, if $F > \frac{2}{11}$ in order to deter entry the incumbent should serve x_1^d consumers in period 1, which means it will have information for PP about consumers located in the interval $[0, x_1^d]$, with $\frac{15}{22} - \frac{3}{11}\sqrt{11F-2} \leq x_1^d \leq \frac{15}{22} + \frac{3}{11}\sqrt{11F-2}$. The upper bound is lower than $\frac{3}{4}$ as long as $F < \frac{3}{16}$. If $F > \frac{3}{16}$ the incumbent deters entry by choosing $\frac{15}{22} - \frac{3}{11}\sqrt{11F-2} \leq x_1^d \leq \frac{3}{4}$. Under entry deterrence, the incumbent acts as a monopolist in both periods, getting an overall profit equal to:

$$\widehat{\pi}_A^d = \left(v - x_1^d\right)x_1^d + \frac{1}{2}x_1^d\left(2v - x_1^d\right) + \left(1 - x_1^d\right)(v-1)$$

As $\frac{\partial \widehat{\pi}_A^d}{\partial x_1} > 0$ as long as $x_1 < \frac{v+1}{3}$, and $\frac{3}{2} < v < 2$, it follows that firm A deters entry by choosing $x_1^d = \frac{15}{22} + \frac{3}{11}\sqrt{11F-2} < \frac{3}{4}$ if $\frac{2}{11} < F \leq \frac{3}{16}$, while it chooses $x_1^d = \frac{3}{4}$ if $\frac{3}{16} \leq F \leq \frac{1}{4}$. Therefore, when entry costs are such that $\frac{2}{11} \leq F \leq \frac{3}{16}$:

$$\widehat{\pi}_A^d = \frac{37}{22}v - \frac{27}{22}F + \frac{3}{11}v\sqrt{11F-2} - \frac{69}{242}\sqrt{11F-2} - \frac{767}{968}$$

The incumbent prefers to deter entry by choosing $x_1^d < x_1^a$ as long as $\widehat{\pi}_A^d - \widehat{\pi}_A^a > 0$. When $\frac{2}{11} < F < \frac{3}{16}$ and $\frac{3}{2} < v < 2$ the previous condition holds, suggesting that the incumbent reduces its data acquisition to deter entry. Look next at the case where $\frac{3}{16} \leq F \leq \frac{1}{4}$ which implies $x_1^d = \frac{3}{4}$ and $\widehat{\pi}_A^d = \frac{7}{4}v - \frac{35}{32}$. In this case $\widehat{\pi}_A^d - \widehat{\pi}_A^a = -\frac{1}{4}v^2 + \frac{7}{4}v - \frac{43}{32} > 0$, for $\frac{3}{2} \leq v \leq 2$, so the incumbent decides to deter entry by choosing $x_1^d = \frac{3}{4} < x_1^a$. $\square$

Proof of Proposition 10. For small entry costs falling within the range of $\frac{1}{8} \leq F \leq \frac{2}{11}$, the incumbent prefers to accommodate entry by choosing $x_1^a = \frac{v}{2}$ when $\frac{3}{2} \leq v \leq 2$ (with $\frac{3}{4} \leq x_1^a \leq 1$), and $x_1^a = 1$ when $v \geq 2$. As $x_1^a \geq \frac{3}{4}$, consumer surplus in period 2 is respectively equal to:

$$CS_2^{pp,pp} = \int_0^{\frac{1}{2}} (v-(1-2x)-x)\,dx + \int_{\frac{1}{2}}^{x_1^a} (v-(2x-1)-(1-x))\,dx + \int_{x_1^a}^{1} \left(v-\left(1-\frac{2}{3}x_1^a\right)-(1-x\right)dx.$$

When $v>2$, $x_1^a=1$, thus $\overline{CS}_2^{pp,pp} = v-\frac{3}{4}$, when $\frac{3}{2}\le v\le 2$, $x_1^a=\frac{v}{2}$, which yields $\underline{CS}_2^{pp,pp} = \frac{7}{3}v-\frac{5}{12}v^2-\frac{7}{4}$. From our previous computations firm A and B's profits are $\underline{\pi}_A^{pp,pp}=\frac{1}{4}$ and $\underline{\pi}_B^{pp,pp}=\frac{1}{4}(v-1)(3-v)-F$, when $\frac{3}{2}\le v\le 2$, while profits are equal to $\overline{\pi}_A^{pp,pp}=\frac{1}{4}$ and $\overline{\pi}_B^{pp,pp}=\frac{1}{4}-F$, when $v>2$. From the expressions for profits and consumer surplus it is straightforward to obtain:

$$\overline{W}_2^{pp,pp} = v-F-\frac{1}{4}.$$

$$\underline{W}_2^{pp,pp} = \frac{10}{3}v-\frac{2}{3}v^2-\frac{9}{4}-F$$

In period 1 $\hat{\pi}_A^1=\frac{v^2}{4}$, $\underline{CS}_1=\int_0^{\frac{v}{2}}\left(v-\frac{v}{2}-x\right)dx=\frac{v^2}{8}$ and $\underline{W}_1=\frac{v^2}{4}+\frac{v^2}{8}=\frac{3}{8}v^2$. Therefore, when the incumbent accommodates entry (a) and v is low we obtain:

$$\underline{\pi}_A^{IS,a}=\frac{1}{4}\left(v^2+1\right) \text{ and } \underline{\pi}_B^{IS,a}=\frac{1}{4}(v-1)(3-v)-F$$

$$\underline{CS}^{IS,a}=\frac{7}{24}\left(8v-v^2-6\right)$$

$$\underline{W}^{IS,a}=\frac{1}{24}v(80-7v)-\frac{9}{4}-F$$

If v is high, in period 1 $\hat{\pi}_A^1=v-1$, $\overline{CS}_1^{pp,pp}=\frac{1}{2}$ and $\overline{W}_1^{pp,pp}=v-\frac{1}{2}$. This yields:

$$\overline{\pi}_A^{IS,a}=v-\frac{3}{4} \text{ and } \underline{\pi}_B^{IS,a}=\frac{1}{4}-F$$

$$\overline{CS}^{IS,a}=v-\frac{1}{4}$$

$$\underline{W}^{IS,a}=2v-F-\frac{3}{4}$$

(ii) When the incumbent chooses to deter entry by choosing to serve x_1^d consumers in period 1 it maintains its monopoly position in period 2. Its overall profit is equal to

$$\Pi^d = v(1+x_1^d)+x_1^d-\frac{3}{2}\left(x_1^d\right)^2-1$$

Consumer surplus in period 2

$$CS_2^d = \int_0^{x_1^d}(v-(v-x)-x)\,dx+\int_{x_1^d}^{1}(v-(v-1)-x)dx$$

$$= \frac{1}{2}\left(x_1^d-1\right)^2,$$

while in period 1 it is equal to

$$CS_1^d = \int_0^{x_1^d}\left(v-(v-x_1^d)-x\right)dx=\frac{1}{2}\left(x_1^d\right)^2$$

Hence,

$$CS^d = x_1^d(x_1^d-1)+\frac{1}{2}$$

Overall welfare is

$$W^d = v(1+x_1^d)-\frac{1}{2}\left(x_1^d\right)^2-\frac{1}{2}$$

As $x_1^d=\frac{15}{22}+\frac{3}{11}\sqrt{11F-2}$, *when* $\frac{2}{11}<F\le\frac{3}{16}$, we obtain:

$$\Pi^{IS,d}=\frac{37}{22}v-\frac{27}{22}F+\frac{3}{11}v\sqrt{11F-2}-\frac{69}{242}\sqrt{11F-2}-\frac{767}{968}$$

$$CS^{IS,d}=\frac{9}{11}F+\frac{12}{121}\sqrt{11F-2}+\frac{65}{484}$$

$$W^{IS,d}=\frac{37}{22}v-\frac{9}{22}F+\frac{3}{11}v\sqrt{11F-2}-\frac{45}{242}\sqrt{11F-2}-\frac{637}{968}$$

When $\frac{3}{16}<F\le\frac{1}{4}$, $x_1^d=\frac{3}{4}$. This yields $CS^{IS,d}=\frac{5}{16}$; $W^{IS,d}=\frac{7}{4}v-\frac{25}{32}$ and $\Pi^{IS,d}=\frac{7}{4}v-\frac{35}{32}$. □

CRediT authorship contribution statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript.

Data availability

No data was used for the research described in the article.

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