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Rosa Branca Esteves

Francisco Carballo-Cruz

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Universidade do Minho
Escola de Economia e Gestão

Can data openness unlock competition when the incumbent has exclusive data access for personalized pricing?*

Rosa-Branca Esteves† Universidade do Minho and NIPE

Francisco Carballo-Cruz‡ Universidade do Minho and NIPE

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Abstract

This paper investigates the role of an incumbent's data investment decisions in shaping the competitive interaction of firms and market structure. We provide antitrust agencies with some insights that may help them to determine whether and when personalized pricing (PP) by a dominant firm, which is enabled by the use of exclusive data, dampens competition and harms consumers. In markets with intermediate entry costs, where entry is blocked without any intervention, a data openness remedy, by means of a mandatory information sharing, is an effective tool to restore competition and boost consumer welfare. Even in markets where entry is inevitable, due to low entry costs, a mandatory information sharing to promote competitive PP further boosts consumer surplus in comparison to the case where only the incumbent employs PP. In contrast, public agencies should consider a ban on PP in markets with sufficiently high entry costs. In these markets, a mandatory information sharing remedy would simply not produce the desired competitive outcome.

JEL: D43, L13.

Keywords: Price discrimination, data investments, data barrier to entry, information sharing, digital markets, GDPR, competition policy and regulation.

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†Department of Economics and NIPE, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal. E-mail: rbranca@eeg.uminho.pt; Phone: +351253601932.

‡Department of Economics and NIPE, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal. E-mail: fcarballo@eeg.uminho.pt; Phone: +351253601932.

1 Introduction

> "*As data is power, those already large, often global, businesses which are able to utilise 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, 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-related behaviors/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. The OECD report on "Consumer data rights and competition" (OECD, 2020a) suggests that foreclosure could potentially occur, especially when a dominant firm has exclusive access to consumer data. The Australian Competition and Consumer Commission (ACCC) in its "Digital Platforms Inquiry" (2019) state that "[...]the breadth and depth of user data collected by the incumbent digital platforms provides them with a strong competitive advantage, creating barriers to rivals entering and expanding in relevant markets".

Second, control over exclusive data can generate market power even without classical market dominance, which is why in general a growing importance of situations of "economic dependence" of even large companies on certain platforms or service operators can be observed (Bougette et al., 2019). Third, while greater collection of personal data allows businesses to innovate and improve the quality of their products/services, it also provides them with competitive advantage to implement sophisticated forms of price discrimination strategies, like personalized pricing

(henceforth PP).[1] As discussed in the OECD paper on "Personalized Pricing in the Digital Era", the personalization of prices generally improves efficiency and often results in consumer gains by encouraging businesses to compete more intensively for each consumer (Thisse and Vives, 1988; OECD, 2018). However, in some circumstances, if implemented by businesses with substantial market power, it may result in consumer and competition harm (Bourreau and De Streel, 2018; OECD, 2018; OECD, 2020b, Montes et al., 2019). Consumer harm will be even greater if the practice of personalized pricing helps incumbent companies with market power to block the entry of new competitors into the market.

Consequently, the new digital ecosystem has pushed competition and regulation bodies around the globe to take actions to improve and adapt the regulatory frameworks for the digital economy. Several reports call for the creation of a specialized regulatory agency, a "Digital Authority" (Stigler report for the US)[2] or a "Digital Market Unit" (Furman report for the UK).[3,4] Additionally, the 10th Amendment of the German Competition Act, which entered into force on January 19, 2021, 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 a crucial criterion. The refusal to provide access to such data in exchange for an adequate fee may also constitute an abuse (OECD, 2020b). Finally, the promotion of some form of data openness intervention in digital markets (e.g. mandatory information sharing, data portability) is often mentioned as a key part of a digital competition policy reform agenda. In particular, these measures have been highlighted in competition authority studies or expert

[1] For example, Shiller (2014) estimates the increase in profit if Netflix would introduce personalised 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 (2017) 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 personalised pricing.

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

[3] 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

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

panels commissioned. We can refer, for instance, the UK Digital Competition Expert Panel, 2019, the US Stigler Committee on Digital Platforms, 2019 and the recent OECD report on "Data Portability, Interoperability and Digital Platform Competition" (OECD, 2021). All of them argue that data openness can stimulate competition by making it easier for new entrants to attract users and potentially alleviate barriers to entry associated with data access (mainly, in those markets for which individual-level data is valuable).

In light of this discussion, this paper aims to answer the following questions: What role can be played by an incumbent's investment in data in affecting the scope of personalized pricing and the entry of a new competitor into the market? What are the incumbent's incentives to sell to more or fewer consumers (i.e., to invest in consumer data) before entry can take place? What are the implications for competition and consumer welfare if the incumbent's database is not replicable and there are no alternative sources of information for rival firms? Finally, under what market conditions can a data openness approach, through a mandatory data sharing policy, restore competition and avoid 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.[5] 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 (consumers' location in the interval $[0, 1]$), 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.[6] 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).

Thisse and Vives (1988) and Montes et al. (2019) rely on a static analysis in which consumer information is exogenously given. Hence, they ignore the process of creating information. Given

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

[6] 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), multi-dimensional product differentiation (e.g. Esteves, 2009), imperfect targetability (Chen et al, 2001).

the importance of data for PP and the effects on competition for the market, our model complements the later works in two ways. First, we endogeneize the incumbent's data acquisition. 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 $x \sim U[0,1]$ is fixed across periods. Consumers wish to buy a single unit of the good in each period, incur a "transport cost" equal to 1 per unit of distance and derive utility v from consuming a unit of the good. In order to ensure that the market is covered under duopoly in the benchmark case with uniform pricing we assume v is sufficiently high, i.e. $v \geq \frac{3}{2}$.[7] 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.[8] Second, 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 (PP,U); otherwise, the incumbent remains in a monopoly position with the ability to quote personalized prices (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. Two approaches have been considered so far. In the switching costs approach (e.g. Chen, 1997), consumers initially view the two firms as perfect substitutes; but in the second period they face a switching cost if they change suppliers (ex-post

[7] See footnote 11.

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

heterogeneity). In the other approach, consumers have ex-ante heterogeneous brand preferences (e.g. Fudenberg and Tirole, 2000). Models in both approaches exhibit best-response asymmetry (Corts, 1998): the strong market of one firm is the weak market of the competitor. A common finding in this literature is that firms charge lower prices to new/rival's customers than to old customers. BBPD is shown to usually lead to lower profits for firms; further, it causes welfare losses due to inefficient shopping by those consumers who switch from one to the other 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 v is not too high ($\frac{3}{2} \leq v \leq 2$), 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 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 analyses 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 sunk and fixed cost of entry ($F = 0$). 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 without any intervention policy, the incumbent ability to engage in personalized prices is an effective tool for consumer welfare exploitation and exclusion.

Our analysis draws interesting insights for policy agencies. If data collected by the incumbent is not replicable at all, or there are no alternative sources of information for rival firms, the incumbent exclusive access to data for PP can, indeed, act to exclude new firms from the market with serious harm on consumers. In this case, the risk of competition and consumer harm might be addressed through different types of policy interventions. We focus on two types of policy interventions: (i) a ban on personalized pricing and (ii) a data openness approach through a mandatory data-sharing remedy.

We show that when the incumbent uses its exclusive data for PP entry is inevitable if $F \leq \frac{1}{8}$, otherwise it is blocked. A remedy of banning PP unlocks competition for entry costs $F \leq \frac{1}{2}$. It is worth noting it could be difficult for public agencies to monitor that the dominant firm is effectively fulfilling this obligation. Additionally, we show that as long as entry occurs, consumers would be better off if public agencies impose the alternative remedy of data openness, through a mandatory information sharing. For intermediate values of entry costs ($\frac{1}{8} < F \leq \frac{1}{4}$), information sharing produces better results in terms of consumer welfare, suggesting that, in these markets, public agencies should pursue data openness as a tool to unlock competition and boost consumer welfare. Even in markets where entry is inevitable due to low entry costs ($F < \frac{1}{8}$), a mandatory information sharing to promote competitive personalised pricing further boosts consumer surplus in comparison to the case where only the incumbent employs PP. 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).[9] While data openness will tackle the key barrier to entry in digital markets, promoting competition, it can harm consumer privacy.

Public agencies should consider a ban on PP in markets with sufficiently high entry costs ($\frac{1}{4} < F \leq \frac{1}{2}$), where a mandatory information sharing remedy would simply not produce the desired competitive and consumer welfare outcomes. In this case, a ban on PP is an effective tool to unlock competition and avoid consumer harm.

Finally, it is worth noting that apart from the policy led approaches discussed, competition might be enhanced by promoting consumer led tools. Although this paper does not look at this possibility, if all consumers buying from the incumbent in period 1 were requesting this company

[9] While data openness will tackle the key barrier to entry in the digital market, promoting cempetition, it can harm consumer privacy

to transfer their data to the new entrant, theoretically, *data portability*−one of the consumers' data rights under the GDPR[10]−would produce the same competitive outcome than a *mandatory data sharing* policy. However, in practice, a consumer led tool like this is far from producing the same result. This happens because consumers are not sophisticated enough to anticipate *how* data collection affects pricing and competition for the market; they are not able to understand clearly the benefits of sharing their personal data with competitors, moreover when competitors are not yet in the market; the request of data portability is time consuming; consumers don't have trust and confidence in how their data is used, to name a few.

Digital markets will only work well if they are supported with strong pro-competition policies countering the forces that can lead to high concentration and a single winner. For this to happen in the future, it is important that competition and consumer protection bodies as well as regulators act together ensuring that consumers have sufficient trust and understanding to take advantage of personal data sharing and mobility.

The rest of the paper is organized as follows. The next section presents the model. The case of an unconstrained monopoly is discussed in section 3. Section 4 is devoted to the equilibrium analysis. Section 5 looks at a data openness approach to enhance competition, through a mandatory information sharing. The welfare analysis is presented in section 6. Results and policy issues are discussed in section 7 that concludes the paper. Appendices A and B collect the proofs that were omitted from the text.

2 The model

Consider a Hotelling linear city model where a unit mass of consumers have unit demands and stay in the market for two periods of consumption, $t = 1, 2$. Consumers are uniformly distributed on $[0, 1]$. The location of a particular consumer $x \in [0, 1]$ is fixed across periods and indicates her respective valuation for the two brands. Consumers have a reservation value v for their ideal product. We assume v is sufficiently high, i.e. $v \geq \frac{3}{2}$.[11] In the first period, only an incumbent,

[10] GDPR stands for (European) General Data Protection Regulation which has entered into force on May 25, 2018.

[11] 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 personalised 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 $v - \frac{3}{2} \geq 0$.

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 $x \in [0, x_1]$. 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 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 $-x$ if she/he buys a unit of good A and $-(1-x)$ 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. In particular, apart from anticipating that the incumbent would engage in PP practices, consumers would also have to predict the outcome of entry decisions and the subsequent price offers.[12]

[12] Extending the analysis to strategic consumers is beyond the scope of this manuscript. 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

3 Benchmark: Unconstrained Monopoly

For future reference, we consider below 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' gross utility is sufficiently low, i.e., if $\frac{3}{2} \leq v \leq 2$*, then at the optimum, 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' gross utility 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 ($\frac{3}{2} \leq v \leq 2$) some consumers are left out of the market in both periods under uniform pricing. Consumer surplus (CS) in each period $t = 1, 2$, is:

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

tomorrow) and/or tracking is also used to provide consumers with personalised (higher-quality) services. The extension of our setting to strategic consumers, although interesting, would introduce additional complications into the model making the answer to our main question less clear-cut. This is left for future research.

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

$$\underline{W}^u = \underline{CS}^u + \underline{\pi}^u = \frac{3}{4}v^2 \tag{2}$$

In contrast, when v is high ($v > 2$) there is full participation. In each period consumer surplus is

$$\overline{CS}_t^u = \int_0^1 (v - \overline{p}_t - x)\, dx = \frac{1}{2} \tag{3}$$

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

$$\overline{W}^u = \overline{CS}^u + \overline{\pi}^u = 2v - 1. \tag{4}$$

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 recognised 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 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:

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

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

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 ($\frac{3}{2} \leq v \leq 2$). 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 welfare is, respectively, equal to:

$$\underline{CS}_1^{pp} = \int_0^{\underline{x}_1^{pp}} \left(v - \underline{p}_1 - x\right) dx = \frac{1}{18}(v+1)^2$$

$$\underline{CS}_2^{pp} = \int_0^{\underline{x}_1^{pp}} (v - p(x) - x)\, dx + \int_{\underline{x}_1^{pp}}^{1} (v - p(x) - x) dx$$

When v is low, overall consumer surplus, given by $\underline{CS}^{pp} = \underline{CS}_1^{pp} + \underline{CS}_2^{pp}$, is equal to:

$$\underline{CS}^{pp} = \frac{1}{9}v^2 - \frac{1}{9}v + \frac{5}{18}. \tag{5}$$

We can now find the social welfare given by $\underline{W}^{pp} = \underline{CS}^{pp} + \underline{\pi}^{pp}$, with $\underline{\pi}^{pp} = \frac{1}{6}v^2 + \frac{4}{3}v - \frac{5}{6}$. This yields:

$$\underline{W}^{pp} = \frac{5}{18}v^2 + \frac{11}{9}v - \frac{5}{9}.$$

Finally, consider the case where v is sufficiently high, i.e., $v > 2$. In this case, all consumers can buy the good in both periods. Consumer surplus in period 1 and 2 is respectively equal to:

$$\overline{CS}_1^{pp} = \int_0^1 \left(v - \overline{p}^1 - x\right) dx = \frac{1}{2} \tag{6}$$

$$\overline{CS}_2^{pp} = \int_0^1 \left(v - p(x) - x\right) dx = 0 \tag{7}$$

This yields an overall consumer surplus equal to $\overline{CS}^{pp} = \frac{1}{2}$. Overall welfare is $\overline{W}_M^{pp} = \overline{CS}^{pp} + \overline{\pi}^{pp}$ with $\overline{\pi}^{pp} = 2v - \frac{3}{2}$. This yields:

$$\overline{W}^{pp} = 2v - \frac{3}{2} + \frac{1}{2} = 2v - 1. \tag{8}$$

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

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

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 would not serve were it constrained to set a uniform pricing. This is the case when v is low (i.e., $\frac{3}{2} \leq v \leq 2$): although aggregate consumer surplus falls with PP, the market expansion effect boosts social welfare.[13] When $v > 2$, all consumers can purchase the good in both periods under uniform and personalised pricing. Because the market expansion effect of PP is null, PP only acts to reduce consumer welfare at the expense 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

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

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.[14] 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, it is silent on the potential *exclusionary* effects of PP. Therefore, it is important to consider whether the exclusive access to personal data for personalized pricing can help an incumbent to exclude a potential competitor from the relevant market. We look at this issue in the next section.

4 Equilibrium analysis

As usual, we solve the game working backwards from the second-stage of period 2.

4.1 Second-stage of period 2: price decisions

Consider first the case where firm B enters and incurs the entry cost F.

No discrimination benchmark: If for any reason the incumbent, firm A, cannot use its data for personalized pricing (due, for instance, to regulation, legal restrictions or consumers hiding strategies), the pricing game is a replication of the Hotelling model, and both firms charge a uniform pricing. For future reference we call this pricing regime (U,U). The equilibrium uniform price is $p_i^{u,u} = 1$, $i = A, B$. If at this price all consumers get a nonnegative surplus, all of them can buy the good. The incumbent serves all consumers at the left of $\frac{1}{2}$, and the entrant serves all consumers at the right of $\frac{1}{2}$. The more distant consumer located at $x = \frac{1}{2}$ buys the good

[14] The OECD (2018) states that this limitation arise beacuse (i) rules on abuse of dominance only apply to firms that have substantial market power, which are in fact the circumstances under which personalised 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.

as long as $v - p_i^{u,u} - \frac{1}{2} \geq 0$, i.e., so long as $v \geq \frac{3}{2}$. As aforementioned this condition ensures that the market is covered under competition. Firm A and B's profits are, respectively, equal to $\pi_A^{u,u} = \frac{1}{2}$ and $\pi_B^{u,u} = \frac{1}{2} - F$. If in contrast, firm B stays out of the market, and the incumbent cannot use its data for price discrimination then firm A behaves as in Proposition 1.

Consider now the case where the incumbent faces no restrictions on the use of its own proprietary data for personalized pricing. Based on the information acquired, the incumbent can set individual prices $p(x)$ to each consumer x that belongs to its database $[0, x_1]$. Because there are no alternative sources of information for the entrant, it can only set a single price. We call this price regime (PP,U). Depending on the incumbent's information acquisition in period 1, $[0, x_1]$, it can gather perfect information about all consumers in the market (if $x_1 = 1$) or only about part of the market (if $x_1 < 1$). Hence, in period 2, the incumbent charges a personalized price, $p_A^{pp,u}(x)$, to identified consumers with $x \in [0, x_1]$ and a non-discrimination price, $p_A^{pp,u}$, to new (anonymous) customers, with $x \in [x_1, 1]$. The entrant quotes a uniform price, $p_B^{pp,u}$.

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

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

Now consider the second-period decision of a consumer x, with $x \in [0, x_1]$. In period 2, the consumer's outside option is not zero, but the utility associated with buying from B at $p_B^{pp,u}$. Therefore, a consumer who bought from firm A before is indifferent between buying from A and B in period 2 so long as

$$p_A^{pp,u}(x) = p_B^{pp,u} + (1 - 2x). \tag{9}$$

Firm A's best offer to the more distant consumer located for instance at $\widehat{x}_A^0$ is zero (its marginal cost), i.e, $p_A^{pp,u}(\widehat{x}_A^0) = 0$. This consumer is indifferent between firm A and B so long as $0 + \widehat{x}_A^0 = p_B^{pp,u} + (1 - \widehat{x}_A^0)$, from which we obtain $\widehat{x}_A^o = \frac{1+p_B^{pp,u}}{2}$. Therefore, firm A is able to serve all old consumers at the left of $\widehat{x}_A^o = \frac{1+p_B^{pp,u}}{2}$. Depending on x_1, firm A's profits from own previous consumers (superscript o) and from new customers (superscript n) are:

$$\begin{aligned} \pi_A^o &= \int_0^{\min\left\{\widehat{x}_A^o, x_1\right\}} p_A(x)dx \\ \pi_A^n &= p_A^{pp,u} \max\left\{\widetilde{x} - x_1, 0\right\} \end{aligned}$$

Firm B's profits are

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

We can consider the following cases. Firstly, suppose that x_1 is high enough, such $x_1 > \widehat{x}_A^o$. When this happens $\frac{1+p_B^{pp,u}}{2} < x_1$. Therefore from $\widetilde{x} = \frac{1+p_B^{pp,u}}{2} - \frac{p_A^{pp,u}}{2}$ it follows that $\widetilde{x} - x_1 < 0$, suggesting that firm A attracts no consumer from the segment of anonymous new customers. Thus when $\widehat{x}_A^o < x_1$:

$$\begin{aligned} \pi_A^o &= \int_0^{\frac{1+p_B^{pp,u}}{2}} p_A(x)dx;\ \pi_A^n = 0 \\ \pi_B &= \left(x_1 - \frac{1+p_B^{pp,u}}{2}\right) p_B^{pp,u} + p_B^{pp,u}(1-x_1) \end{aligned}$$

From the derivative of π_B with respect to $p_B^{pp,u}$ we get that $p_B^{pp,u} = \frac{1}{2}$ and so $\widehat{x}_A^0 = \frac{3}{4}$. Firm A serves all consumers located at the left of $\frac{3}{4}$, and firm B serves the remaining ones. Therefore:

$$p_A^{pp,u}(x) = \begin{cases} (\frac{3}{2} - 2x) & if \quad x \leq \frac{3}{4} \\ 0 & if \quad x \geq \frac{3}{4} \end{cases} \tag{10}$$

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 $p_A^{pp,u}(x)$ firm A will at most attract x_1 consumers. However, in this situation, 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 equal to:

$$\begin{aligned} \pi_A^o &= \int_0^{x_1} p_A^{pp,u}(x)dx, \\ \pi_A^n &= p_A^{pp,u}(\widetilde{x} - x_1) \ \text{ with } \widetilde{x} \geq x_1, \\ \pi_B &= p_B(1 - \widetilde{x}). \end{aligned}$$

The next proposition summarizes the equilibrium price decisions in 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 $\frac{3}{4} \leq x_1 \leq 1$:

$$p_A^{pp,u}(x) = \begin{cases} \frac{3}{2} - 2x & if \quad x \leq \frac{3}{4} \\ 0 & if \quad x \geq \frac{3}{4} \end{cases} \tag{11}$$

$$p_B^{pp,u} = \frac{1}{2}, \tag{12}$$

each firm's profit is respectively equal to

$$\pi_A^{pp,u} = \frac{9}{16}, \tag{13}$$

$$\pi_B^{pp,u} = \frac{1}{8} - F. \tag{14}$$

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

$$p_A^{pp,u}(x) = \begin{cases} 2(1-x-\frac{1}{3}x_1) & if \quad x \leq 1-\frac{1}{3}x_1 \\ 0 & if \quad x \geq 1-\frac{1}{3}x_1 \end{cases} \tag{15}$$

$$p_A^{pp,u} = 1-\frac{4}{3}x_1 \tag{16}$$

$$p_B^{pp,u} = 1-\frac{2}{3}x_1 \tag{17}$$

each firm profit is

$$\pi_A^{pp,u} = \frac{1}{2}+\frac{1}{9}x_1\left(6-7x_1\right), \tag{18}$$

$$\pi_B^{pp,u} = \frac{1}{2}-\frac{2}{9}x_1\left(3-x_1\right)-F. \tag{19}$$

Proof.

See the Appendix.

Proposition 3 provides interesting insights on the relation between personal data acquisition by an incumbent and competitive interaction in case of entry. To begin with, it shows that the informed firm makes higher profits with PP than with UP $\left(\pi_A^{pp,u}-\pi_A^{u,u}>0\right)$, the reverse happens to the uninformed firm $\left(\pi_B^{pp,u}-\pi_B^{u,u}<0\right)$. It also shows that incumbent informed firm makes higher profits than the uninformed entrant $\left(\pi_A^{pp,u}>\pi_B^{pp,u}\right)$. We should stress that the profit advantage of the informed is already shown in the literature (e.g. Liu and Serfes, 2004; Montes et al., 2019). More importantly, Proposition 3 highlights that there is an important link between the incumbent's data acquisition decisions before any entry takes place and the role of access to exclusive data in shaping the competitive interaction of firms and market structure in period 2.

Remark 1. *A higher incumbent's data acquisition (higher* x_1*) intensifies price competition in case of entry.*

This result is very intuitive. As the incumbent's share of identified customers x_1 increases, the entrant has to compete more aggressively in the wider segment of firm A's identified customers and in the shrinking unidentified one. As prices are strategic complements, this also results in lower prices charged by the incumbent to identified and anonymous customers.

Before proceeding it is also interesting to compare our equilibrium second-period prices in case of entry (PP,U) with the 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 shows that a subset of customers will pay higher prices under (PP,U), while others will pay lower prices. Specifically, customers with strong preferences for the incumbent, located in the interval $\left[0, \frac{1}{2} - \frac{1}{3}x_1\right[$ purchase again from A at a price higher than 1. All other consumers pay lower prices under (PP,U) than under (U,U). Now suppose that $x_1 \geq \frac{3}{4}$. Consumers with preferences within $\left[0, \frac{1}{4}\right[$ purchase the good from the incumbent at a 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 (the consumer located at $x = \frac{3}{4}$ benefits the most as it pays 0). Consumers located at $\left[\frac{3}{4}, 1\right]$ buy from B at price $\frac{1}{2}$.

Regarding the effects of the incumbent's data acquisition on firm profits we 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. Indeed, each firm second-period profits are equal to a constant for any $x_1 \geq \frac{3}{4}$. In contrast, if $x_1 < \frac{3}{4}$ we 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 $x_1 > \frac{3}{7}$. Thus, if the incumbent 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 case of entry. This suggests that entry accommodation calls for underinvestment in consumer data. Under this accommodation strategy, known as the "*puppy dog strategy*", the incumbent wants to be small to look inoffensive, so as to trigger a favourable response from the entrant.

4.2 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 or not to enter in the market.

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 we have:

Remark 2. *If price discrimination is not permitted in period 2, firm B decides to enter if* $F \leq \frac{1}{2}$; *otherwise it stays out of the market.*

In contrast, when the incumbent firm can use its personal data to charge personalized prices to its previous recognized customers, then the entrant's profits in case of entry are:

$$\pi_B^{pp,u} = \begin{cases} \frac{1}{8} - F & if \quad x_1 \geq \frac{3}{4} \\ \frac{1}{2} - \frac{2}{9}x_1\left(3 - x_1\right) - F & if \quad x_1 < \frac{3}{4} \end{cases} \tag{20}$$

Otherwise, if the entrant decides to stay out of the market its profits are null, which amounts to selling nothing and saving the sunk entry cost F. We summarize firm B's entry decisions conditional on the incumbent's information acquisition decision in period 1 in the following corollary.

Corollary 2. *When personalized pricing is permitted then:*

(i) If the incumbent's data acquisition is such that $x_1 \leq \frac{3}{4}$, *firm* B *decides to enter as long as* $F \leq \frac{1}{2} - \frac{2}{9}x_1(3 - x_1)$, *otherwise it stays out of the market.*

(ii) If the incumbent's initial data acquisition is high $\left(i.e., x_1 \geq \frac{3}{4}\right)$, firm B decides to enter as long as $F \leq \frac{1}{8}$, otherwise it stays out of the market.

This result highlights that regardless the incumbent's data acquisition x_1, firm B enters for any entry sunk cost $F < \frac{1}{8}$. For higher entry costs, firm B's decision depends on the incumbent 'investment' on data acquisition for PP.

As explained, in this model after having acquired information about its previous customers, the incumbent uses its own proprietary information to produce very accurate estimates about consumers willingness to pay to charge them personalized prices. As we are assuming that there are no alternative sources of such refined personal information for rival firms, without information sharing impositions, rival firms have no alternative but to compete with a uniform price.

Therefore, our analysis highlights that if user data is commercially valuable, lack substitutes, and is not shared across firms, then the incumbent's exclusive access to personal data as an input for PP can limit the number of viable competitors and create a "data barrier to entry". If in the beginning of the game the incumbent strongly invests in getting detailed information about a high proportion of its own customers−i.e., $x_1 \in \left[\frac{3}{4}, 1\right]$ −the ability to use this data to target personalized prices, acts to discourage entry by a rival firm in comparison to uniform pricing. Indeed, under personalized prices the dominant firm is able to exclude a rival firm from the market in the range of entry costs that would otherwise lead to entry under uniform pricing, specifically for entry costs in the interval $\left]\frac{1}{8}, \frac{1}{2}\right]$. Hence, our analysis suggests that a data-rich incumbent is able to cement its position and make more money by using its data for price personalisation and entry deterrence. As stated in the UK Report of the Digital Competition Expert Panel (Furman et al, 2019) data can indeed act as a barrier to entry in digital markets, raising antitrust and consumer harm concerns.

4.3 Period 1: Information acquisition decisions

As aforementioned, in the beginning of the game the incumbent has no data about consumers, so it sets a uniform price. However, after consumers have made their purchasing decisions, the incumbent is able to acquire perfect information about the preferences of the consumers it served, those located at the interval $[0, x_1]$. This data will then be used in period 2 to price discriminate and influence entry.

Therefore, the incumbent takes into account that its initial price decision determines the share of served customers, and so, the size of its database, that will affect its future price behavior and the profits the entrant can attain upon entry. By serving more consumers today ($\uparrow x_1$), the incumbent increases the list of (perfectly) identified customers and commits to play more aggressively tomorrow in case 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 can behave as an unconstrained monopolist without fearing entry.*

Entry is blockaded if it is not profitable even though the incumbent behaves as unconstrained monopolist. If the use of personal data as an input for PP is permitted, Proposition 2 part (i) shows that when v is low ($\frac{3}{2} \leq v \leq 2$) an unconstrained monopolist chooses $\underline{x}_1^{pp} \geq \frac{5}{6}$. Because $\frac{5}{6} > \frac{3}{4}$, entry is not profitable for any sunk entry cost $F > \frac{1}{8}$.

Remark 4. (Entry is inevitable): *When $F \leq \frac{1}{8}$ firm B always finds it profitable to enter. Therefore, the incumbent modifies its data acquisition behavior to accommodate entry.*

Taking into account Proposition 3, we know that when firm B enters and personalized pricing is permitted, if the incumbent's initial data acquisition is $x_1 \in \left[\frac{3}{4}, 1\right]$, then the incumbent's second-period profit is equal to a constant, i.e., $\frac{9}{16}$. Its first-period profit is $p_1 x_1$ with $x_1 = v - p_1$. Equivalently, its first-period profit can be written as $(v - x_1)\, x_1$. Thus, in the beginning of the game, the incumbent chooses x_1 to maximize its overall profits given by

$$\overline{\Pi}_A^{pp,u} = (v - x_1)\, x_1 + \frac{9}{16}. \tag{21}$$

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 $x \in [0, x_1]$ with $x_1 < \frac{3}{4}$. Proposition 3 shows that when firm B enters, the incumbent second period profit is $\frac{1}{2} + \frac{1}{9} x_1 (6 - 7x_1)$. Its first-period profit is $(v - p_1)\, p_1$. Thus, in the beginning of

the game, the incumbent chooses p_1 (or equivalently x_1) to maximize its overall profits given by

$$\underline{\Pi}_A^{pp,u} = (v - x_1)\, x_1 + \left(\frac{1}{2} + \frac{1}{9} x_1 \left(6 - 7x_1\right)\right). \tag{22}$$

The first-order condition (FOC) with respect to x_1 yields $x_1 = \frac{9}{32}v + \frac{3}{16}$. It is straightforward to obtain the next proposition.

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 sunk entry cost is sufficiently low ($F \leq \frac{1}{8}$) then in the SPNE:*

(i) If $v > 2$, under entry accommodation, the incumbent optimal decision is to invest strongly in consumer data 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 2 are:

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

$$\overline{p}_B^{pp,u} = \frac{1}{2}, \tag{24}$$

overall profits are:

$$\overline{\Pi}_A^{pp,u} = v - \frac{7}{16}, \tag{25}$$

$$\overline{\pi}_B^{pp,u} = \frac{1}{8} - F. \tag{26}$$

(ii) If $\frac{3}{2} \leq v \leq 2$, under entry accommodation, the incumbent charges $\underline{p}_1^{EA} = \frac{1}{32}(23v - 6)$ and $\underline{x}_1^{EA} = \frac{9}{32}v + \frac{3}{16}$ with $\frac{39}{64} \leq \underline{x}_1^{EA} \leq \frac{3}{4}$. Firm B enters and second-period prices are:

$$\underline{p}_A^{pp,u}(x) = \begin{cases} \frac{3}{16}(10 - v) - 2x & if \quad x \leq \frac{3}{32}(10 - v) \\ 0 & if \quad x \geq \frac{3}{32}(10 - v) \end{cases} \tag{27}$$

$$\underline{p}_A^{pp,u} = \frac{3}{4} - \frac{3}{8}v = \frac{3}{8}(2 - v) \tag{28}$$

$$\underline{p}_B^{pp,u} = \frac{7}{8} - \frac{3}{16}v = \frac{1}{16}(14 - 3v) \tag{29}$$

each firm overall profits are:

$$\underline{\Pi}_A^{pp,u} = \frac{9}{64}v^2 + \frac{3}{16}v + \frac{9}{16}, \tag{30}$$

$$\underline{\pi}_B^{pp,u} = \frac{9}{512}v^2 - \frac{21}{128}v + \frac{49}{128} - F. \tag{31}$$

In order to prove the expression obtained for overall equilibrium profits defined above we only need to substitute x_1 by $\underline{x}_1^{EA}$ in equations (19), (21) and (22).

Finally, note that $\underline{x}_1^{EA}$ is an increasing function of v. When $v = \frac{3}{2}$ then $\underline{x}_1^{EA} = \frac{39}{64} \simeq 0.61$, when $v = 2$ it follows that $\underline{x}_1^{EA} = \frac{3}{4}$. Thus, when $\frac{3}{2} \leq v \leq 2$ under entry accommodation the incumbent decides to acquire information about consumers located in the interval $\left[0, \underline{x}_1^{EA}\right]$ with $\underline{x}_1^{EA} \in \left[\frac{39}{64}, \frac{3}{4}\right]$. In this case, consumers in the interval $\left[0, \underline{x}_1^{EA}\right]$ buy from firm A at the personalised price $\underline{p}_A^{pp,u}(x)$, consumers in the interval $\left[\underline{x}_1^{EA}, \widetilde{x}\right]$ buy from firm A at price $\underline{p}_A^{pp,u}$ and consumers in the interval $[\widetilde{x}, 1]$ buy from B at price $\underline{p}_B^{pp,u}$, with $\widetilde{x} = \frac{3}{32}(v+6)$.

Therefore, when $\frac{3}{2} \leq v \leq 2$, firm A and B second-period profits are:

$$\underline{\pi}_{A2}^{pp,u} = -\frac{63}{1024}v^2 + \frac{27}{256}v + \frac{153}{256} \tag{32}$$

$$\underline{\pi}_B^{pp,u} = \frac{9}{512}v^2 - \frac{21}{128}v + \frac{49}{128} - F. \tag{33}$$

Remark 5. *When $\frac{3}{2} \leq v \leq 2$ 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, 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 of period 2. This is achieved by quoting a higher price in period 1 ($\underline{p}_1^{EA} > \underline{p}_M^{pp}$), serving less consumers in that period, and getting perfect information about a lower proportion of customers. By doing so, when entry is inevitable, the incumbent prices less aggressively under (PP,U).

Finally, we determine consumer surplus and social welfare. We look first at welfare, which in period 2 equals:

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

Consumer surplus is $\underline{CS}_2^{pp,u} = \underline{W}_2^{pp,u} - \underline{\pi}_{A2}^{pp,u} - \underline{\pi}_B^{pp,u}$, which yields:

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

In period 1 we get:

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

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

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

Therefore, when v is low, overall consumer surplus and welfare is:

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

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

Doing the same for the case where v is high ($v > 2$), social welfare in period 1 and 2 is respectively equal to:

$$\begin{aligned}
\overline{W}_2^{pp,u} &= \int_0^{\frac{3}{4}} (v-x)\,dx + \int_{\frac{3}{4}}^1 (v-(1-x))dx - F = v - \frac{5}{16} - F, \\
\overline{W}_1^{pp,u} &= \int_0^1 (v-x)dx = v - \frac{1}{2}.
\end{aligned}$$

Overall welfare is

$$\overline{W}^{pp,u} = 2v - \frac{13}{16} - F.$$

Consumer surplus in period 1 and 2 is, respectively $\overline{CS}_2^{pp,u} = v - 1$

$$\overline{CS}_2^{pp,u} = v - 1 \text{ and } \overline{CS}_1^{pp,u} = \frac{1}{2},$$

from which we get that overall consumer surplus is

$$\overline{CS}^{pp,u} = v - \frac{1}{2}.$$

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. Antitrust rules are better at condemning exclusionary conducts than exploitative ones. 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 highlights that in some circumstances it might be possible to qualify personalized pricing as an *exclusionary* abuse, specifically whenever an incumbent firm uses its consumer data and its pricing strategies to target lower prices to customers with a preference for competitors' products, in an attempt to foreclose the market. When this happens, the incumbent is able to maintain its dominant position with serious harm on competition and consumer welfare. Finally, following the 10th Amendment of the German Competition Act 2021, in assessing market dominance, particular account shall be taken of a company's access to data and its effects on market entry and competition. The refusal to provide access to such data (even in exchange for an adequate fee) may also constitute an important form of abuse in the digital economy.

Summing up, in markets relatively well represented by the features of this model, policy intervention is needed to foster competition and avoid consumer harm. Even though we have seen that a ban on PP can restore competition for a wide range of entry costs, it is important to stress that it could be difficult for public agencies to monitor that the dominant firm is effectively fulfilling the obligation.[15] Additionally, we will see that as long as entry occurs, consumers would be better off if public agencies impose the alternative remedy of mandatory information sharing, since it enables competitive PP, where firms are struggling for each consumer.

5 Mandatory information sharing

In the case of a company's exclusive access to competition-relevant data, a critical question relates to the nature of the remedy that could be used to restore competition and offset the harm to consumer welfare. As aforementioned, the promotion of some form of data openness intervention in digital markets (e.g. mandatory information sharing, data portability) is often

[15] Indeed, the firm may circumvent the remedy by setting a listed uniform price for the product, and then providing consumers with secret targeted discounts (based on their willingness to pay) that are difficult to detect.

mentioned as a key part of a digital competition policy reform agenda. In particular, this kind of policy intervention has been highlighted in competition authority studies or expert panels commissioned. To name a few, in the UK (Digital Competition Expert Panel, 2019), in the US (Stigler Committee on Digital Platforms, 2019) and in the recent OECD report on "Data Portability, Interoperability and Digital Platform Competition" (OECD, 2021). All of them argue that data openness can stimulate competition by making it easier for new entrants to attract users and potentially alleviate barriers to entry associated with data access (mainly, in those markets for which individual-level data is valuable).

As discussed, in our model the risk of competition harm is especially important in markets with intermediate entry costs $\frac{1}{8} < F \leq \frac{1}{2}$. Suppose that after the incumbent has made its data acquisition decision and just before entry decisions take place in stage 1 of period 2, a remedy of mandatory information sharing is imposed by an antitrust agency. If entry occurs, the entrant supports the entry cost F, and due to information exchange it has access to the information required to employ PP. We call this price regime (PP,PP).

We have seen that when $F > \frac{1}{8}$ the incumbent acts as an unconstrained monopolist, gathering perfect information for PP about consumers located on the interval $[0, x_1^{pp}]$, with $\underline{x}_1^{pp} = \frac{1}{3}(v+1)$ if $\frac{3}{2} \leq v \leq 2$, and $\overline{x}_1^{pp} = 1$ if $v > 2$.

Consider first the case where $v > 2$ and $\overline{x}_1^{pp} = 1$. Under information sharing, if firm B decides to enter both firms have perfect information about the location of all consumers in the market. Under PP each firm quotes the consumer located at x the personalized price $p_i^{pp,pp}(x)$, $i = A, B$. The pricing game in stage 2 of period 2 is similar to Thisse and Vives (1988). Thus, each firm's price schedule is:

$$\overline{p}_A(x) = \begin{cases} 1-2x & if \quad x \leq \frac{1}{2} \\ 0 & if \quad x > \frac{1}{2} \end{cases},$$

$$\overline{p}_B(x) = \begin{cases} 2x-1 & if \quad x \geq \frac{1}{2} \\ 0 & if \quad x < \frac{1}{2} \end{cases}.$$

with corresponding equilibrium profits:

$$\overline{\pi}_A^{pp,pp} = \frac{1}{4},$$
$$\overline{\pi}_B^{pp,pp} = \frac{1}{4} - F \text{ with } F \leq \frac{1}{4}.$$

Now consider the case where $\frac{3}{2} \leq v \leq 2$ and $\underline{x}_1^{pp} = \frac{1}{3}(v+1)$ with $\frac{5}{6} \leq \underline{x}_1^{pp} \leq 1$. In this case, the incumbent has perfect information about only a proportion of consumers, those who

bought its product in period 1, located on the interval $[0, \underline{x}_1^{pp}]$. It has no information at all about the remaining consumers, located on the interval $[\underline{x}_1^{pp}, 1]$. Again under information sharing both firms can set a personalized pricing $p_i^{pp,pp}(x)$ to the consumer $x \in [0, \underline{x}_1^{pp}]$, and a uniform price $p_i^{pp,pp}$ to the group of anonymous consumers, $i = A, B$. As $\underline{x}_1^{pp} > \frac{1}{2}$ each firm price schedule under (PP,PP) is:

$$\underline{p}_A^{pp,pp}(x) = \begin{cases} 1-2x & if \quad x \leq \frac{1}{2} \\ 0 & if \quad \frac{1}{2} < x < x_1 \end{cases},$$

$$\underline{p}_B^{pp,pp}(x) = \begin{cases} 2x-1 & if \quad \frac{1}{2} \leq x < x_1 \\ 0 & if \quad x < \frac{1}{2} \end{cases}.$$

Consider next each firm's price decision to the group of unidentified consumers located on the interval $[\underline{x}_1^{pp}, 1]$, $\underline{x}_1^{pp} = \frac{1}{3}(v+1)$ with $\underline{x}_1^{pp} \geq \frac{5}{6} > \frac{3}{4}$. The indifferent consumer is located at $\widetilde{x}$ given by $\widetilde{x} = \frac{1}{2} + \frac{p_B - p_A}{2}$. If $\frac{1}{2} + \frac{p_B - p_A}{2} = \underline{x}_1^{pp}$ no consumer buys from A and all consumers buy from B. If $\frac{1}{2} + \frac{p_B - p_A}{2} < \underline{x}_1^{pp}$ then $(\underline{x}_1^{pp} - \widetilde{x})$ consumers buy from A and $(1 - \widetilde{x})$ buy from B. Thus firm A and B profits are, respectively equal to:

$$\pi_A = \max\left\{\underline{p}_A^{pp,pp}(\underline{x}_1^{pp} - \widetilde{x}), 0\right\}$$
$$\pi_B = \min\left\{\underline{p}_B^{pp,pp}(1 - \underline{x}_1^{pp}), \underline{p}_B^{pp,pp}(1 - \widetilde{x})\right\}$$

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 $p_A^{pp,pp} = 0$. This is especially the case when $\underline{x}_1^{pp} > \frac{3}{4}$, which is the case when $\frac{3}{2} \leq v \leq 2$. Consequently, firm B's best-response in order not to lose the marginal consumer located at $\underline{x}_1^{pp}$ is to quote $\underline{p}_B^{pp,pp} = 2\underline{x}_1^{pp} - 1$. Therefore, in equilibrium we get

$$\underline{p}_A^{pp,pp} = 0 \tag{34}$$

$$\underline{p}_B^{pp,pp} = \frac{1}{3}(2v-1) \tag{35}$$

and each firm second-period profits when $\frac{3}{2} \leq v \leq 2$ are:

$$\underline{\pi}_A^{pp,pp} = \int_0^{\frac{1}{2}} \underline{p}_A^{pp,pp}(x)dx = \frac{1}{4},$$

$$\underline{\pi}_B^{pp,pp} = \int_{\frac{1}{2}}^{\underline{x}_1^{pp}} \underline{p}_B^{pp,pp}(x)dx + (1 - \underline{x}_1^{pp})\underline{p}_B^{pp,pp} = \frac{4}{9}v - \frac{1}{9}v^2 - \frac{7}{36} - F.$$

The remedy of data-openness through a mandatory information sharing, implies that in comparison to (PP,U), the incumbent makes lower profits while the entrant makes higher profits. As expected, while the entrant benefits from information sharing, the incumbent is clearly worse off. This suggests that if information sharing is not mandatory, then the incumbent firm will have greater incentives to deny the rival access to its customers' data (even in exchange for an appropriate fee).

Looking at firm B's entry decisions under information sharing, we can establish the following result.

Remark 6. *If by way of regulation the incumbent must exchange its consumer data with the entrant, then the entrant decides to enter so long as* $F \leq \overline{F}$ *with* $\overline{F} = \frac{4}{9}v - \frac{1}{9}v^2 - \frac{7}{36}$, *if* $\frac{3}{2} \leq v \leq 2$; *and* $\overline{F} = \frac{1}{4}$ *if* $v \geq 2$.

This result highlights that an information sharing remedy is, in fact, an effective policy tool to restore competition in the market. Specifically, it increases the likelihood of entrance in markets with entry costs $F \in \left]\frac{1}{8}, \overline{F}\right]$ with $\overline{F} \leq \frac{1}{4}$. If for instance $v = \frac{3}{2}$, $\overline{F} = \frac{2}{9} \simeq 0.222$. While entry would be blocked with no policy intervention, it becomes inevitable with a mandatory data sharing remedy so long as $F \leq 0.222$. If $v > 2$, entry occurs so long as $F \leq 0.25$, while it would be blocked if $F > 0.125$. Hence, information sharing can restore competition as long as $F \in \left]\frac{1}{8}, \overline{F}\right]$ with $\overline{F} = \frac{4}{9}v - \frac{1}{9}v^2 - \frac{7}{36}$ if $\frac{3}{2} \leq v \leq 2$; and $\overline{F} = \frac{1}{4}$ if $v \geq 2$.

Turn now to the determination of consumer surplus and overall welfare in case of a mandatory information sharing. Consider first period 2. When $v > 2$, consumer surplus and welfare in period 2 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 $\frac{3}{2} \leq v \leq 2$, we obtain:

$$\begin{aligned}
\underline{CS}_2^{pp,pp} &= \int_0^{\frac{1}{2}} \left[v - \underline{p}_A^{pp,pp}(x) - x\right] dx + \int_{\frac{1}{2}}^{\underline{x}_1^{pp}} \left[v - \underline{p}_B^{pp,pp}(x) - (1-x)\right] dx \\
&\quad + \int_{\underline{x}_1^{pp}}^1 \left[v - \underline{p}_B^{pp,pp} - (1-x)\right] dx \\
&= \frac{1}{9}v^2 + \frac{5}{9}v - \frac{11}{36},
\end{aligned}$$

and

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

Taking into account the two periods, and that in period 1 the incumbent acts as an unconstrained monopolist anticipating the possibility of using consumer data for PP, we get that under information sharing (IS) firm A's total profits are $\pi_A^{IS} = \pi^{pp} + \pi_A^{pp,pp}$, firm B's profits are $\pi_B^{IS} = \pi_B^{pp}$, overall consumer surplus and welfare are respectively, $CS^{IS} = CS^{pp} + CS^{pp,pp}$ and $W^{IS} = W^{pp} + W^{pp,pp}$. When $v > 2$ we obtain:

$$\overline{\pi}_A^{IS} = \overline{\pi}^{pp} + \overline{\pi}_A^{pp,pp} = v - \frac{3}{4},$$

$$\overline{\pi}_B^{IS} = \frac{1}{4} - F,$$

$$\overline{CS}^{IS} = \overline{CS}_1^{pp} + \overline{CS}_2^{pp,pp} = v - \frac{1}{4},$$

$$\overline{W}^{IS} = \overline{W}^{pp} + \overline{W}^{pp,pp} = 2v - \frac{3}{4} - F;$$

when $\frac{3}{2} \leq v \leq 2$ we obtain:

$$\underline{\pi}_A^{IS} = \underline{\pi}_A^{pp} + \underline{\pi}_A^{pp,pp} = \frac{2}{9}v^2 + \frac{1}{9}v + \frac{5}{36},$$

$$\underline{\pi}_B^{IS} = \frac{4}{9}v - \frac{1}{9}v^2 - \frac{7}{36} - F,$$

$$\underline{CS}^{IS} = \underline{CS}_1^{pp} + \underline{CS}_2^{pp,pp} = \frac{1}{6}v^2 + \frac{2}{3}v - \frac{1}{4},$$

and

$$\underline{W}^{IS} = \frac{5}{18}v^2 + \frac{11}{9}v - F - \frac{11}{36}.$$

6 Welfare analysis

This section looks at profits (π_i, $i = A, B$), consumer surplus (CS) and social welfare (W) under the different market structures and price regimes we have analysed so far. To ease discussion, Tables 1 and 2 present firms' profits, consumer surplus and welfare using two numerical examples: (i) $v = 1.8$ (for $\frac{3}{2} \leq v \leq 2$) and (ii) $v = 3$ (for $v > 2$). Appendix B presents the exact expressions for profits, consumer surplus and welfare for the two cases: v low, $\frac{3}{2} \leq v \leq 2$; and v high, $v > 2$.

Table 1: $v = 1.8$

Pricing	π_A	π_B	π_{ind}	CS	W
U	1.62	0	1.62	0.81	2.43
PP	2.107	0	2.107	0.438	2.544
(U,U) & $F \leq \frac{1}{2}$	1.31	$0.5 - F$	$1.81 - F$	0.955	$2.765 - F$
(PP,U) & $F \leq \frac{1}{8}$	1.356	$0.144 - F$	$1.5 - F$	1.005	$2.505 - F$
(PP,PP) & $F \leq \overline{F} \leq \frac{1}{4}$	1.059	$0.246 - F$	$1.305 - F$	1.490	$2.795 - F$

Table 2: $v = 3$

Pricing	π_A	π_B	π_{ind}	CS	W
U	4.0	0	4.0	1	5.0
PP	4.5	0	4.5	0.5	5.0
(U,U) & $F \leq \frac{1}{2}$	2.5	$0.5 - F$	$3 - F$	2.25	$5.25 - F$
(PP,U) & $F \leq \frac{1}{8}$	2.563	$0.125 - F$	$2.688 - F$	2.5	$5.188 - F$
(PP,PP) & $F \leq \overline{F} \leq \frac{1}{4}$	2.25	$0.25 - F$	$2.5 - F$	2.75	$5.25 - F$

Based on the expressions presented in Appendix B, Proposition 5 summarizes the welfare results when there is no policy intervention at all.

Proposition 5. *With 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 with high entry costs where entry is blocked $\left(F > \frac{1}{8}\right)$, the use of data by an incumbent monopolistic firm for price discrimination harms consumers at the expense of profits. However, if $\frac{3}{2} \leq v \leq 2$, price discrimination can boost social welfare due to the demand expansion effect.

Proof. The proof of this proposition is straightforward taking into account the expressions presented in Appendix B.

The next proposition summarizes the main consumer and welfare results under two types of policy intervention, a ban on price discrimination and a data openness approach through a mandatory information sharing remedy.

Proposition 6. *With policy intervention:*

(i) If the use of data for price discrimination is not permitted, entry occurs if $F \leq \frac{1}{2}$, boosting consumer surplus and overall welfare. *However, if* $F \leq \frac{1}{8}$, *regardless of* v, *consumer surplus is higher when an incumbent firm, with access to data, is able to engage in personalized prices (PP,U), than if it is forced to quote a uniform price (U,U).*

(ii) When $\frac{1}{4} < \overline{F} \leq \frac{1}{2}$, *a policy of banning the use of data for price discrimination restores competition in the market (while a mandatory information sharing does not), allowing consumer surplus and overall welfare to increase, in comparison to the monopoly case.*

(iii) An information sharing mandatory policy restores competition for entry costs $\frac{1}{8} < \overline{F} \leq \frac{1}{4}$ *and boosts consumer surplus and aggregate welfare at the expense of profits. Indeed, in this case, consumer welfare gains are greater under an information sharing policy than under a ban on price discrimination.*

Proof. The proof of this proposition is straightforward taking into account the expressions presented in Appendix B.

To close this section, we discuss under what market conditions an incumbent's exclusive access to data is expected to harm competition and consumer welfare and the impact on market structure and welfare of two policy tools−(i) a ban on the use of data for price discrimination or (ii) a mandatory information sharing. We take the view that consumer welfare is the appropriate perspective to motivate competition policy.

Data access for PP raises no barrier to entry: In markets where the likelihood of entry is high due to sufficiently low entry costs (i.e., $0 \leq F \leq \frac{1}{8}$), consumers are clearly better off in comparison to a monopoly market. More interestingly, Proposition 5 highlights that consumers as a whole are better off under (PP,U) than under (U,U). The expressions presented in Tables 1B and 2B (Appendix B) reveal 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, personalized pricing 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 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 personalized pricing favours 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, for instance, to privacy and fairness issues, which is beyond the scope of this model, competition authorities that prioritize the promotion of consumer welfare may find no good reasons to prohibit the use of data for PP by an incumbent when entry is inevitable. 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. Nevertheless, it is important to stress that even when there is no harm of exclusion, an information sharing remedy promoting (PP,PP) is an effective remedy to boost consumer surplus and reduce the risk of exploitation (in comparison to (PP,U)).

Data access for PP raises a barrier to entry: As aforementioned, in terms of policy intervention, the most relevant markets are those exhibiting intermediate entry costs, specifically $\frac{1}{8} < F \leq \frac{1}{2}$. If the incumbent were not able to charge personalized prices, either because it has no data or because price discrimination is, for any reason, not permitted, the competitor would always decide to enter. In contrast, if the incumbent is able to compete with personalised pricing, then its data/pricing flexibility advantage acts to exclude the rival from the market. Our analysis highlights that absent any policy intervention, the incumbent's data acquisition (for future price personalisation) in an early stage, will clearly raise a barrier to entry, with significant harm on consumer and social welfare ($CS^{pp} - CS^{pp,pp} < 0$ and $W^{pp} - W^{pp,pp} < 0$). Firm B would decide to stay out of the market and firm A would be able to sustain its monopoly position and capture 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*.

In markets like this, a critical question relates to the nature of the remedy that can offset consumer harm and restore competition. In such a situation, a competition authority might

restore the level of competition that would otherwise exist by (i) *not permitting the incumbent to use data for pricing* (U,U) and (ii) *by mandating the incumbent to grant some form of access to its data to the entrant* (PP,PP).

We have seen that a ban on PP would restore competition at (U,U) for entry costs $F \leq \frac{1}{2}$, at the benefit consumers and overall welfare. Another policy intervention is to pursue data openness as a tool to increase competition in markets where $F \leq \frac{1}{4}$. When all competing firms have access to the same piece of information, the intensity of competition increases, with a positive impact on consumer welfare, which reaches its maximum value at (PP,PP) and on social surplus. When public agencies impose a mandatory information sharing, our analysis reveals that when entry becomes possible, i.e. when $\frac{1}{8} < F \leq \overline{F}$, then competition is restored and consumer harm is avoided: $CS^{pp,pp} > CS^{p,u} > CS^{u,u}$. Finally, it is important to stress that the comparison between a ban on PP and mandatory information sharing remedy, suggests that as long as entry occurs under PP ($F \leq \frac{1}{4}$) a mandatory information sharing remedy to promote competitive PP produces the better outcome in terms of consumer welfare than a ban on PP. In contrast, when entry costs are sufficiently high, i.e., $\frac{1}{4} < F \leq \frac{1}{2}$, competition can only be restored and consumer harm avoided as long as PP is not permitted. Hence, a ban on PP should be considered as a policy intervention to promote competition only in markets with high entry costs ($\frac{1}{4} < F \leq \frac{1}{2}$).

7 Policy issues and final remarks

As aforementioned, the 10th Amendment of the German Competition Act which entered into force on January, 19 2021, addresses abuse of dominance and is intended to further shape and complete the regulatory framework of competition in the digital economy. Following the Amendment, market power might arise from the fact that a company is dependent for its own business strategies, like pricing, on access to data controlled by another company.

Additionally, according to a recent report by the UK's Digital Competition Expert Panel on competition in digital markets (see Furman et al., 2019) companies active in the digital economy are able to collect and hold huge volumes of customers' personal data, that represents an important asset enabling them to improve their understanding of customers' demands, habits and needs. This data-based consumer knowledge is key to support greater use of personalisation, in particular personalised pricing, where companies use their data-driven insights into consumers to set prices according to the individual's willingness to pay. Although such personalisation

can have some merits, such as allowing companies to serve more customers, in some cases it can harm competition, consumers and society as a whole. Following Furman et al. (2019) "Evidence suggests that large data holdings are at the heart of the potential for some markets to be dominated by single players and for that dominance to be entrenched in a way that lessens the potential for competition for the market.[...] in these circumstances, 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."

This manuscript has tried to shed some light on these issues by assuming that the collection and accumulation of consumer data by an incumbent company in the past can provide it with a powerful advantage to engage in personalized pricing in the future. If data collected is not replicable at all, or there are no alternative sources of information for rival firms, the incumbent exclusive access to data for PP can act to exclude new firms from the market with serious harm on consumers. The risk of competition and consumer harm from personalized pricing by a data holding incumbent firm might be addressed through different types of policy interventions. This manuscript has focused on two types of policy interventions: (i) a ban on personalized pricing and (ii) a mandatory data-sharing (or data openness) remedy.

In markets characterised by intermediate entry costs ($\frac{1}{8} < F \leq \frac{1}{4}$) and with no alternative sources of information for rival firms, our analysis highlights that a mandatory information sharing is an effective tool to foster competition and boost consumer welfare. Indeed, even in markets where entry is inevitable, due to low entry costs ($F < \frac{1}{8}$), a mandatory information sharing to promote competitive personalised pricing is proved to further boost consumer surplus in comparison to the case where only the incumbent employs PP ($CS^{pp,pp} > CS^{pp,u}$). In contrast, public agencies should consider a ban on the use of data for PP (or simply a ban on PP) in markets with sufficiently high entry costs. In these markets, a mandatory information sharing remedy would simply not produce the desired competitive outcome. Although the entrant profits are higher under (PP,PP) than under (PP,U), the equilibrium profits under (PP,PP) when $\frac{1}{4} < F \leq \frac{1}{2}$ are not enough to make entry profitable. In contrast, when $\frac{1}{4} < F \leq \frac{1}{2}$, a ban on PP is an effective tool to restore competition.

Finally, apart from the discussed policy led approaches to increase competition, which clearly offers benefits to consumers and facilitates the entry of new businesses, it is important to stress that competition might also be enhanced by promoting consumer led tools. Indeed, under the GDPR consumers are provided with control over their personal data. Specifically, the right to data portability gives individuals the right to receive personal data they have provided to a

company and also gives them the right to request that a company transmits this data directly to a competitor. This suggests that, in the context of our model, consumers could play an important role in affecting access to data, the scope for PP and competition.

Theoretically, if all consumers buying from the incumbent in period 1 decide to request this company to transfer their data to the new entrant, *data openness by means of data mobility* would produce the same competitive outcome than data openness by means of a *mandatory data sharing* policy. However, in practice, this is far from true. Firstly, consumers are not sophisticated enough to anticipate *how* data collection affects pricing and competition for the market and they are not able to understand clearly the benefits of sharing their personal data with competitors, moreover when we are talking about companies that are not yet in the market. Secondly, even if some consumers do request data mobility, others will certainly not do that. This might happen because they are not aware of this possibility, they don't have sufficient trust and understanding to take advantage of personal data mobility or simply because this is time consuming. While competition is not typically a key objective for the GDPR, more focused on data protection and privacy issues, we do believe that in the years to come personal data mobility will play an important pro-competitive role in data-driven markets. For this to happen, regulators should ensure that consumers have sufficient trust and understanding to take advantage of personal data mobility. For this to happen, regulators should ensure that consumers have sufficient trust and understanding to take advantage of personal data mobility.

At this stage, digital markets that are relatively well represented by the features of our model, data openness through, for instance, a mandatory information sharing, is an essential tool to promote entry of new businesses and avoid consumer harm. However, any approach to support a mandatory data sharing remedy will also have to ensure that robust privacy safeguards are adopted to respect the privacy rights and expectations of users. Requiring the opening up of a part of a business's legitimately obtained data would be a significant intervention. Companies would reasonably be concerned about the impact upon their business model, the legitimacy of requiring access to a significant asset, and the impact on incentives for investment in future data collection and management. Following Furman et al. (2019), public agencies and regulators should base its use in any digital market on a thorough analytical assessment that weighs these factors against the potential benefits, and considers whether less interventionist solutions would produce the desired competitive outcome.

Hence, the ubiquitous importance of data as a driver of a barrier to competition will further push competition and regulation bodies around the globe to take actions to improve and adapt

the regulatory frameworks for the digital economy. Competition should be at the heart of the discussion and consumer welfare should be the standard criterion. Any policy intervention should lead companies to produce better outcomes for consumers, helping new companies to enter and grow, and continuing to encourage existing companies to innovate.

8 Appendix A

This appendix collects the proofs that were omitted from the 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 $\pi = p\left(v-p\right)$, 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

$$\begin{aligned}\pi_A &= \int_0^{\frac{1+p_B^{pp,u}}{2}} p_A(x)dx \\ \pi_B &= \left(x_1-\frac{1+p_B^{pp,u}}{2}\right)p_B^{pp,u}+p_B^{pp,u}\left(1-x_1\right)-F\end{aligned}$$

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

$$p_A^{p,u}(x)=\begin{cases}\frac{3}{2}-2x & if \quad x\leq\frac{3}{4}\\ 0 & if \quad x\geq\frac{3}{4}\end{cases} \tag{36}$$

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

$$\begin{aligned}\pi_A &= \int_0^{\frac{3}{4}} p_A^{p,u}(x)dx=\frac{9}{16}\\ \pi_B &= \frac{1}{4}p_B^{pp,u}-F=\frac{1}{8}-F\end{aligned}$$

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 :

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

Thus

$$\begin{aligned}
\pi_A^o &= \int_0^{x_1} p_A^{pp,u}(x)dx \\
\pi_A^n &= p_A^{pp,u}\left(\frac{1}{2} + \frac{p_B^{pp,u} - p_A^{pp,u}}{2} - x_1\right) \\
\pi_B &= p_B\left(1 - \left(\frac{1}{2} + \frac{p_B^{pp,u} - p_A^{pp,u}}{2}\right)\right)
\end{aligned}$$

From the FOC we get

$$\begin{aligned}
p_A^{pp,u} &= 1 - \frac{4}{3}x_1 \\
p_B^{pp,u} &= 1 - \frac{2}{3}x_1 \\
\widetilde{x} &= \frac{1}{3}x_1 + \frac{1}{2}
\end{aligned}$$

From, $p_A^{pp,u}(x) = p_B^{pp,u} + (1 - 2x)$, we get that $p_A^{pp,u}(x) = 2\left(1 - x - \frac{1}{3}x_1\right)$ 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:

$$\pi_A^o = \int_0^{x_1} p_A(x)dx = \int_0^{x_1} \left(1 - \frac{2}{3}x_1 + 1 - 2x\right)dx = \frac{1}{3}x_1\left(6 - 5x_1\right)$$

$$\pi_A^n = \frac{1}{2} + \frac{8}{9}x_1^2 - \frac{4}{3}x_1$$

Firm A and B overall second-period profits are:

$$\pi_A^{pp,u} = \pi_A^o + \pi_A^n = \frac{1}{2} - \frac{7}{9}x_1^2 + \frac{2}{3}x_1$$

$$\pi_B^{pp,u} = \frac{2}{9}x_1^2 - \frac{2}{3}x_1 + \frac{1}{2} - F.\blacksquare$$

9 Appendix B

This appendix presents the general expressions for profits, consumer surplus and social welfare when v is low (Table 1) and when v is high (Table 2).

Table 1: Profits, consumer surplus and welfare when $\frac{3}{2} \leq v \leq 2$

Pricing	π_A	π_B	CS	W
U	$\frac{v^2}{2}$	0	$\frac{v^2}{4}$	$\frac{3v^2}{4}$
PP	$\frac{1}{6}v^2+\frac{4}{3}v-\frac{5}{6}$	0	$\frac{1}{9}v^2-\frac{1}{9}v+\frac{5}{18}$	$\frac{5}{18}v^2+\frac{11}{9}v-\frac{5}{9}$
(U,U)&$F \leq \frac{1}{2}$	$\frac{v^2}{4}+\frac{1}{2}$	$\frac{1}{2}-F$	$\frac{1}{8}v^2+v-\frac{5}{4}$	$\frac{3}{8}v^2+v-\frac{1}{4}-F$
(PP,U)&$F \leq \frac{1}{8}$	$\frac{9}{64}v^2+\frac{3}{16}v+\frac{9}{16}$	$\frac{9}{512}v^2-\frac{21}{128}v+\frac{49}{128}-F$	$\frac{153}{2048}v^2+\frac{563}{512}v-\frac{623}{512}$	$\frac{477}{2048}v^2+\frac{575}{512}v-\frac{139}{512}-F$
(PP,PP)&$F \leq \overline{F} \leq \frac{1}{4}$	$\frac{2}{9}v^2+\frac{1}{9}v+\frac{5}{36}+f$	$\frac{4}{9}v-\frac{1}{9}v^2-\frac{7}{36}-(f+F)$	$\frac{1}{6}v^2+\frac{2}{3}v-\frac{1}{4}$	$\frac{5}{18}v^2+\frac{11}{9}v-\frac{11}{36}-F$

Table 1: Profits, consumer surplus and welfare when $v > 2$

Pricing	π_A	π_B	CS	W
U	$2v-2$	0	1	$2v-1$
PP	$2v-\frac{3}{2}$	0	$\frac{1}{2}$	$2v-1$
(U,U) & $F \leq \frac{1}{2}$	$v-\frac{1}{2}$	$\frac{1}{2}-F$	$v-\frac{3}{4}$	$2v-\frac{3}{4}-F$
(PP,U) & $F \leq \frac{1}{8}$	$v-\frac{7}{16}$	$\frac{1}{8}-F$	$v-\frac{1}{2}$	$2v-\frac{13}{16}-F$
(PP,PP) & $F \leq \overline{F} \leq \frac{1}{4}$	$v-\frac{3}{4}+f$	$\frac{1}{4}-f-F$	$v-\frac{1}{4}$	$2v-\frac{3}{4}-F$

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