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Exclusive Data, Price Manipulation and Market Leadership

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Abstract

The unprecedented access of firms to consumer level data not only facilitates more precisely targeted individual pricing but also alters firms' strategic incentives. We show that exclusive access to a list of consumers can provide incentives for a firm to endogenously assume the price leader's role, and so to strategically manipulate its rival's price. Prices and profits are non-monotonic in the length of the consumer list. For an intermediate size, price leadership entails an equilibrium outcome characterised by supra-competitive prices and low consumer surplus. In contrast, for short or long lists of consumers, exclusive data availability intensifies market competition.

JEL Classification: D43; K21; L11; L13; L41; L86; M21; M31.
Keywords: Exclusive data, Personalised pricing, Price leadership, Strategic price manipulation.

1 Introduction

Firms' access to individual level data is unprecedented and it is influencing their interaction in the market. Tech giants such as Amazon, Apple or Google have collected, stored and analysed users' data for years (e.g., clicks, purchase histories, connected devices). Even brick and mortar companies like the British grocery retailer Tesco or Starbucks cafés have been accumulating data through loyalty programmes or other technological innovations. Most of these data is *exclusive* and can potentially be employed to personalise

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offers.[1] Exclusive data access, hence, is an asset that can deliver an advantage relative to rival firms competing in similar segments, which often have limited access to consumers' characteristics.

This article explores the issue of *exclusive access* to customer data and shows how this can affect firms' *competitive strategies*, in the forms of price leadership, tacit coordination and market segmentation. We present a model of price competition with horizontal product differentiation in which one firm has access to an exclusive list of consumer locations. Through this list, which only includes a share of all consumers in the market, the accessing firm (informed) can personalise its offers and price discriminate by matching the utility of the rival's offer for the profiled consumers. Whereas such consumers are anonymous only to the non-accessing firm (uninformed), the rest of the consumers remain anonymous to both firms. This setting allows us to study the impact of accessing exclusive consumer information on the strategic incentives of firms to lead in price competition. In particular, the two firms independently and simultaneously decide on whether to announce their price "early" or "late" (Hamilton and Slutsky, 1990). If their choices coincide, then simultaneous competition follows. Otherwise, the firm that selects "early" announces its price first and acts as a price leader. Then, the other firm sets its price after observing its rival's move.

We find that exclusive possession of data, by enabling personalised pricing, has the potential to dramatically affect firms' strategic incentives. When the share of identifiable consumers is small, both firms would prefer to be a follower rather than a leader. Being a price follower provides the opportunity to undercut the rival to obtain a higher profit than when leading (d'Aspremont and Gerard-Varet, 1980; Hamilton and Slutsky, 1990).

As the size of the list increases, the ability to price discriminate becomes an important strategic asset for a firm. A *novel mechanism* enabled by the exclusive information works through the linkage between the prices. The firm owning the list can induce the rival firm to raise its price by willingly posting a high price itself first. As a result, the rival can profitably undercut the price of the list-accessing firm in the anonymous segment and serve it entirely. The list-accessing firm can in turn serve consumers in the list segment by matching the utility the rival firm offers them at its relatively high price. Such a strategic price manipulation leads to a "win-win" scenario for both firms: the informed firm's price in the anonymous segment is high and so is the rival's undercutting price.

The mechanism described can generate enough profit from the identified consumers to induce the list-accessing firm to completely abandon the anonymous segment by setting a high price there in the first place. The strategy is also profitable to the uninformed follower, as long as the size of the list is not too large. In the latter case, the anonymous segment is very small and, as a result, the firm without access to data would find it profitable to compete also in the list segment by setting a low price that cannot be not matched by the informed firm. Therefore, the above mechanism no longer holds grows very large.

[1] Whereas all these practices are not new, "big data" are enabling increasingly precise (and often subtle) discrimination, particularly online (Mikians et al., 2012, 2013; Hannak et al., 2014).

There are real world markets in which the conditions exist for the forces highlighted by our model to operate. For instance, Amazon marketplace has revolutionised e-commerce. The platform has access to a huge volume of exclusive data on its users' browsing histories. This information can be used to personalise its product and price offers, which is often implemented through the "exclusive deals" reserved to certain groups of customers.[2] On the other hand, Dastin (2017) reports that engineers at Wal-Mart access Amazon's website several million times a day and "Wal-Mart relies on computer programs that scan competitors' prices, so it can adjust its listings accordingly".[3] These observations clearly hint at Amazon's potential practice of personalised pricing and price leadership.

Further, the coffee chain Starbucks uses its loyalty rewards app to collect geo-location and purchasing data.[4] These data are used to send app notifications and emails with personalised beverage and food offers. Established rival café chains are unlikely to have access to the same depth and precision of information. In the US, Dunkin' Donuts is currently updating and reviving its loyalty programme, whereas in the UK a close competitor, Costa, is only piloting a mobile ordering service (Comunicaffe, 2019; Tyko, 2019).

The previous examples underline the interactions between information rich leaders and less informed followers that our model effectively captures. Indeed, exclusive access to a sufficiently large list of customers can affect the leaders' pricing incentives, potentially setting the stage for the tacit coordination mechanism that our results highlight. Such anti-competitive effects do not always arise in equilibrium. We find instead that exclusive access to a very small or very large amount of data has a pro-competitive effect: it stimulates market competition by reducing prices and firms' profits. Our mechanism is even more likely to operate if being on the list is correlated with a preference for the firms who owns it. This scenario is particularly plausible in the case of grocery retailers' loyalty programmes: the usual clientele of Tesco, the largest supermarket chain in the UK, is more likely to sign up for Clubcard.[5] Similarly, it can also apply when a firm acquires targeted data from third party data holders (e.g., data brokers) or when an online marketplace exploits user information based on past transactions and browsing history.

The significance of our analysis is, then, to emphasise that exclusive access to consumer level information *can* lead to pro- or anti-competitive conduct, depending on the size of the list. Unlike most part of the received literature on competitive price discrimination (Thisse and Vives, 1988; Armstrong, 2006; Stole, 2007), consumers' information and segmentation might act as a coordination device that softens price competition, with enhanced profitability and surplus extraction from consumers.

[2] Evidence suggests that coupons on Amazon can be set to target specific groups such as Prime members, Amazon Student members, or Amazon Mom members, or be directed to customers who viewed or purchased certain items (Salesbacker.com, 2018).

[3] In the context of e-commerce, scraping the market leaders' prices is not unusual: the Portuguese Autoridade da Concorrência (2019) reports that almost half of the inquired firms systematically engaged in it.

[4] Starbucks even experimented licence plate recognition in its drive through affiliates (Hodgson, 2019).

[5] Empirical studies show that Tesco often leads in setting prices (Seaton and Waterson, 2013; Kim et al., 2020).

Further, the mechanism we highlight may provide one rationale for the recently documented online price rigidity. A large body of empirical evidence found that online prices do not change as frequently as conventional wisdom may suggest. Whereas online prices are usually more flexible than offline ones, their patterns are qualitatively comparable and remain stable for relatively long periods (Cavallo, 2017; Gorodnichenko and Talavera, 2017; Gorodnichenko et al., 2018). Our rationalisation, based on a coordination device, complements the existing literature associating substantial managerial costs with the process of revising prices (DellaVigna and Gentzkow, 2019; Ellison et al., 2018).

The rest of the article unfolds as follows. In Section 2 we briefly review the most closely related literature to further locate our contribution. Section 3 presents the model. Section 4 studies price competition. Section 5 presents the main results and their implications. Section 6 extends the model to allow for a correlation between user preference for a firm and being on its list. Section 7 provides a discussion of the testable and managerial implications of the main findings (Section 7.1) and of the policy insights of our analysis (Section 7.2).

2 Related literature and contribution

There is a vast literature on competitive price discrimination. A common finding is that, if firms are symmetric, price discrimination leads to lower profits relative to uniform pricing. The results are rooted in the so called "best response asymmetry": the "strong market" (less elastic segment) of one firm is the "weak market" (more elastic segment) of its rival, and vice versa (Thisse and Vives, 1988; Armstrong, 2006; Stole, 2007). Such an asymmetry makes firms more aggressive in their respective weak market, thereby leading to fiercer competition and low equilibrium prices. These forces are so robust that lead to similar results in models of "behaviour based price discrimination", whereby firms condition their prices to purchase history (Villas-Boas, 1999; Fudenberg and Tirole, 2000).[6]

Here, we focus on one stream of this literature which considers the effect of data endowment on firms' strategies.[7] In the marketing jargon, this has been referred to as "addressability", that is, the possibility to identify consumers and offer personalised prices (Blattberg and Deighton, 1991). In this regard, Chen and Iyer (2002) and Belleflamme et al. (2020) study competition between firms that have access to addressable segments, and price discrimination can be profitable if firms have heterogeneous degrees of addressability.

In Chen and Iyer (2002), investments in addressability partition the market into four

[6]See Fudenberg and Villas-Boas (2006) and Esteves (2009) for in depth reviews of the different developments of this literature. For more recent contributions see, e.g., Pazgal and Soberman (2008), Zhang (2011), Jing (2016) and Choe et al. (2017).

[7]Other streams of this literature have dealt with related issues such as privacy and its market implications (Taylor, 2004; Casadesus-Masanell and Hervas-Drane, 2015; Shy and Stenbacka, 2016; Anderson et al., 2019), pro- and anti-competitive effects of data (De Cornière and Taylor, 2020), modelling of the data broker industry (Bergemann and Bonatti, 2015, 2019; Bounie et al., 2020; Gu et al., 2019; Ichihashi, 2019), and data ownership (Dosis and Sand-Zantman, 2020).

segments, depending on whether consumers are profiled by both, one or none of the firms. This leads to two countervailing effects: on the one hand, a "surplus extraction" effect, whereby a firm cannot match its rival's price in a given segment; on the other hand, a "competitive effect" driven by the fiercer competition in the common addressable segment. Heterogeneity ensures that the first effect dominates for at least one firm; at the same time, the rival gets low profits as a result.

Belleflamme et al. (2020) consider a homogeneous product and identify three segments of consumers: those profiled by both firms, those only known to the informationally advantaged one and non-addressable consumers. In a mixed strategy equilibrium, the expected price is higher than marginal cost, and the informationally disadvantaged firm posts the highest price with non-zero probability. This relaxes the competition for consumers profiled only by the advantaged firm.

Although our analysis is related to theirs, there are important differences. Uniquely to our framework, it is endogenous timing and price leadership that offer a credible commitment and allow for price manipulation, firms' "coordination", and market segmentation. Moreover, equilibrium prices are non-monotonic in the size of the "addressable segment". On top of that, differently from Belleflamme et al. (2020), our model also features differentiated products and contains pure strategy equilibria. Furthermore, in Chen and Iyer (2002) the addressable segment is captive, whereas in our setting such a segment is contestable and segmentation arises endogenously. Finally, we reach the result of high prices and profitable price discrimination with a fully covered market: firms' prices do not "cut out" consumers, and hence do not alter the elasticity of the different segments (Pazgal et al., 2013).

Our approach to model consumer profiling resembles Montes et al. (2019) which, on the other hand, addresses a different question: how does a data broker optimally sell a list of consumers. They find that the revenue of the data owner is maximised through exclusive sale to one of the competing firms, that achieves addressability through the list. Montes et al. (2019) allow consumers to be removed from the database.[8] If the costs of preserving privacy is not too high, the consumers left on the list have a higher average willingness to pay. This leads the informed firm to post a high price and the uninformed does not compete for the addressable segment. This outcome is reminiscent of ours, but the forces in operation are different. In Montes et al. (2019), it is consumers' behaviour that enables better segmentation and prices higher than those in the standard Hotelling model; in our setting, instead, price leadership, together with an intermediate share of consumers on the list, enables both firms to charge a high price.

A second key contribution of our results is to the literature on timing in oligopoly games. The incentives to lead were studied in the pioneering articles of d'Aspremont and Gerard-Varet (1980) and Hamilton and Slutsky (1990). Price competition between identical firms is typically characterised by a second-mover advantage: even in the presence of differentiated

[8]Chen et al. (2020) also consider active consumers but with a different connotation: all consumers receive personalised offers but some search further for the posted prices.

products, the follower benefits from the possibility of undercutting (Gal-Or, 1985).[9] In this context, this article is closely related to Van Damme and Hurkens (2004) and Amir and Stepanova (2006). Both articles show that cost asymmetries between firms can overturn firms' strategic incentives and, if costs are sufficiently heterogeneous, the most efficient firm has an incentive to lead. The main difference is that in Van Damme and Hurkens (2004) deciding to move first requires commitment, whereas in Amir and Stepanova (2006) it does not.

Our article complements and adds to this literature by showing that technologically identical firms may still have an incentive to lead in price competition in the presence of heterogeneous access to an immaterial asset. Moreover, we also endogenise the timing of the pricing choice in the presence of price discrimination.

Finally, Rotemberg and Saloner (1990) consider an infinitely repeated game where in equilibrium a firm that is better informed about market-wise demand shocks sets its price first to allow for more profitable tacit price fixing. However, their sequential price setting differs fundamentally to the price manipulation mechanism studied in the present paper: in their model set the follower's incentive to undercut the leader is obliterated by the trigger strategy that supports the equilibrium price fixing outcome. In contrast, the leader in our model willingly let the follower undercut its price in the anonymous segment so as to gain higher profits in the profiled segment.

3 The framework

We consider a market in which two profit maximising firms sell a horizontally differentiated product to a unit mass of consumers by competing in prices. Let the two firms, $i = A, B$, be located at 0 and 1 on the Hotelling line, respectively. Each consumer demands at most one unit of the product. Consumers are uniformly distributed on the Hotelling line and indexed by their location $x \in [0, 1]$. Hence, for consumer x the indirect utility from buying product A at price p_A is $V_A = v - p_A - tx$, where v is a consumer's reservation value and t measures transport cost. Likewise, for consumer x the indirect utility from buying product B at price p_B is $V_B = v - p_B - t(1 - x)$. For both firms, we assume constant marginal cost of production which is normalised at zero. Throughout the article, we also assume that v is sufficiently large so that the market is covered.[10]

Turning to consumer information, we assume that one of the firms, without loss of generality, Firm A, has exclusive access to a list of consumers. For ease of exposition, we refer to it

[9]The importance of market leadership and of informational advantage is also highlighted by Calzolari and Pavan (2006). In their model of sequential contracting, an upstream seller can take advantage of its (exogenous) leadership by revealing or not some information to another seller. In our case, there is no information sharing but the informational advantage can induce a firm to act as a leader while influencing the rival one.

[10]More specifically, for our analysis, $v > 4t$ is sufficient.

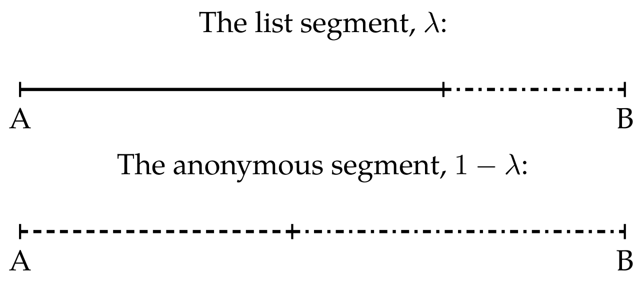


Figure 1: The market

Note: The figure presents the two segments of the market. λ represents the percentage of consumers who are identified by Firm A and can be offered a personalised price $\widetilde{p}_A(x)$. Those consumers can of course also observe p_B, Firm B's uniform price. For consumers in the anonymous segment, they observe both p_A (Firm A's uniform price for consumers it cannot identify) and p_B but are not offered the personalised price $\widetilde{p}_A(x)$. In this example, Firm A can match the utility Firm B offers with a personalised offer in the list segment up to a certain point (solid line). The rest buys from Firm B (dot-dashed line). In the anonymous segment, the usual purchase decisions as in the standard Hotelling model apply.

as the "informed firm" and to Firm B the "uninformed firm". The list is exogenously given and can be thought as having been previously obtained, through either a data broker or active collection. Although generic data are typically non-rival and often largely available to firms (e.g., data harvested on the Web), as discussed, customer-specific data can be rendered practically excludable or unequally commercially valuable: this happens both as a reflection of market players' unequal data endowment as well as their heterogeneous analytical capabilities (e.g., Amazon vs. Wal-Mart, Tesco vs. ASDA).[11]

Formally, Firm A's customer data availability is captured by the length of the list $\lambda \in (0, 1)$, which can be interpreted as the percentage of the consumers whose location x is known to A. This information enables price discrimination, as for those consumers who are on the list the firm can make personalised offers conditional on their location, i.e., offer $\widetilde{p}_A(x)$ to consumer x. As a result, Firm A can distinguish two segments of the market depending on whether or not a consumer is on the list. We refer to the former as the "list" segment and the latter the "anonymous" segment. For simplicity, we assume consumers in each segment to be uniformly located. Without any consumer information, Firm B, however, can only set one uniform price for its product. The model is illustrated in Figure 1.

In this setting, we study firms' strategic incentives to lead or to follow in price competition. To this end, consider the following extensive game. In the first stage, Firms A and B independently and simultaneously decide whether to announce their price for the *anonymous segment* early (τ_0) or late (τ_1). Depending on the outcome of the first stage, three different types of subgames follow.

In the two outcomes where the timing choices coincide, i.e., (τ_0, τ_0) or (τ_1, τ_1), in the second stage the two firms set their prices in the anonymous segment, p_A and p_B, independently

[11] In a looser interpretation, this assumption can also be thought as capturing firms' asymmetric data endowment, where the exclusive part available to one of the firms is crucial for implementing effective personalised pricing.

and simultaneously. Then, after observing Firm B's price p_B, in the third and final stage Firm A price discriminates in the list segment by setting a location dependent price schedule $\widetilde{p}_A(x)$ attempting to match the utility that the consumer located at x can obtain by buying from firm B at price p_B.

If the first stage outcome is (τ_0, τ_1), in the second stage Firm A sets a price p_A for the anonymous segment and then in the third stage Firm B chooses p_B after observing p_A. Finally, in the fourth and final stage, Firm A sets a schedule $\widetilde{p}_A(x)$ for the list segment.

Lastly, if the first stage outcome is (τ_1, τ_0), in the second stage Firm B sets a price p_B and then in the third and final stage Firm A chooses p_A for the anonymous segment and also $\widetilde{p}_A(x)$ for the list segment.

Note that we have assumed Firm A sets $\widetilde{p}_A(x)$ after observing p_B in all subgames. This reflects the observation that in this information age, Firm A can update its personalised prices more quickly than Firm B can adjust its uniform price. The game is solved by backward induction.

4 Price competition subgames

In this section we solve the three types of pricing subgames in turn, starting from simultaneous price competition in the anonymous market. We then proceed to characterise the outcomes when Firm B or A leads in the price competition, respectively.

4.1 Simultaneous price competition in the anonymous market

Suppose that either (τ_0, τ_0) or (τ_1, τ_1) has resulted in the first stage. In this case, the two firms set prices simultaneously.

To identify firm profits, we first consider Firm A's price schedule for the list segment in the last stage. Given p_B, Firm A's optimal list segment schedule $\widetilde{p}_A(x)$ should aim to match the next best alternative for consumers in the list segment. That is, Firm A may set $\widetilde{p}_A(x)$ for a consumer located at x in the list segment such that she is indifferent between buying from A or B:

$$\widetilde{p}_A(x) = p_B + t(1 - 2x). \tag{1}$$

This requires us to consider two cases depending on p_B.

First, if $p_B < t$, Firm A can only attract consumers up to $\bar{x} = {}^{(t+p_B)}/_{2t}$. This is because Firm B's price is so low that even if Firm A sets its price at zero for consumers to the right of $\bar{x}$, they would still buy from B due to savings on the transport cost. Thus, in the list segment, the profits of the firms are

$$\widetilde{\pi}_A = \int_0^{\bar{x}} \widetilde{p}_A(x)dx = \frac{(t+p_B)^2}{4t}, \tag{2}$$

$$\widetilde{\pi}_B = p_B(1-\bar{x}) = \frac{p_B(t-p_B)}{2t}.$$

For a given pair of uniform prices (p_A, p_B), the firms' respective total profits from both segments are

$$\pi_A = \lambda \frac{(t+p_B)^2}{4t} + (1-\lambda)p_A\left(\frac{1}{2} + \frac{p_B - p_A}{2t}\right),$$

$$\pi_B = \lambda \frac{p_B(t-p_B)}{2t} + (1-\lambda)p_B\left(\frac{1}{2} + \frac{p_A - p_B}{2t}\right).$$

Following the standard procedure, the candidate equilibrium is $p_A = \frac{3}{\lambda+3}t$ and $p_B = \frac{3-\lambda}{\lambda+3}t$. Note that $p_B < t$, indeed, holds.

Second, if $p_B \geq t$, then Firm B does not serve the list segment. As a consequence, the firms' best responses are entirely determined in the anonymous segment. Thus, the only candidate equilibrium is $(p_A, p_B) = (t, t)$, as in the standard Hotelling model. However, this is not an equilibrium since a profitable deviation exists for Firm B. We show this formally in Appendix A.1.

The following proposition summarises our main findings in this simultaneous pricing subgame.

Proposition 1. *The subgame perfect Nash equilibrium in a simultaneous pricing subgame consists of the unique pair*

$$p_A = \frac{3}{\lambda+3}t, \;\; p_B = \frac{3-\lambda}{\lambda+3}t.$$

The two firms' profits are

$$\pi_A = \frac{9(\lambda+1)}{2(\lambda+3)^2}t, \;\; \pi_B = \frac{(3-\lambda)^2}{2(\lambda+3)^2}t.$$

Proof: See Appendix A.1.

Proposition 1 provides interesting insights. First, it demonstrates that if prices are posted simultaneously, exclusive access to consumer data makes the market more competitive. Compared to the prices in the standard Hotelling model ($\lambda = 0$), Firm A's access to consumer information makes Firm B price more aggressively, in order to serve some of those consumers who are included in the list. As prices are strategic complements, this also results in a lower posted price charged by Firm A.

Second, for Firm B the price effect triggered by the rival's access to the list dominates, and it obtains a lower profit than in the absence of the list. In contrast, Firm A's profit increases with the length of the list, λ, thanks to its ability to price discriminate consumers in that segment. This observation highlights both the absolute and relative benefit of having access to consumer information, compared to the uninformed firm.

The above reasoning is supported by simple comparative statics, which shows that an increase in λ leads to fiercer competition and both posted prices, p_A and p_B, go down. Between p_A and p_B, Firm B's price decreases even faster: the uninformed firm has to compete more aggressively to attract consumers in the wider list segment and in the shrinking anonymous one. Increased price competition, however, still grants a profit advantage to the informed firm.

4.2 Firm B as the price leader

We now consider the subgame following (τ_1, τ_0) where Firm B first sets its posted price p_B, and then Firm A chooses its pricing after observing it. To organise our analysis, we proceed in two steps. First, we address Firm A's optimal schedule for the list segment and its best response in the anonymous segment after observing p_B (Lemma 1). Second, we present Firm B's optimal price at the beginning of this subgame (Proposition 2).

We start by characterising Firm A's best responses in the list segment and in the anonymous segment, respectively. When p_B is a viable option for consumer x, Firm A shall try to set $\widetilde{p}_A(x)$ to make her indifferent between buying A and B. However, as discussed in Section 4.1, if p_B is so low, such that Firm A has no chance of luring the consumer at x, any permissible price would be a best response. On the other hand, when p_B is so high that it is itself not a viable option for consumer x, $\widetilde{p}_A(x)$ shall make her indifferent between buying A or not buying at all. Lemma 1 summarises these results and, in addition, presents Firm A's best response in the anonymous segment, which also depends on the level of p_B.

Lemma 1. *For given $p_B \geq 0$ and $x \in [0,1]$, Firm A's optimal list segment schedule is*

$$\widetilde{p}_A(x) \begin{cases} = v - tx & \textit{if } p_B \geq v - t(1-x) \\ = p_B + t(1-2x) & \textit{if } \max\{(2x-1)t, 0\} < p_B < v - t(1-x) \\ \in [0, +\infty) & \textit{if } 0 \leq p_B \leq \max\{(2x-1)t, 0\} \end{cases}.$$

For a given $p_B \geq 0$, Firm A's best response price in the anonymous segment is

$$p_A(p_B) = \begin{cases} v - t, & \textit{if } p_B \geq v \\ p_B - t, & \textit{if } 3t \leq p_B < v \\ \frac{t}{2} + \frac{p_B}{2}, & \textit{if } 0 \leq p_B < 3t \end{cases}.$$

Proof: See Appendix A.2.

On the basis of Firm A's best responses (Lemma 1), we can now characterise Firm B's possible profits and its optimal choice when leading in price competition. First note that, when $p_B \geq 3t$, Firm A's best response is to match B's offer in the list segment and undercut entirely in the anonymous segment. Thus, firm B obtains no demand, and hence, such prices are clearly (weakly) dominated. So, we can focus on $p_B < 3t$.

Yet, there are two cases to be considered. If $t < p_B < 3t$, the price is relatively high and Firm B receives no demand in the list segment. Given A's best response in Lemma 1 and the profits in the anonymous segment, a candidate equilibrium is identified. If $p_B \leq t$, we proceed similarly. In this case, Firm B serves all those list consumers to whom Firm A is unable to match its offer, and a share of the anonymous segment. As long as the length of the list is not too short, an interior solution exists and a second candidate equilibrium is identified. Thus, the question for Firm B is when to set a price below or above t. By comparing Firm B's profits associated with these two candidate equilibrium prices, we can identify the share of consumers in the list for which Firm B is indifferent between choosing a relatively high and a low price. The details of these results are in Proposition 2 and its proof in Appendix A.3.

Proposition 2. *When Firm B leads in the price competition, the subgame perfect Nash equilibrium in this pricing subgame is as follows.*

(*i*) *If $\lambda \leq 3/5$, then the equilibrium prices are*

$$p_A = \frac{5}{4}t, \ \ p_B = \frac{3}{2}t,$$

with respective profits

$$\pi_A = \frac{25 + 23\lambda}{32}t, \ \ \pi_B = \frac{9}{16}(1 - \lambda)t.$$

(*ii*) *If $\lambda > 3/5$, then*

$$p_A = \frac{5 + \lambda}{4(1 + \lambda)}t, \ \ p_B = \frac{3 - \lambda}{2(1 + \lambda)}t,$$

with respective profits

$$\pi_A = \frac{(5 + \lambda)^2}{32(1 + \lambda)}t, \ \ \pi_B = \frac{(3 - \lambda)^2}{16(1 + \lambda)}t.$$

Proof: See Appendix A.3.

The results in Proposition 2 have an intuitive interpretation. If the share of consumers on the list is not too large ($\lambda \leq 3/5$), Firm B can charge a relatively high price ($p_B > t$) as a leader. In this case, giving up the list segment is not too costly and it is more than compensated by the higher profits made on the anonymous segment. Firm A, in fact, follows and responds with a lower yet relatively high price ($p_A > t$). On the other hand, as the list segment becomes important ($\lambda > 3/5$), Firm B would rather set a low price ($p_B < t$) to make sure that it attracts demand from the list segment too.

We note further that when the list is relatively small, prices are not affected by how many consumers can be actually profiled. However, an increase in the list size increases the share of market demand received by the informed firm, and hence increases its profit and decreases that of the uninformed firm. In contrast, if the list is sufficiently comprehensive, $\lambda > 3/5$, increasing the list size makes Firm B increasingly concerned of list segment profits, and induces it to place more weight on the low price designed to fend off A's matching offers in the list segment. This, in turn, enhances the competitive pressure on p_A in the anonymous segment, which then lowers the firms' profits.

4.3 Firm A as the price leader

Consider the subgame following (τ_0, τ_1) where Firm A chooses its price in the anonymous segment p_A first, and then Firm B sets its price p_B after observing p_A. Finally, Firm A sets the price schedule in the list segment, after observing p_B. To present the results in this section, we introduce two critical values of the list size, λ_1 and λ_2, with the property that $0 < \lambda_1 < \lambda_2 < 1$. For brevity, the exact expressions of λ_1 and λ_2 are given by (9) and (10) in Appendix A.4.1. The steps involved in demonstrating the results are, however, the following.

First, we identify the expressions of Firm B's profit function for any possible level of the posted prices, p_A and p_B. There are a number of cases to be considered as, for a given leader price p_A, the choice of p_B could result in the follower to face demand: (i) from no segment of consumers; (ii) from part of the anonymous segment; (iii) from part of the anonymous and the list segment; (iv) from all of the anonymous segment; (v) from all of the anonymous segment and part of the list segment.

Second, we derive Firm B's best response function. Intuitively, being the follower Firm B can always undercut Firm A in the anonymous segment. Hence, if Firm A posts a relatively low price, Firm B's best response also involves a low price, in which firms divide both segments of the market. If, instead, Firm A posts a relatively high price, Firm B can undercut in the anonymous segment and still post a fairly high price compared to the transportation cost, i.e., the equilibrium price in the standard Hotelling model. In this case, either the two firms divide both segments of the market or Firm B may be able to serve the anonymous segment on its own.

Finally, we can state Firm A's profit function taking into account Firm B's best responses. The optimal choice of the leader depends on the share of consumers on the list, λ. In particular, the thresholds identified at the beginning of this subsection, λ_1 and λ_2, result from comparing the profits of the leader in the identified candidate price equilibria. In fact, at the beginning of this subgame, Firm A picks the price that maximises its profit, anticipating Firm B's best responses.

Following the above steps, we can state the below proposition.

Proposition 3. *Consider the subgame following (τ_0, τ_1) where Firm A leads in the price competition. The subgame perfect Nash equilibrium in this pricing subgame is as follows.*

(*i*) *If $0 < \lambda < \lambda_1$, then the equilibrium prices are*

$$p_A = \frac{3-\lambda}{1-\lambda}\frac{t}{2}, \ \ p_B = \frac{5-3\lambda}{1-\lambda}\frac{t}{4},$$

with respective profits

$$\pi_A = \frac{(9-7\lambda)(1+\lambda)}{16(1-\lambda)}t, \ \ \pi_B = \frac{(5-3\lambda)^2}{32(1-\lambda)}t.$$

(*ii*) *If $\lambda_1 \leq \lambda \leq \lambda_2$, then*

$$p_A = v, \ \ p_B = v - t,$$

with respective profits

$$\pi_A = \lambda(v-t), \ \ \pi_B = (1-\lambda)(v-t).$$

(*iii*) *If $\lambda_2 < \lambda < 1$, then*

$$p_A \in \left[\frac{2+\lambda}{2\lambda}t, v\right], \ \ p_B = \frac{2-\lambda}{2\lambda}t,$$

with respective profits

$$\pi_A = \frac{(2+\lambda)^2}{16\lambda}t, \ \ \pi_B = \frac{(2-\lambda)^2}{8\lambda}t.$$

Proof: See Appendix A.4.

The results in Proposition 3 are important for the rest of the article. A key feature is that the equilibrium price and profits are *non-monotonic* in the share of consumers profiled in the list, λ.

To see this, consider each case in more detail. First, suppose the list is relatively short $(0 < \lambda < \lambda_1)$. In this case, Firm B's best response is

$$p_B(p_A) = \begin{cases} \frac{(1-\lambda)p_A + t}{2} & \text{if } 0 < p_A \leq \frac{t}{\sqrt{1-\lambda}} \\ \frac{p_A + t}{2} & \text{if } \frac{t}{\sqrt{1-\lambda}} < p_A \leq 3t \\ p_A - t & \text{if } 3t < p_A \leq v \end{cases}. \tag{3}$$

As explained above, Firm B always has an incentive to undercut in the anonymous segment, but (3) shows that the amount and the implications depend on the leader's price. Indeed, by anticipating this, the informed firm sets a uniform price $p_A = \frac{3-\lambda}{1-\lambda}\frac{t}{2}$. This is a relatively low price, and it enables Firm A to attract consumers in the anonymous segment. At the same time, setting an even lower price, $p_A \leq \frac{t}{\sqrt{1-\lambda}}$, would lead Firm B to best respond according to the first line of (3). However, this would hurt profits. A further alternative for Firm A would be to set a very high price, i.e., $p_A > 3t$, in the third line of (3). However, this would imply letting Firm B serve the whole anonymous segment. As the list segment is relatively small, such a high price would not be sufficient to maximise the profit of Firm A. As a result, in this first case, the equilibrium is characterised by relatively low posted prices, $p_A = \frac{3-\lambda}{1-\lambda}\frac{t}{2}$ and $p_B = \frac{5-3\lambda}{1-\lambda}\frac{t}{4}$.

Second, consider an intermediate size of the list ($\lambda_1 \leq \lambda \leq \lambda_2$). Unlike the above case, Firm A finds now profitable to set a very high price ($p_A > 3t$) and, indeed, pushes it to its maximum, i.e., the consumers' reservation value v. Whereas this implies giving up the anonymous segment, the relatively large share of consumers in the list makes it worthwhile. In fact, as Firm B's best response is to charge $p_B = v - t$, Firm A is guaranteed to serve all the list segment. As the price posted by Firm B is also high, Firm A's personalised offers are rather effective in extracting surplus from consumers. The outcome is profitable for both firms, with profits being $\pi_A = \lambda(v - t)$ and $\pi_B = (1 - \lambda)(v - t)$.

Hence, for an intermediate length of the list, exclusive data enable the price leader to achieve a manipulative and profitable outcome. The informed firm, in fact, chooses such a high price that no consumer ever pays. However, this strategy encourages the follower to undercut just enough and secure the whole anonymous segment. The informed firm can then "cash in" through personalised offers that attract all the consumers on its list. Indeed, the mechanism generates an endogenous market segmentation. In this case, the classical "best response asymmetry" of price competition is pushed to the limit: the breaking point is reached and each firm serves a fully separated segment.

Finally, a large share of consumers are on the list ($\lambda_2 < \lambda \leq 1$). As the list size increases beyond λ_2, the manipulative mechanism above cannot be sustained. The reason lies in the fact that, as noted above, Firm B makes profit only on the anonymous segment, which becomes proportionally smaller as a higher percentage of consumers are profiled. Therefore, Firm B's best response is no longer the high price, $p_B = v - t$, but a lower price. More in detail,

$$p_B(p_A) = \begin{cases} \frac{(1-\lambda)p_A+t}{2} & \text{if } 0 < p_A < \frac{2+\lambda}{2\lambda}t \\ \frac{2-\lambda}{2\lambda}t & \text{if } \frac{2+\lambda}{2\lambda}t \leq p_A \leq v \end{cases}.$$

As a result, by setting $p_B = \frac{2-\lambda}{2\lambda}t$, Firm B can serve all the anonymous segment but also a fraction of the list segment. The combined profit is larger than $(1 - \lambda)(v - t)$. If that is the case, Firm A is indifferent between any price above $\frac{2+\lambda}{2\lambda}t$, i.e., all the equilibrium prices are consistent with $p_B < p_A - t$. Moreover, it can be shown that Firm A does not have an incentive to decrease its price too much. When $p_A \leq t$, Firm B's best response is $p_B(p_A) = \frac{(1-\lambda)p_A+t}{2}$. The resulting candidate equilibrium features very low prices, but the wide list does not justify for Firm A competing too fiercely in posted prices to attract the relatively small share of consumers in the anonymous segment.

5 Incentive to lead and welfare implications

In this section we study the incentive to lead or to follow in the whole game, and how this crucially relates to the share of consumers on the list. We distinguish four cases using critical values identified in Propositions 2 and 3. For each of them, in Figure 4, Appendix A.5, we provide the normal form representation of the game, and hence, summarise the strategic situation faced by the firms.

A well understood and recurring result in the literature on price competition with endogenous timing is that a firm normally prefers to be the follower rather than the leader (d'Aspremont and Gerard-Varet, 1980; Hamilton and Slutsky, 1990, *inter alios*). This holds true also in our setting for the uninformed firm: indeed, the following lemma confirms that Firm B's profits are always higher when it follows than when it leads.

Lemma 2. *For all $0 < \lambda < 1$, Firm B earns more profits in (τ_0, τ_1) than in (τ_1, τ_0).*

Proof: See Appendix A.5.

The question at this point, however, is to uncover Firm A's incentives to lead. We can then state the following results.

Proposition 4. (i) *For any given length of the list, the game has two, and only two, subgame perfect Nash equilibria in our market game. (τ_0, τ_1) and (τ_1, τ_0).*

(ii) *If the list is sufficiently long, $\lambda > \hat{\lambda} = \frac{25t}{32v-55t}$,*

- (a) *Firm A's profit is higher as a price leader than as a price follower, and*
- (b) *the equilibrium (τ_0, τ_1) is payoff dominant.*

Proof: See Appendix A.6.

Proposition 4 contains the main findings of the article. First, and consistent with the received literature on price competition with endogenous timing, the normal form game (Figure 4, Appendix A.5) always has two pure strategy equilibria, (τ_0, τ_1) and (τ_1, τ_0). No matter what is the share of the consumers on the list of Firm A, one of the firms leads and the other follows. This standard outcome extends to the context of price discrimination enabled by consumer level information.

Second, if the share of consumers on the list is relatively small ($0 < \lambda \leq \hat{\lambda}$), the usual logic of price competition applies: both the firms would be better off as followers rather than leaders. Firms clearly face a coordination problem and it is hard to predict which firm ends up leading. Relying on a refinement like payoff/Pareto dominance (Harsanyi and Selten, 1988) does not lead to a conclusion in this case.

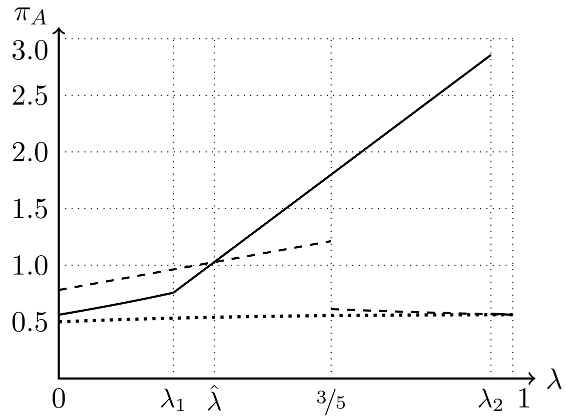
As the list becomes more comprehensive, however, incentives and strategies do change. By part (ii) of Proposition 4, a clear payoff ranking between the outcomes can be found as long as the share of consumers profiled exceeds the threshold $\hat{\lambda} = {}^{25t}/_{32v-55t}$. In this case, access to consumer information enables a novel mechanism, operating through the linkage between the prices. The firm owning the list benefits from leading, as it can induce the rival firm to raise its price, which in turn can make price discrimination in the list segment more profitable.

More importantly, if the list consists of an intermediate share of consumers, $\hat{\lambda} < \lambda \leq \lambda_2$, the payoff dominant outcome is characterised by high prices and profits. In this interval, as discussed in section 4.3, the firms "specialise" on different segments of the market. This result is innovative and contributes to the literature. The access to exclusive consumer information and the consequent price discrimination does give the informed firm an incentive to lead in price competition, provided that only an intermediate share of consumers is profiled. Unlike Van Damme and Hurkens (2004) and Amir and Stepanova (2006) endogenous price leadership stems from an immaterial asset, rather than productive efficiency.

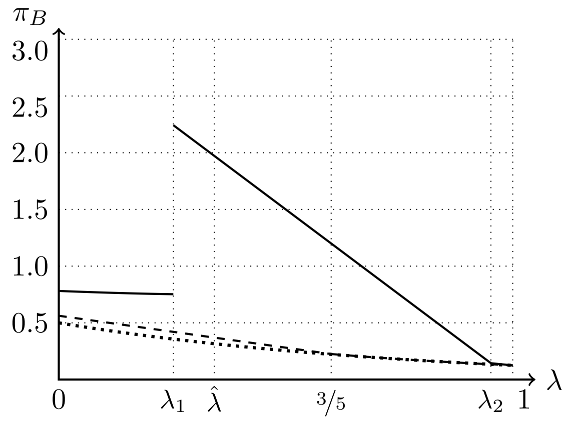
Interestingly, the highlighted mechanism works as a credible commitment of Firm A towards Firm B: by doing so, Firm A anticipates and allows Firm B's undercutting, but starting from a high initial price. This way, Firm A manipulates B's strategies and reaps high profits from consumers in the list segment. Crucially, this is also in the interest of Firm B and constitutes a coordination device in which both firms charge high prices.

Last but not least, if $\lambda_2 < \lambda < 1$, the list segment becomes too appealing and the uninformed firm competes to attract consumers there. As a result, it reduces its price to such a level that cannot be matched by the rival's offers for some consumers in the list. Despite the drop in profits, Firm A's incentive to lead remains.

Figure 2 illustrates the above findings through an example, where $v = 4$ and $t = 1$. Firm A's profit (top panel) when leading the price competition is depicted as a solid line. The dashed line represents Firm A's profit when it follows. The dotted line is Firm A's profit in simultaneous price competition. As it can be seen in the graph, A's profit in simultaneous price competition is always below that in a sequential price competition. Moreover, A's profit as a leader is higher than that as a follower when $\lambda > \hat{\lambda} = 0.342$. In contrast, by the same logic as in a traditional symmetric sequential price game, Firm B's profit (bottom panel) when moving as a follower (solid line) is always higher than that in any of the other two scenarios.



(a) Firm A's profits.



(b) Firm B's profits.

Figure 2: Length of the list and firms' profits ($v = 4$, $t = 1$).

Note: The figure presents the profits of Firm A (panel a) and Firm B (panel b) in the different subgames, as a function of the length of the list λ. The solid line identifies the case in which Firm A leads, whereas the dashed line the case in which it follows. The dotted line identifies simultaneous price competition.

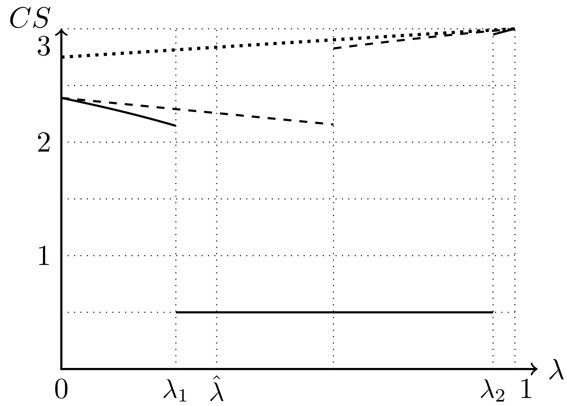
5.1 Welfare implications

The above findings have important implications not only for firm profits but also for consumer surplus and social welfare. We define the latter as the sum of the industry profit and consumer surplus. The next proposition summarises the main result.

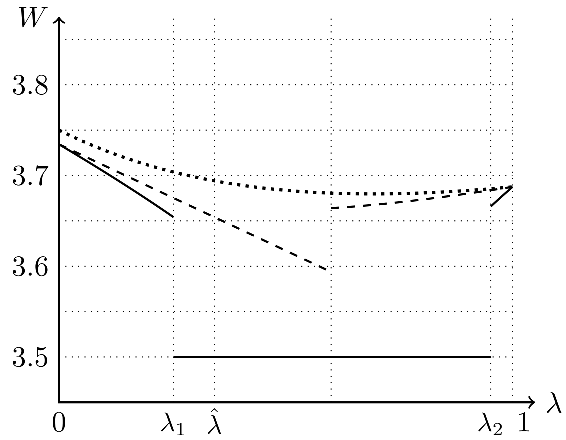
Proposition 5. *Both consumer surplus and social welfare are the lowest when the informed firm leads.*

Proof: See Appendix A.7.

Proposition 5 indicates that an informed price leader would be socially inefficient relative to when firms set prices simultaneously or when the uninformed firm leads. Interestingly, the fall in social welfare is driven by the very high transport costs imposed to consumers. In fact, for an intermediate length of the list, each firm exclusively serves one of the segments



(a) Consumer surplus.



(b) Social welfare.

Figure 3: Consumers surplus and social welfare ($v = 4, t = 1$).

Note: The figure presents consumer surplus (panel a) and social welfare (panel b) in the different subgames, as a function of the list size λ. The solid line identifies the case in which Firm A leads, whereas the dashed line the case in which it follows. The dotted line identifies simultaneous price competition.

of the market. As a result, on average, there is substantial mismatch between consumer taste and the product they buy. For example, consumers with strong preferences for Firm B would buy the product from Firm A if the latter firm profiles them and makes a personalised offer. This results in an inefficient product allocation. Such mismatch is less pronounced when the uninformed firm leads or when firms compete simultaneously.

Figure 3 graphically summarises the above discussion and provides further insights. The top panel presents the consumer surplus, whereas the bottom panel presents the social welfare. The solid line indicates the scenario in which Firm A leads, the dashed line the case in which it follows, and finally the dotted line the case of simultaneous price competition.

First, we note that the regime that maximises consumer surplus and social welfare is that of simultaneous competition which, however, never arises in an equilibrium.

Second, the difference between Firm A leading or following is minimised at the extremes, that is, when a very small or a very large percentage of consumers are profiled. When the size of the list is very small, there is no payoff dominant Nash equilibrium. On the other hand, for a very comprehensive list, Firm A inefficiently leads in the payoff dominant equilibrium. However, in this case the difference between the regimes narrows for both consumer surplus and social welfare. We further note that consumer surplus is maximal when (almost) everyone is profiled as this entails a very large pro-competitive effect.

Last but not least, for an intermediate size of the list, that is, when firms coordinate on high prices, consumer surplus reaches its minimum. Such a result is driven both by high mismatch costs (i.e., transport costs) and the very high prices set by firms in the different segments of the market. Clearly, the former effect is the main driver of the sharp reduction in social welfare, which also reaches its minimum.

6 Correlated preferences on the list

In this section, we explore a variant of our model and show that the main insights are robust to this variation. More specifically, suppose the share of consumers on the list, λ, for which Firm A exclusively has access to, is uniformly distributed on $[0, 1/2]$ (rather than $[0, 1]$). This is an extreme situation for the case in which consumers that are on the list also have a preference for that firm. For instance, one firm has acquired granular data from a data broker, and those are from consumers with potential interests for the firm.

Similarly, one may also imagine a scenario in which an online marketplace, like Amazon, has exclusive access to data of its users regarding past transactions and browsing histories that can help infer preferences. Another case may arise when considering supermarkets and retail chains, that collect scanner data from their customers. In this light, the proposed setting may suit well the example of loyalty cards, as in the case of British grocery chains where Tesco uses its own Clubcard programme. Its main competitors either do not collect data, such as Asda, or introduced similar programmes more recently.[12]

Intuitively, the model changes as follows. The consumers in the list segment are hard to reach for Firm B. Indeed, they are basically "captive" to Firm A: even if Firm B charges a very low price, its offer can still be matched by Firm A. This can be seen through equation (1): even $p_B = 0$ would not ensure that Firm B gets any demand on the list segment.

In turn, the incentive to set a high price and to lead in the price competition for Firm A is *unaffected*. This is because both the profits for a short ($0 < \lambda \leq \lambda_1$) and an intermediate or a long ($\lambda > \lambda_1$) list increase by the same amount, reflecting the additional revenues obtained on the captive list segment. Hence, the threshold λ_1 obtained in the previous analysis still holds.

Moreover, as Firm B is cut out of the list segment and can only attract the anonymous

[12]For example, Sainsburys' loyalty programme has been lagging behind Tesco's Clubcard (Company Cards, 2013). More recently, the budget chain Lidl also launched its own loyalty app (Radojev, 2020).

consumers, the incentive in the standard case to decrease its price when the list segment gets too large to ignore is no longer present. This implies that there is no λ_2.

Indeed, the semi-collusive outcome identified in the standard case also applies in the presence of correlated preferences, and the parameter range in which prices are supra-competitive gets wider. We can therefore state the following proposition.

Proposition 6. *Suppose consumers on the list are uniformly distributed on* $[0, 1/2]$.

(i) *The subgame perfect Nash equilibrium in a simultaneous pricing subgame consists of the unique pair*

$$p_A = p_B = t.$$

(ii) *When Firm B leads in the price competition, the subgame perfect Nash equilibrium in this pricing subgame consists of the unique pair*

$$p_A = \frac{5}{4}t, \;\; p_B = \frac{3}{2}t.$$

(iii) *When Firm A leads in the price competition, the subgame perfect Nash equilibrium is as follows.*

 (a) *If* $0 < \lambda < \lambda_1$, *then the equilibrium prices are*

$$p_A = \frac{3-\lambda}{1-\lambda}\frac{t}{2}, \;\; p_B = \frac{5-3\lambda}{1-\lambda}\frac{t}{4},$$

 (b) *If* $\lambda_1 \leq \lambda < 1$, *then the equilibrium prices are*

$$p_A = v, \;\; p_B = v - t.$$

(iv) *If the list is sufficiently long,* $\lambda > \hat{\lambda} = \frac{25t}{32v-55t}$, *Firm A's profit is higher as a price leader than as a price follower, and the equilibrium* (τ_0, τ_1) *is payoff dominant.*

Proof: See Appendix A.8.

One may note that less extreme situations, whereby consumers are distributed on a wider subset of the Hotelling line (i.e., $[0, x_A]$, $1/2 < x_A < 1$), would lead to qualitatively similar conclusions, but at a cost in terms of analytical complexity. Similar results would also apply in case Firm B has access to a relatively small amount of exclusive information about consumers with preferences for its product. To see this, suppose Firm B has access to a shorter list than Firm A does (e.g., the list of Firm B has length $\lambda_B < \lambda_A$ and features consumers located relatively close to Firm B). In such a scenario, Firm A's incentive to lead and focus only on its own list segment can still be present, so long as its own list segment is large enough. On the contrary, Firm B would profitably maintain its market reach in the anonymous segment, by charging a very high uniform price, and also extract further surplus by charging personalised prices to those consumers in its list.

7 Discussion

7.1 Managerial and testable implications

Several managerial and testable implications are arising from our model. First, the coordination outcome that we identified can also be interpreted as a form of co-opetition (Nalebuff and Brandenburger, 1997). Our results suggested that securing such a successful "coordination" depends on both the ability to manipulate the uniform price through leadership and the ability to price discriminate profiled consumers. Hence, a firm should invest in profiling technologies to gain exclusive access to a number of consumers and then signal to rivals price leadership. However, excessive profiling may disrupt co-opetition.

Second, we rationalise the overwhelming evidence of price rigidity occurring in both online and more traditional markets. While online prices are generally perceived more flexible than prices in offline chains, recent studies have found that they are qualitatively comparable and online prices do not vary so frequently (Cavallo, 2017; Gorodnichenko and Talavera, 2017; Gorodnichenko et al., 2018). The literature has so far identified how managerial inertia and behavioural factors might explain why retail chains prefer not to adopt local prices but instead rely on uniform or semi-uniform prices (DellaVigna and Gentzkow, 2019). Our analysis suggests that price rigidity might also be explained by a coordination of price leaders and followers, yielding supra-competitive prices. For example, if endowed with exclusive access to data, dominant companies such as Amazon.com might manipulate the incentives of rivals, inducing market segmentation and coordination on high prices.

Such a coordination would be more likely to apply in industries in which prices are more transparent or, for example, where offline rivals monitor and collect online prices. As online firms are more likely to collect data, our analysis identifies that they would find it optimal to move as a price leader to influence the pricing behaviour of firms with a less developed online presence. The exclusive access to the list and the size of the profiled consumers' segment, however, are key to generate the above coordination. Collecting and using too little data or too much data might trigger harsh competition and, hence, hurt firms' profits.

Moreover, the underlying mechanisms we described can also operate in offline markets, such as the grocery sector where loyalty programmes are quite common and facilitate the collection of exclusive information on consumers. As price leadership is a historical feature of this market, prices are generally publicly available (e.g., brochures, online websites) and often uniform across stores (DellaVigna and Gentzkow, 2019), coordination on pricing along the lines of the present paper can potentially apply. Indeed, the UK grocery sector is an example of the presence of both competition and coordination, with both major players acting as leader (Seaton and Waterson, 2013).

Finally, we studied the impact of exclusive access to data in the context of competition between retailing firms. However, the price manipulation mechanism enabled by information and endogenous leadership may apply and provide insights in other settings where agents have access to exclusive information. For instance, in a directed search labour market (Wright et al., 2020), employers can be highly asymmetric in their information about relevant candidates' characteristics (e.g., specialisation, skills, work location preferences, housing, alternative job offers). A similar mechanism may also apply in financial markets (Pagano and Jappelli, 1993), where some big players feature a competitive advantage over rivals. In this sense, our model provides the rationale for coordination to take place in different markets which can be further investigated in empirical analyses.

7.2 Policy implications

The delicate balance between the market power and its potential abuse is one of the key challenges for the long run sustainability platform ecosystems and data-driven business models (Parker et al., 2020). Competition policy authorities and scholars from different fields (e.g., economics, law, computer science) have been increasingly paying attention to the development of data analytics and the large amount of data harvesting. On the one hand, the legal literature suggests that big data constitute a source of entry barriers or, more generally, competitive advantage (Stucke and Grunes, 2016; Graef, 2017). On the other hand, others argue that data are non-rival and non-excludable, and access to them does not, *per se*, lead to anti-competitive concerns (Varian, 2018; Tucker, 2019).[13] Specific to personalised offers, recent studies and policy reports highlighted that the impact of data-driven price discrimination on consumer welfare is mostly ambiguous (Taylor and Wagman, 2014; Bourreau et al., 2017; Bourreau and de Streel, 2018), although "exclusive possession of data, combined with a lack of engagement by consumers, can lead to a lack of competitive pressure" (Furman et al., 2019, p 34).

In this context, we studied the impact of exclusive data availability on the incentives of competing firms to lead or follow in price competition. We found that when a sufficient share of consumers is identified, the ability to price discriminate enabled by data becomes an important strategic asset, and the informed firm has an incentive to lead in the pricing game and manipulate the rival's pricing strategy. Such a practice can potentially lead to supra-competitive prices and tacit "coordination".

Our findings suggest that collecting and using data is not, *per se*, a source of competitive advantage. Rather, we show that exclusive data availability may entail pro- or anti-competitive

[13] A discussion on data-driven incumbency advantage is also provided by Biglaiser et al. (2019).

conduct depending on the share of consumers profiled. This is because the effect on consumer welfare is U-shaped and prices are non-monotonic in the size of the list. However, there are potentially anti-competitive effects which would ring alarm bells, particularly when the share of profiled consumers is intermediate.

Policymakers worldwide are restricting data collection. How does stricter regulation on privacy affect firms' market strategies? In this context, privacy regulations that limit firms' data gathering, such as the EU GDPR, the ePrivacy Regulation or the Californian CCPA, may have unintended consequences. For instance, a firm with potential exclusive access to a very large dataset may be constrained by regulation to reduce the number of consumers profiled. Consequently, this policy intervention may restore firms' ability to coordinate their prices. On the other hand, when exclusive data access is intermediate, a strict regulation might prevent firms from price coordination.

To an extent, whereas the UK CMA (2018) stated that "tacit coordination and personalised pricing are very unlikely to occur together", our results suggest caution. Tacit coordination, in fact, might stem from the joint presence of exclusive information to price discriminate and price leadership. Currently, a topical debate concerns the role of artificial intelligence in entailing coordinated outcomes between firms (Assad et al., 2020; Calvano et al., 2020; Klein, 2018; Miklós-Thal and Tucker, 2019) as algorithms may learn to coordinate their pricing strategies. Our conclusion, instead, suggests that tacit coordination may also arise as a result of firms' asymmetric ability to price discriminate.

A Appendix

A.1 Proof of Proposition 1

If $p_B \leq t$, given the profit functions, the candidate equilibrium is identified by the following first order conditions:

$$\frac{\partial \pi_A}{\partial p_A} = (1-\lambda)\left(\frac{1}{2} + \frac{p_B - 2p_A}{2t}\right) = 0, \text{ and}$$
$$\frac{\partial \pi_B}{\partial p_B} = (1-\lambda)\left(\frac{1}{2} + \frac{p_A - 2p_B}{2t}\right) + \lambda\frac{(t-2p_B)}{2t} = 0.$$

By solving the system of equations, the equilibrium prices in the anonymous segment are

$$p_A = \frac{3}{\lambda+3}t \text{ and } p_B = \frac{3-\lambda}{\lambda+3}t,$$

and the personalised price can be found by substituting the above p_B into equation (1). The second order conditions also hold. As a result, firms' profits are

$$\pi_A = \frac{9(\lambda+1)}{2(\lambda+3)^2}t \text{ and } \pi_B = \frac{(3-\lambda)^2}{2(\lambda+3)^2}t.$$

If $p_B \geq t$, instead, Firm A by setting (1) attracts all the consumers in the list segment. Hence,

$$\widetilde{\pi}_A = \int_0^1 \widetilde{p}_A(x)dx = p_B \tag{4}$$

and $\widetilde{\pi}_B = 0$. In this case, firms' respective profits are

$$\pi_A = \lambda p_B + (1-\lambda)p_A\left(\frac{1}{2} + \frac{p_B - p_A}{2t}\right), \text{ and}$$
$$\pi_B = (1-\lambda)p_B\left(\frac{1}{2} + \frac{p_A - p_B}{2t}\right).$$

As the firms' best responses are entirely determined in the anonymous segment as in the standard Hotelling model, the only candidate equilibrium is $(p_A, p_B) = (t, t)$. However, Firm B can profitably deviate by lowering its price from t and attracting additional consumers. This is because there is always a $\delta > 0$ such that

$$\begin{aligned}\pi_B(t, t-\delta) &= (1-\lambda)(t-\delta)\left(\frac{1}{2} + \frac{\delta}{2t}\right) + \lambda\frac{\delta(t-\delta)}{2t}\\ &= (1-\lambda)\frac{t-\delta}{2} + \frac{\delta(t-\delta)}{2t} > (1-\lambda)\frac{t}{2} = \pi_B(t,t).\end{aligned}$$

Thus, $p_B \geq t$ can not be a part of an equilibrium. *Q.E.D.*

A.2 Proof of Lemma 1

Let Firm B's price p_B be given. To establish the results, we consider four cases: (i) Firm B's price is very high ($p_B \geq v$), (ii) Firm B's price is relatively high ($v - t \leq p_B < v$), (iii) Firm B's price is relatively low ($t \leq p_B < v - t$) and, finally, (iv) Firm B's price is low ($p_B < t$).

(i) Let $p_B \geq v$. In this case, Firm A can serve the list segment by charging the price schedule: $\widetilde{p}_A(x) = v - tx$. The associated profits obtained from consumers in the list segment are $\widetilde{\pi}_A = v - \frac{t}{2}$. In the anonymous segment, p_B is also so high that Firm A can serve it all by setting $p_A = v - t$.

(ii) Let $v - t \leq p_B < v$. The price of Firm B is still so high that Firm A can match offers on the list segment and serve it all. In particular, there is a threshold location $\widetilde{x}$ such that to the left of it, Firm A is a local monopolist and the outside option is not buying, while to the right of $\widetilde{x}$, Firm B is a viable option and Firm A has to match it. The threshold is implicitly defined by $v - p_B - t(1-\widetilde{x}) = 0$, implying

$$\widetilde{x} = 1 - \frac{v - p_B}{t}.$$

It then follows that Firm A can attract all the list segment by adopting the following price schedule

$$\widetilde{p}_A(x) = \begin{cases} v - tx & \text{if } 0 < x \leq \widetilde{x} \\ p_B + t(1-2x) & \text{if } \widetilde{x} < x \leq 1 \end{cases}.$$

As neither Firm A's price schedule nor its demand in the list segment depends on its own price in the anonymous segment, Firm A's best response in the anonymous segment is unaffected by the presence of the list segment. Moreover, as $v > 4t$, $p_B \geq v - t > 3t$ and hence, Firm A only has to price at $p_B - t$ to fully capture the anonymous segment. To see this, note that the standard best response $t/2 + p_B/2 < p_B - t$ which is unnecessarily low.

(iii) Let $t \leq p_B < v - t$. Such prices are sufficiently low for B to be a potential option for all consumers on the list segment. At the same time, the price is sufficiently high for Firm A to match it and attract all consumers in that segment. In summary, for any p_B in this range, $\widetilde{p}_A(x) = p_B + t(1-2x)$ with associated list segment profit $\widetilde{\pi}_A = p_B$ and $\widetilde{\pi}_B = 0$. By the same reasoning as that in the above case, Firm A's best response price in the anonymous segment is

$$p_A(p_B) = \begin{cases} p_B - t & \text{if } 3t \leq p_B < v - t \\ \frac{t}{2} + \frac{p_B}{2} & \text{if } t < p_B < 3t \end{cases}.$$

(iv) Let $p_B < t$. In this case, excluding the possibility of negative prices, Firm A can attract consumers only up to $\bar{x} = \frac{t+p_B}{2t}$. Firm B can serve the remaining consumers on the list segment. In the anonymous segment the standard Hotelling best response applies,

$$p_A(p_B) = \frac{t}{2} + \frac{p_B}{2}.$$

Firm A's best responses in Lemma 1 then result from the above four cases. *Q.E.D.*

A.3 Proof of Proposition 2

It is standard to verify that if $p_B \geq 3t$, Firm B can not obtain demand from any segment and $\pi_B = 0$. These prices are weakly dominated.

If $t < p_B < 3t$, Firm B receives no demand in the list segment, and hence its profit, given

A's best response in Lemma 1, is

$$\pi_B = (1-\lambda)\, p_B \left(\frac{1}{2} + \frac{p_A(p_B) - p_B}{2t} \right).$$

From the first order conditions, an interior solution is identified and the second order conditions hold. The candidate equilibrium price is then $p_B = {}^{3t}/_{2}$ with Firm A's best response in the anonymous segment being $p_A = {}^{5t}/_{4}$. Their respective profits are

$$\pi_A = \frac{23\lambda + 25}{32} t \text{ and } \pi_B = \frac{9\,(1-\lambda)}{16} t. \tag{5}$$

If $p_B \leq t$, Firm B serves those consumers for whom Firm A is unable to match its offer. Given Firm A's best response in both segments, Firm B's profits are

$$\pi_B = \lambda \frac{p_B\,(t - p_B)}{2t} + (1-\lambda) p_B \left(\frac{1}{2} + \frac{p_A(p_B) - p_B}{2t} \right).$$

The first order condition yields $p_B = \frac{3-\lambda}{1+\lambda}\frac{t}{2}$ if $\lambda > {}^{1}/_{3}$. Firm A's best response in the anonymous segment then is $p_A = \frac{t}{4}\frac{\lambda+5}{\lambda+1}$ and Firm B's total profits are $\pi_B = \frac{t}{16}\frac{(\lambda-3)^2}{\lambda+1}$. If, on the other hand, $\lambda < {}^{1}/_{3}$, the best Firm B can do under the constraint of $p_B \leq t$ is $p_B = t$. However, Firm B's profit by doing so is $\pi_B = (1-\lambda){}^{t}/_{2}$ which is lower than that in (5) when $p_B = {}^{3t}/_{2}$ instead.

Comparing Firm B's profits in these cases, we have

$$\frac{9\,(1-\lambda)}{16} t \geq \frac{t}{16}\frac{(\lambda-3)^2}{\lambda+1},$$

if $\lambda \leq {}^{3}/_{5}$. *Q.E.D.*

A.4 Proof of Proposition 3

To demonstrate the results, we start from Firm B's profit function for different choices of p_B (Section A.4.1). We then derive Firm B's best responses for different lengths of the list and finally firm A's optimal pricing strategy for a short, an intermediate and a long list (Sections A.4.2, A.4.3 and A.4.4, respectively).

A.4.1 The follower's profit function

As Firm A is leading, p_A is given when Firm B is called to choose its price. There are three possible cases depending on p_A. In each case, the profits of Firm B are as follows.

If $0 < p_A \leq t$, then

$$\pi_B = \begin{cases} 0 & \text{if } p_B > p_A + t \\ (1-\lambda)p_B\left(\frac{1}{2} + \frac{p_A - p_B}{2t}\right) & \text{if } t \leq p_B \leq p_A + t \\ \lambda\frac{p_B(t-p_B)}{2t} + (1-\lambda)p_B\left(\frac{1}{2} + \frac{p_A-p_B}{2t}\right) & \text{if } 0 < p_B < t \end{cases}. \tag{6}$$

If $p_B > p_A + t$, the price set by Firm B is too large. Hence, it has no demand. Suppose Firm B sets a price $t \leq p_B \leq p_A + t$, then it can obtain a share $\left(\frac{1}{2} + \frac{p_A - p_B}{2t}\right)$ of consumers in the anonymous market. Finally, by further lowering the price below t, Firm B can gain extra demand, $\frac{t-p_B}{2t}$, in the list segment.

If $t < p_A \leq 2t$, then

$$\pi_B = \begin{cases} 0 & \text{if } p_B > p_A + t \\ (1-\lambda)p_B\left(\frac{1}{2} + \frac{p_A - p_B}{2t}\right) & \text{if } t \leq p_B \leq p_A + t \\ \lambda\frac{p_B(t-p_B)}{2t} + (1-\lambda)p_B\left(\frac{1}{2} + \frac{p_A-p_B}{2t}\right) & \text{if } p_A - t < p_B < t \\ \lambda\frac{p_B(t-p_B)}{2t} + (1-\lambda)p_B & \text{if } p_B \leq p_A - t \end{cases}. \tag{7}$$

The expressions of Firm B's profits in the first three lines are identical to those obtained in equation (6). However, as shown in the fourth line, Firm B receives all the demand of the anonymous segment if its price is below $p_A - t$. The difference between the third and fourth line is due to the fact that Firm B prices very aggressively in response to an intermediate price of its rival.

Finally, if $2t < p_A \leq v$, then

$$\pi_B = \begin{cases} 0 & \text{if } p_B > p_A + t \\ (1-\lambda)p_B\left(\frac{1}{2} + \frac{p_A - p_B}{2t}\right) & \text{if } p_A - t < p_B \leq p_A + t \\ (1-\lambda)p_B & \text{if } t \leq p_B \leq p_A - t \\ \lambda\frac{p_B(t-p_B)}{2t} + (1-\lambda)p_B & \text{if } p_B < t \end{cases}. \tag{8}$$

Note that p_A is very high in this case. The first two lines are similar to the previous cases. In the third line, however, Firm B can obtain all the demand in the anonymous segment by undercutting p_A by t, while still setting a price $p_B > t$. Finally, by setting a price below t, Firm B can also attract consumers on the list segment, besides serving the entire anonymous market.

To complete the proof of the results, we first define two critical values of the list size. Namely, let

$$\lambda_1 = \frac{8v - 9t - 4\sqrt{2}\sqrt{(v-3t)(2v-3t)}}{16v - 23t}, \tag{9}$$

$$\lambda_2 = \frac{2\left(2v - t + 2\sqrt{(v-2t)(v-t)}\right)}{8v - 7t}, \tag{10}$$

where $0 < \lambda_1 < \lambda_2 < 1$. In what follows, we present the the best response functions for a given list size.

A.4.2 A relatively short list $(0 < \lambda < \lambda_1)$

Firm B's best response function

If $p_A \leq t$, it follows that Firm B's best response is $p_B(p_A) = \frac{(1-\lambda)p_A+t}{2}$. To see this, note that the candidate best response in the second line of (3) is the same as that in a standard Hotelling model and results in profits

$$\pi_B(p_A) = \frac{(p_A+t)^2(1-\lambda)}{8t}.$$

The best response in the third line is $p_B(p_A) = \frac{(1-\lambda)p_A+t}{2}$, which results in profits

$$\pi_B(p_A) = \frac{(p_A(1-\lambda)+t)^2}{8t}.$$

Hence, π_B is maximised in the third line of (6) as $\frac{(p_A(1-\lambda)+t)^2}{8t} > \frac{(p_A+t)^2(1-\lambda)}{8t}$ for $p_A \leq t$.

Next, consider $t < p_A \leq 2t$. By the discussion above, which still applies in this case, the best response is $\frac{p_A+t}{2}$ in the second line of (7). However, Firm B may now consider to lower its price to a local critical point $p_B(p_A) = \frac{(1-\lambda)p_A+t}{2}$, which is found by maximising the third line of (7). As in this subcase $p_A - t < p_B < t$, a best response equal to $p_B(p_A) = \frac{(1-\lambda)p_A+t}{2}$ is only feasible for $p_A < \frac{t}{1-\lambda}$. If the latter condition is satisfied, Firm B attracts part of the consumers in the list segment and maximises the third line of (7), obtaining profits $\pi_B(p_A) = \frac{(p_A(1-\lambda)+t)^2}{8t}$. On the other hand, if $p_A > \frac{t}{1-\lambda}$, Firm B can increase profit by raising its price up to the upper limit t to obtain $\pi_B(p_A) = \frac{(p_A+t)^2(1-\lambda)}{8t}$.

Moreover, as $\lambda < \lambda_1$, the first order derivative with respect to p_B of the fourth line of (7) is positive. Hence, Firm B can set its maximum price in this subcase, $p_B = p_A - t$. Note, however, that the associated profit, $\pi_B(p_A) = \frac{(p_A-t)(2t-\lambda p_A)}{2t}$, is dominated by that obtained by setting a price equal to $\frac{(1-\lambda)p_A+t}{2}$, third line of (7), or higher.

To summarize, B's best response when $p_A \in (t, 2t]$ can be found by comparing profits in the second and third lines of (7) and it is equal to

$$p_B(p_A) = \begin{cases} \frac{(1-\lambda)p_A+t}{2} & \text{if } t < p_A \leq \frac{t}{\sqrt{1-\lambda}} \\ \frac{p_A+t}{2} & \text{if } \frac{t}{\sqrt{1-\lambda}} < p_A \leq 2t \end{cases},$$

where the critical value, $\frac{t}{\sqrt{1-\lambda}}$, is the price p_A that equalises Firm A's profits.

Finally, if $p_A > 2t$, the second line of (8) is maximised through a best response equal to $\frac{p_A+t}{2}$, which entails a profit $\frac{(1-\lambda)(t+p_A)^2}{8t}$. According to the third line, instead, Firm B covers entirely the anonymous segment and its profit does not depend on p_A. This leads firm B to charge the highest possible price compatible with such demand configuration, $p_B(p_A) = p_A - t$ with resulting profit being $(1-\lambda)(p_A - t)$. Also, note that, in the second line, a price $\frac{p_A+t}{2}$ is available only when $p_A \leq 3t$ as $p_B \geq p_A - t$. If $3t < p_A \leq v$, the third line of (8) applies and determines the best response. Moreover, for similar reasons as before, the scenario in the fourth line is dominated.

Overall, Firm B can set a price p_B according to the third line of (8) if $3t < p_A \leq v$, and to the second if $2t < p_A \leq 3t$. Hence, Firm B's best response if $p_A > 2t$ is obtained by comparing profits in these two subcases and is

$$p_B(p_A) = \begin{cases} \frac{p_A+t}{2} & \text{if } 2t < p_A \leq 3t \\ p_A - t & \text{if } 3t < p_A \leq v \end{cases}.$$

To facilitate the analysis, the expression below summarises Firm B's best response for all $0 < \lambda < \lambda_1$.

$$p_B(p_A) = \begin{cases} \frac{(1-\lambda)p_A+t}{2} & \text{if } 0 < p_A \leq \frac{t}{\sqrt{1-\lambda}} \\ \frac{p_A+t}{2} & \text{if } \frac{t}{\sqrt{1-\lambda}} < p_A \leq 3t \\ p_A - t & \text{if } 3t < p_A \leq v \end{cases}.$$

Firm A's optimal pricing

Consider now the first stage of the game where Firm A acts as a leader and chooses p_A. With Firm B's best response given above, Firm A's profit is as follows.

$$\pi_A = \begin{cases} \lambda \frac{\left(t + \frac{t+(1-\lambda)p_A}{2}\right)^2}{4t} + (1-\lambda)p_A \left(\frac{1}{2} + \frac{\frac{t+(1-\lambda)p_A}{2} - p_A}{2t}\right) & \text{if } 0 < p_A \leq \frac{t}{\sqrt{1-\lambda}} \\ \lambda \frac{p_A+t}{2} + (1-\lambda)p_A \left(\frac{1}{2} + \frac{\left(\frac{t+p_A}{2}\right) - p_A}{2t}\right) & \text{if } \frac{t}{\sqrt{1-\lambda}} \leq p_A \leq 3t \\ \lambda(p_A - t) + (1-\lambda)(0) & \text{if } 3t < p_A \leq v \end{cases}. \quad (11)$$

In the first line of (11), p_A is relatively low and will be met with a low response. Hence, Firm A will only be able to serve a fraction of the list segment, with its profit given in (2). However, Firm A also receives a fraction of the anonymous segment. In the second and third line, since the best response of Firm B is above t, Firm A satisfies the demand of all the list segment consumers. Firm A's profit is hence given by (4). Note that in the second line Firm A also serves some consumers in the anonymous market, but not in the third.

The first order derivative of the expression in the first line of (11) is

$$\frac{1-\lambda}{8t}\left[3t(2+\lambda)-(4+3\lambda+\lambda^2)p_A\right].$$

One verifies that it is positive when evaluated at $\frac{t}{\sqrt{1-\lambda}}$. Thus, the best Firm A can achieve in this subcase would be to set $p_A = \frac{t}{\sqrt{1-\lambda}}$. However, by comparing the first and second line of (11), going above this price increases profits and hence, it cannot be a part of an equilibrium.

Maximising the second line of (11) gives rise to

$$p_A = \frac{3-\lambda}{1-\lambda}\frac{t}{2}, \tag{12}$$

with Firm A's associated profit of

$$\pi_A = \frac{(1+\lambda)(9-7\lambda)}{1-\lambda}\frac{t}{16}. \tag{13}$$

Similarly, maximising the third line of (11) indicates $p_A = v$ as a candidate equilibrium and Firm A's profit is equal to $\lambda(v-t)$. In this case, Firm A gives up serving the anonymous segment and only serves the list segment.

By comparing the profits associated with the candidate prices $p_A = v$ and $p_A = \frac{3-\lambda}{1-\lambda}\frac{t}{2}$, we find that Firm A sets (12), if, and only if, the profit (13) is larger than $\lambda(v-t)$. This indeed holds if, and only if, $\lambda < \lambda_1$.

As the equilibrium p_A is given in (12), Firm B charges

$$p_B = \frac{t + \frac{t}{2}\frac{3-\lambda}{1-\lambda}}{2} = \frac{5-3\lambda}{1-\lambda}\frac{t}{4},$$

with profit

$$\pi_B = \frac{(3\lambda-5)^2}{32(1-\lambda)}t.$$

A.4.3 An intermediate list ($\lambda_1 \leq \lambda \leq \lambda_2$)

From the result in Section A.4.2, it follows that when λ is above λ_1, Firm A would prefer to set its price at v, earning a profit of $\lambda(v-t)$. In this case, Firm B's best response is $v-t$ with a profit of $(1-\lambda)(v-t)$.

As the list segment grows, Firm A has no incentive to change pricing as long as Firm B's best response does not change. However, Firm B's best response does change when it finds profitable to compete on the list segment as well. Formally, we need to investigate Firm B's profit when firm A sets a high price, namely, (8). As the list grows, Firm B compares the profit of serving the entire anonymous segment, $(1-\lambda)(v-t)$, with the best it can achieve by decreasing its price and competing for list consumers. This implies maximising the fourth line of (8). The result is found to be $p_B = \frac{2-\lambda}{2\lambda}t$, with associated profit $\frac{(2-\lambda)^2}{8\lambda}t$. The latter profit is larger than $(1-\lambda)(v-t)$ if, and only if, $\lambda > \lambda_2$. Note also, when $\lambda > \lambda_2$, $p_B = \frac{2-\lambda}{2\lambda}t < t$, which is consistent with the fourth line of (8).

Hence, when $\lambda_1 \leq \lambda \leq \lambda_2$, Firm A finds it optimal to set a price equal to $p_A = v$, whereas Firm B charges $p_B = v - t$. Equilibrium profits are $\pi_A = \lambda(v-t)$ and $\pi_B = (1-\lambda)(v-t)$. Firm A only serves the list segment and Firm B only serves the anonymous segment.

A.4.4 A long list ($\lambda_2 < \lambda < 1$)

Firm B's best response function

Finally, we consider $\lambda_2 < \lambda < 1$. As shown in Section A.4.3, if Firm A's price is high enough such that by setting $p_B = \frac{2-\lambda}{2\lambda}t$, Firm B can ensure the entire anonymous segment demand, then it is indeed Firm B's best response. This is, if $p_A \geq \frac{2+\lambda}{2\lambda}t$. The reason is that, as $\lambda > \lambda_2$, by setting $p_B = \frac{2-\lambda}{2\lambda}t$ and provided that $p_A > p_B + t$, Firm B obtains the whole anonymous segment and a fraction of the list market, with a combined profit larger than $(1-\lambda)(v-t)$, the best it can achieve in the anonymous segment alone.

On the other hand, when $p_A \leq t$, Firm B's best response is $p_B(p_A) = \frac{(1-\lambda)p_A + t}{2}$, as before. With λ being relatively large, Firm B's profit when $t < p_A < \frac{2+\lambda}{2\lambda}t$ is as in (7). Note that, as the upper bound $\frac{2-\lambda}{2\lambda}t$ is larger than $p_A - t$, the best Firm B can do in the fourth line is to set $p_A - t$, with a profit of $\frac{(p_A - t)(2t - \lambda p_A)}{2t}$. In the third line, Firm B can set $p_B(p_A) = \frac{(1-\lambda)p_A + t}{2}$ and obtain $\frac{(t + (1-\lambda)p_A)^2}{8t}$. Since $p_A < \frac{2+\lambda}{2\lambda}t < \frac{t}{1-\lambda}$, $p_B(p_A) = \frac{(1-\lambda)p_A + t}{2}$ is attainable, and its profit is higher than that of $p_A - t$.

To summarise, when $\lambda_2 < \lambda < 1$, Firm B's best response is

$$p_B(p_A) = \begin{cases} \frac{(1-\lambda)p_A + t}{2} & \text{if } 0 < p_A < \frac{2+\lambda}{2\lambda}t \\ \frac{2-\lambda}{2\lambda}t & \text{if } \frac{2+\lambda}{2\lambda}t \leq p_A \leq v \end{cases}. \tag{14}$$

Firm A's optimal pricing

Given Firm B's best response in (14), Firm A's profit is as follows.

$$\pi_A = \begin{cases} \lambda \frac{\left(t + \frac{t + (1-\lambda)p_A}{2}\right)^2}{4t} + (1-\lambda)p_A \left(\frac{1}{2} + \frac{\frac{t + (1-\lambda)p_A}{2} - p_A}{2t}\right) & \text{if } 0 < p_A < \frac{2+\lambda}{2\lambda}t \\ \lambda \frac{\left(t + \frac{2-\lambda}{2\lambda}t\right)^2}{4t} & \text{if } \frac{2+\lambda}{2\lambda}t \leq p_A \leq v \end{cases}, \tag{15}$$

where in the first line, Firm A partially serves the anonymous and the list segment of the market, and in the second line, by setting a sufficiently large price, Firm A only serves the list segment.

Maximising the first line of (15) gives the following candidate equilibrium price:

$$p_A = \frac{3(2+\lambda)t}{\lambda^2+3\lambda+4} < \frac{2+\lambda}{2\lambda}t,$$

with associated profit of

$$\pi_A = \frac{9}{4}\frac{(1+\lambda)t}{\lambda^2+3\lambda+4}. \tag{16}$$

On the other hand, by setting a price above $\frac{2+\lambda}{2\lambda}t$, Firm A can obtain

$$\pi_A = \frac{(\lambda+2)^2}{16\lambda}t,$$

which is larger than that in (16). Thus, Firm A is indifferent between all prices above $\frac{2+\lambda}{2\lambda}t$ and hence any of them can be a part of subgame perfect equilibrium. *Q.E.D.*

A.5 Proof of Lemma 2

We consider $\Delta_B := \pi_B(\tau_0,\tau_1) - \pi_B(\tau_1,\tau_0)$ in the four different cases identified in Figure 4 depending on the length of the list.

(i) Let $\lambda \in (0, \lambda_1]$. In this case, the difference Δ_B is

$$\left(\frac{(3\lambda-5)^2}{32(1-\lambda)} - \frac{9(1-\lambda)}{16}\right)t = \frac{t}{32}\frac{8-(1-3\lambda)^2}{1-\lambda} > 0.$$

(ii) Let $\lambda \in (\lambda_1, 3/5]$. Δ_B is

$$(1-\lambda)(v-t) - \frac{9(1-\lambda)}{16}t = (1-\lambda)\left(v - \frac{25}{16}t\right) > 0.$$

(iii) Let $\lambda \in (3/5, \lambda_2]$. The difference Δ_B reads $(1-\lambda)(v-t) - \frac{(\lambda-3)^2}{16(1+\lambda)}$ which is strictly positive if $\lambda < \frac{3t+8\sqrt{2}\sqrt{(2v-3t)(v-t)}}{16v-15t}$. Note, however, $\lambda \leq \lambda_2$ and λ_2 is strictly less than this critical value of $\frac{3t+8\sqrt{2}\sqrt{(2v-3t)(v-t)}}{16v-15t}$. Thus, $\pi_B(\tau_0,\tau_1) - \pi_B(\tau_1,\tau_0) > 0$ in this case.

(iv) Let $\lambda \in (\lambda_2, 1)$. The difference Δ_B is

$$\left(\frac{(2-\lambda)^2}{8\lambda} - \frac{(\lambda-3)^2}{16(1+\lambda)}\right)t = \frac{t}{16}\frac{\lambda^3-9\lambda+8}{\lambda^2+\lambda} > 0.$$

Hence, for all $0 < \lambda < 1$, Firm B earns more profits in (τ_0,τ_1) than in (τ_1,τ_0). *Q.E.D.*

(i) Short list ($0 < \lambda \leq \lambda_1$)

		Firm B	
		τ_0	τ_1
Firm A	τ_0	$\frac{9(1+\lambda)}{2(3+\lambda)^2}t, \frac{(3-\lambda)^2}{2(3+\lambda)^2}t$	$\frac{(9-7\lambda)(1+\lambda)}{16(1-\lambda)}t, \frac{(3\lambda-5)^2}{32(1-\lambda)}t$
	τ_1	$\frac{(23\lambda+25)}{32}t, \frac{9(1-\lambda)}{16}t$	$\frac{9(1+\lambda)}{2(3+\lambda)^2}t, \frac{(3-\lambda)^2}{2(3+\lambda)^2}t$

(ii) Relatively short list ($\lambda_1 < \lambda \leq 3/5$)

		Firm B	
		τ_0	τ_1
Firm A	τ_0	$\frac{9(1+\lambda)}{2(3+\lambda)^2}t, \frac{(3-\lambda)^2}{2(3+\lambda)^2}t$	$\lambda(v-t), (1-\lambda)(v-t)$
	τ_1	$\frac{(23\lambda+25)}{32}t, \frac{9(1-\lambda)}{16}t$	$\frac{9(1+\lambda)}{2(3+\lambda)^2}t, \frac{(3-\lambda)^2}{2(3+\lambda)^2}t$

(iii) Relatively long list ($3/5 < \lambda \leq \lambda_2$)

		Firm B	
		τ_0	τ_1
Firm A	τ_0	$\frac{9(1+\lambda)}{2(3+\lambda)^2}t, \frac{(3-\lambda)^2}{2(3+\lambda)^2}t$	$\lambda(v-t), (1-\lambda)(v-t)$
	τ_1	$\frac{(5+\lambda)^2}{32(1+\lambda)}t, \frac{(\lambda-3)^2}{16(1+\lambda)}t$	$\frac{9(1+\lambda)}{2(3+\lambda)^2}t, \frac{(3-\lambda)^2}{2(3+\lambda)^2}t$

(iv) Long list ($\lambda_2 < \lambda < 1$)

		Firm B	
		τ_0	τ_1
Firm A	τ_0	$\frac{9(1+\lambda)}{2(3+\lambda)^2}t, \frac{(3-\lambda)^2}{2(3+\lambda)^2}t$	$\frac{(\lambda+2)^2}{16\lambda}t, \frac{(2-\lambda)^2}{8\lambda}t$
	τ_1	$\frac{(5+\lambda)^2}{32(1+\lambda)}t, \frac{(\lambda-3)^2}{16(1+\lambda)}t$	$\frac{9(1+\lambda)}{2(3+\lambda)^2}t, \frac{(3-\lambda)^2}{2(3+\lambda)^2}t$

Figure 4: Normal form representation of the game at the first stage

Note: The matrix represents the payoffs of Firm A and B when leading, following, or acting simultaneously for different lengths of the list.

A.6 Proof of Proposition 4

We consider the difference between Firm A's profit when following and leading, $\Delta_A := \pi_A(\tau_1, \tau_0) - \pi_A(\tau_0, \tau_1)$ in the four different cases in turn.

(i) Let $\lambda \in (0, \lambda_1]$. $\Delta_A = \frac{(23\lambda+25)}{32}t - \frac{(9-7\lambda)(1+\lambda)}{16(1-\lambda)}t$ which is larger than 0 if and only if $\lambda < \frac{2\sqrt{2}-1}{3}$. As $\lambda_1 < \frac{2\sqrt{2}-1}{3}$, $\Delta_A > 0$.

(ii) Let $\lambda \in (\lambda_1, 3/5]$. Then, $\Delta_A = \frac{(23\lambda+25)}{32}t - \lambda(v-t)$ which is larger than 0 if, and only if, $\lambda < \frac{25t}{32v-55t}$. That is,

$$\Delta_A \begin{cases} > 0 & \text{if } \lambda_1 < \lambda < \frac{25t}{32v-55t} \\ = 0 & \text{if } \lambda = \frac{25t}{32v-55t} \\ < 0 & \text{if } \frac{25t}{32v-55t} < \lambda \leq \frac{3}{5} \end{cases}.$$

(iii) Let $\lambda \in (3/5, \lambda_2]$. In this case, $\Delta_A = \frac{(5+\lambda)^2}{32(1+\lambda)}t - \lambda(v-t)$ which is larger than 0 if, and only if, $\lambda < \frac{21t-16v+8\sqrt{2(2v+3t)(v-t)}}{32v-33t}$. However, this critical value is less than $3/5$ and hence $\Delta_A < 0$.

(iv) Let $\lambda \in (\lambda_2, 1)$. Then $\Delta_A = \frac{(5+\lambda)^2}{32(1+\lambda)}t - \frac{(\lambda+2)^2}{16\lambda}t = \frac{(1-\lambda)(\lambda^2+\lambda-8)t}{32\lambda(1+\lambda)} < 0$.

To summarise, Firm A's profit is strictly larger when leading than following if, and only if, $\lambda > \frac{25t}{32v-55t}$. *Q.E.D.*

A.7 Proof of Proposition 5

The relevant expressions for each subgame are as follows. We denote aggregate profits as Π, consumer surplus as CS, and social welfare as W.

A.7.1 Simultaneous price competition

First, consider the case with simultaneous competition. Industry profits are

$$\Pi = \pi_A + \pi_B = \frac{18 + \lambda(3+\lambda)}{2(3+\lambda)^2}t.$$

Consumer surplus is defined as follows

$$\begin{aligned} CS = & \lambda\Big\{ \int_0^{\bar{x}} [v - tx - \tilde{p_A}(x))]dx + \int_{\bar{x}}^1 [v - t(1-x) - p_B)]dx \Big\} + \\ & (1-\lambda)\Big\{ \int_0^{\frac{p_A-p_B}{2t}} [v - tx - p_A)]dx + \int_{\frac{p_A-p_B}{2t}}^1 [v - t(1-x) - p_B)]dx \Big\}, \end{aligned}$$

with $\bar{x} = (t+p_B)/2t$. Simplifying and rearranging, consumer surplus is equal to

$$CS = v - \frac{45 + \lambda(21 - 2\lambda)}{4(3+\lambda)^2}t.$$

As a result, social welfare is equal to

$$W = v - \frac{9 + \lambda(15 - 4\lambda)}{4(3+\lambda)^2}t.$$

For ease of exposition, in the next two sequential cases, we report only the final expressions. The derivations are available upon request from the authors.

A.7.2 Firm B leads

Consider when Firm B leads the pricing game. Depending on the dimension of the list segment, industry profits are

$$\Pi = \begin{cases} \frac{43+5\lambda}{32}t & \text{if } 0 < \lambda \leq \frac{3}{5} \\ \frac{43+\lambda(3\lambda-2)}{32(1+\lambda)}t & \text{if } \frac{3}{5} < \lambda \leq 1 \end{cases}.$$

Consumer surplus is equal to

$$CS = \begin{cases} v - \frac{103+25\lambda}{64}t & \text{if } 0 < \lambda \leq \frac{3}{5} \\ v - \frac{103+\lambda(143+\lambda(9+\lambda))}{64(1+\lambda)^2}t & \text{if } \frac{3}{5} < \lambda \leq 1 \end{cases}.$$

As a result, social welfare is

$$W = \begin{cases} v - \frac{17+15\lambda}{64}t & \text{if } 0 < \lambda \leq \frac{3}{5} \\ v - \frac{17+\lambda(61-\lambda(5\lambda-7))}{64(1+\lambda)^2}t & \text{if } \frac{3}{5} < \lambda \leq 1 \end{cases}.$$

A.7.3 Firm A leads

Consider when the list-accessing firm, Firm A, leads the pricing game. Note that, in this case, there are two critical values λ_1 and λ_2 as defined in Section 4.3. Industry profits are

$$\Pi = \begin{cases} \frac{43-\lambda(26+5\lambda)}{32(1-\lambda)}t & \text{if } 0 < \lambda < \lambda_1 \\ v - t & \text{if } \lambda_1 \leq \lambda \leq \lambda_2 \\ \frac{1}{16}\left(3\lambda - 4 + \frac{12}{\lambda}\right) & \text{if } \lambda_2 < \lambda < 1 \end{cases},$$

whereas consumer surplus is as follows

$$CS = \begin{cases} v - \frac{103-25\lambda(2+\lambda)}{64(1-\lambda)}t & \text{if } 0 < \lambda < \lambda_1 \\ \frac{t}{2} & \text{if } \lambda_1 \leq \lambda \leq \lambda_2 \\ v - \frac{t}{\lambda} & \text{if } \lambda_2 < \lambda < 1 \end{cases}.$$

As a result, social welfare is

$$W = \begin{cases} v - \frac{17-(15\lambda-2)\lambda}{64(1-\lambda)}t & \text{if } 0 < \lambda < \lambda_1 \\ v - \frac{t}{2} & \text{if } \lambda_1 \leq \lambda \leq \lambda_2 \\ v - \frac{(2-\lambda)(2+3\lambda)}{16\lambda} & \text{if } \lambda_2 < \lambda < 1 \end{cases}.$$

Results follow from a direct comparison: both consumer surplus and social welfare are lower when Firm A leads. *Q.E.D.*

A.8 Proof of Proposition 6

Suppose the share of consumers on the list, λ, is uniformly distributed on $[0, 1/2]$ (rather than $[0, 1]$). In what follows, we replicate the main model under all sets of cases considered.

Simultaneous competition

Consider first the case in which both firms make decisions simultaneously. According to (1), a consumer is indifferent in the list segment if

$$\tilde{p}_A(x) = p_B + t(1 - 2x).$$

One can note that, even setting a very low price (e.g., $p_B = 0$), Firm B cannot get consumers from the list segment if Firm A decides to match Firm B's utility offer.

The profit functions are then

$$\begin{aligned}\pi_A &= \lambda \int_0^{1/2} [p_B + t(1 - 2x)]\, 2dx + (1 - \lambda)p_A \left(\frac{1}{2} + \frac{p_B - p_A}{2t}\right) \\ &= \lambda \left(p_B + \frac{t}{2}\right) + (1 - \lambda)p_A \left(\frac{1}{2} + \frac{p_B - p_A}{2t}\right), \text{ and} \\ \pi_B &= (1 - \lambda)p_B \left(\frac{1}{2} + \frac{p_A - p_B}{2t}\right).\end{aligned}$$

Standard derivations show that firms set prices focusing on the anonymous segment, and the equilibrium prices are as in the standard Hotelling model: $p_A = p_B = t$. The corresponding profits are $\pi_A = 3/2\lambda t + (1 - \lambda)t/2 = (\lambda + 1/2)t$ and $\pi_B = (1 - \lambda)t/2$.

To sum up, the equilibrium in a simultaneous pricing subgame consists of the unique pair $p_A = p_B = t$. The two firms' profits are

$$\pi_A = \left(\lambda + \frac{1}{2}\right) t \text{ and } \pi_B = (1 - \lambda)\frac{t}{2}.$$

Firm B leads

Consider now the case in which Firm B leads. As remarked above, Firm A can always successfully match any price of Firm B for the consumers on the list. It follows that for a given $p_B \geq 0$ and $x \in [0, 1/2]$, Firm A's optimal list segment schedule is

$$\widetilde{p}_A(x) = \begin{cases} v - tx & \text{if } p_B \geq v - t(1-x) \\ p_B + t(1-2x) & \text{if } 0 < p_B < v - t(1-x) \end{cases}.$$

For a given $p_B \geq 0$, Firm A's best response in the anonymous segment is

$$p_A(p_B) = \begin{cases} v - t, & \text{if } p_B \geq v \\ p_B - t, & \text{if } 3t \leq p_B < v \\ \frac{t}{2} + \frac{p_B}{2}, & \text{if } 0 \leq p_B < 3t \end{cases}.$$

Note that these results are identical to those presented in Lemma 1. As Firm A can always match any offer of Firm B in the list segment, the latter firm's profits are

$$\pi_B = (1 - \lambda) p_B \left(\frac{1}{2} + \frac{p_A - p_B}{2t} \right).$$

Anticipating that $p_B < 3t$ and substituting Firm A's best response, we have

$$\pi_B = (1 - \lambda) p_B \left(\frac{1}{2} + \frac{t - p_B}{4t} \right).$$

The first order conditions leads to $p_B = 3t/2$ and, consequently, $p_A = 5t/4$.

As Firm B does not have access to the list segment, there is no incentive to change their price, regardless of λ. In turn, the results under Proposition 2 would change as follows. When Firm B leads in the price competition, in the unique subgame perfect Nash equilibrium the prices are

$$p_A = \frac{5}{4}t \text{ and } p_B = \frac{3}{2}t,$$

with respective profits

$$\pi_A = \frac{t}{32}(39\lambda + 25) \text{ and } \pi_B = \frac{9}{16}(1 - \lambda)t.$$

Firm A leads

Finally, consider the case in which Firm A leads. If λ is small, Firm A prefers to compete. This implies that also in this case firms focus on the anonymous segment. As λ increases, Firm A can use its leadership as a commitment device to induce Firm B to post high prices. Specifically, given p_A, Firm B's profits are as follows. If $t < p_A \leq v$, then

$$\pi_B = \begin{cases} 0 & \text{if } p_B > p_A + t \\ (1 - \lambda) p_B \left(\frac{1}{2} + \frac{p_A - p_B}{2t} \right) & \text{if } p_A - t < p_B \leq p_A + t \\ (1 - \lambda) p_B & \text{if } p_B \leq p_A - t \end{cases}.$$

If $0 < p_A \leq t$, then

$$\pi_B = \begin{cases} 0 & \text{if } p_B > p_A + t \\ (1-\lambda)p_B\left(\frac{1}{2} + \frac{p_A - p_B}{2t}\right) & \text{if } 0 \leq p_B \leq p_A + t \end{cases}.$$

The best responses of Firm B can either be $p_B = p_A - t$ if Firm A price is relatively high, or $p_B = \frac{p_A + t}{2}$ if Firm A price is relatively low.

In turn, Firm A behaves as price leader and anticipates Firm B best responses. Profits are given by

$$\pi_A = \lambda\left(p_B + \frac{t}{2}\right) + (1-\lambda)p_A \cdot \max\left\{\left(\frac{1}{2} + \frac{p_B - p_A}{2t}\right), 0\right\}.$$

If Firm A chooses a relatively high price, the prices and profits are $p_A = v$, $p_B = v - t$ and $\pi_A = \lambda(v - t/2)$, $\pi_B = (1-\lambda)(v-t)$. On the contrary, if Firm A chooses a relatively low price, profits are also made on the anonymous segment. In this case, provided that $\lambda < 3/5$, profit maximisation requires to set $p_A = \frac{3-\lambda}{1-\lambda}\frac{t}{2}$, with Firm A's associated profit being

$$\pi_A = \lambda t + \frac{(3-\lambda)^2}{16(1-\lambda)}t.$$

Proposition 3 then changes as follows. In the subgame perfect Nash equilibrium of this subgame,

(a) if $0 < \lambda < \lambda_1$, then

$$p_A = \frac{3-\lambda}{1-\lambda}\frac{t}{2} \text{ and } p_B = \frac{5-3\lambda}{1-\lambda}\frac{t}{4},$$

with profits

$$\pi_A = \lambda t + \frac{(3-\lambda)^2}{16(1-\lambda)}t \text{ and } \pi_B = \frac{(5-3\lambda)^2}{(1-\lambda)}\frac{t}{32};$$

(b) if $\lambda_1 \leq \lambda < 1$, then

$$p_A = v \text{ and } p_B = v - t,$$

with profits

$$\pi_A = \lambda\left(v - \frac{t}{2}\right) \text{ and } \pi_B = (1-\lambda)(v-t).$$

Subgame Perfect Nash Equilibrium

As in the main model, the game has two, and only two, pure strategy Nash equilibria in the first stage: (τ_0, τ_1) and (τ_1, τ_0). Moreover, there exists one critical value of λ, $\hat{\lambda} = \frac{25t}{32v - 55t}$, such that for all $\lambda > \hat{\lambda}$, Firm A's profit is higher as a price leader than as a price follower, and the equilibrium (τ_0, τ_1) is payoff dominant. *Q.E.D.*

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