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DATA-DRIVEN MERGERS AND PERSONALIZATION

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Data-Driven Mergers and Personalization*

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Abstract

This paper studies tech mergers that involve a large volume of consumer data. The merger links the markets for data collection and data application through a consumption synergy. The merger-specific efficiency gains exist in the market for data application due to the consumption synergy and data-enabled personalization. Prices fall in the market for data collection due to the merged firm's incentives to expand its outreach in the market for data application. But in the market for data application, prices generally rise as the efficiency gains are extracted away through personalized pricing, rather than being passed on to consumers. When the consumption synergy is large enough, the merger can result in monopolization of both markets, with further consumer harm when stand-alone competitors exit in the long run. We discuss policy implications including various merger remedies.

Key words: big data, personalization, tech mergers
JEL Classification: D43, L13, L41, K21

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1 Introduction

Remarkable advances in digital computing technologies, underpinned by information and communication technologies, are making fundamental changes to virtually every part of the modern world. At the heart of the digital revolution is the vast amount of granular data – big data – that has become the 'new oil' for the functioning of many industries.[1] Consumer data analyzed by powerful machine-learning tools can allow firms to improve the quality of products they offer, utilize more target-oriented business models, and exploit new business opportunities. Due to strong network effects and data-powered economies of scale and scope that are most prominent in the digital economy, data can also contribute to market tipping and entry barriers through a positive feedback loop: firms with larger data sets can offer better-targeted products thanks to data-enabled learning, thereby attracting more customers, which leads to more data, hence creating a self-reinforcing loop. Given the increasing availability of granular data due to the advances in information and communication technologies, and the improvements in machine-learning algorithms, the importance of data can only increase.

The most important source of data for many firms is the interaction with existing and potential customers, which produces various user-generated content and data, or machine-generated data such as web server logs, network event logs, location data, etc. But firms also rely on data brokers for additional data[2], or collect new sets of data through acquisition of other firms. While data is relevant to almost all mergers involving tech firms, it is gaining growing importance, and played an especially salient role in several prominent merger cases such as Facebook/Instagram (2012), Google/Waze (2013), Facebook/WhatsApp (2014), Microsoft/LinkedIn (2016), Apple/Shazam (2018) and, more recently, the Google/Fitbit merger which is under regulatory probe at the time of writing this article.[3]

[1] "The world's most valuable resource is no longer oil, but data", *The Economist*, May 16, 2017.

[2] The global data broker industry comprises thousands of firms and is estimated to generate US$200 billion in annual revenue (https://pando.com/2014/01/08/surveillance-valley-scammers-why-hack-our-data-when-you-can-just-buy-it/). One of the largest data brokers, Acxiom (since renamed LiveRamp), claimed to have information on 700 million consumers worldwide, and over 3,000 propensities for nearly every U.S. consumer (US Senate Committee on Commerce, Science, and Transportation, 2013).

[3] According to an OECD estimate, 'big data related' mergers and acquisitions rose from 55 in 2008 to 134 in 2012 (Stucke and Grunes, 2016). For the discussion of the cases cited above except Google/Fitbit, see Argentesi et al. (2019). For Google's bid for Fitbit, see, for example, "EU launches probe into Google's $2 bn bid for Fitbit", *Financial Times*, August 5, 2020, and the related press release by the European Commission (https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1446). After the first draft of this article was completed, the European Commission approved the Google/Fitbit merger on December 17, 2020 subject to conditions that pertain to the use of health data for Google ads, access to the Fitbit Web API, and competition in the market for wearable devices (https://ec.europa.eu/commission/presscorner/detail/en/ip_20_2484). But similar undertakings were rejected by the Australian Competition and Consumer Commission. Despite the rejection, Google completed the transaction on January 14, 2021 so that the case has become an enforcement investigation of a completed merger (https://www.accc.gov.au/public-registers/mergers-registers/public-informal-merger-reviews/google-llc-proposed-acquisition-of-fitbit-inc). In the US, Google also completed the transaction even though the case is still under review by the Department of Justice (https://www.bloomberg.com/news/articles/2021-01-14/google-closes-fitbit-deal-amid-ongoing-u-s-doj-review).

In the Google/Fitbit case, the main concern raised by regulators is that sensitive health data held by Fitbit can be added to users' personal profiles Google aggregates from its other services such as emails, maps, and online searches. In a bid to alleviate these concerns, Google pledged that it would not use Fitbit data for advertising purposes. But this does not rule out Google's use of the data in other markets such as health care. By connecting Fitbit data with user data from Google's Cloud Healthcare API, Google can build a more comprehensive patient profile and offer more personalized health care. Indeed, Google's bid for Fitbit is consistent with its strategies to expand into health care, life sciences, and insurance.[4]

Mergers involving tech firms with a large volume of data can have both beneficial and harmful effects. Access to richer sets of data can enable firms to tailor their products in a way that is more personalized and better targeted for individual consumers. This can improve the quality of matching between firms and consumers. It can be also pro-competitive by allowing the merging parties to enter a new market through data-driven innovation. But the positive feedback loop discussed previously can harm competition and lead to market tipping. In addition, the flip side of personalization is the firm's ability to engage in price discrimination and consumer exploitation. Moreover, merging parties can extend market power to related markets, potentially leading to foreclosure and consumer exploitation there. For instance, Google could enter the health insurance market with highly personalized products by leveraging Fitbit's data, massive medical records Google has access to through Google Cloud and Project Nightingale, and its own data analytics capabilities.[5] Finally, data-driven mergers can raise privacy concerns, which can be further exacerbated due to data externalities whereby some consumers' data can be used to infer personal information about other consumers (Choi et al., 2019).

Thus tech mergers warrant careful assessment of costs and benefits that are not often adequately addressed in the existing merger review. As a result, they can go under the radar of competition authorities. Indeed, the five largest tech firms have made over 400 acquisitions globally over the last 10 years, but none was blocked and very few had conditions attached to approval (Furman et al., 2019). As Tirole (2020) argues, since old-style regulation is impractical for tech firms, competition policy including merger review to "prevent the eggs from being scrambled in the first place" may remain the main policy tool in the digital era.

The purpose of this paper is to study data-driven mergers and their implications for competition policy. Issues relevant to tech mergers such as network effects, economies of scale and scope, innovation incentives, incumbency advantage, and so on, are also relevant to non-tech mergers,

[4]In the Online Appendix, we provide a brief account of Google's expansion into health care. Sundar Pichai, the CEO of Alphabet and its Google subsidiary, said health care offers the biggest potential for Alphabet over the next 10 years for using AI to improve outcomes (https://www.cnbc.com/2020/01/22/google-ceo-eyes-major-opportunity-in-health-care-says-it-will-protect-privacy.html). As of 2019, there are around 30 million active Fitbit users worldwide (https://www.statista.com/topics/2595/fitbit/).

[5]As explained in the Online Appendix, Google has already gained a foothold in the health insurance market with its health tech subsidiary, Verily. But Google's ambition in health care extends beyond health and life insurance.

albeit in varying degrees. Our specific focus in this paper is on the role of data since data plays a uniquely important role in tech mergers. By doing so, we make a number of important contributions to the growing body of literature on tech mergers reviewed below.

We start by sketching our model. Since Google/Fitbit serves as our motivating example, we refer to this case whenever relevant. There are two related markets, A for data application such as the digital health care and B for data collection such as the market for wearable devices. Each market is represented by a horizontally differentiated Hotelling duopoly with the identical population of consumers. We consider a merger between a firm in market A, say A_1, and a firm in market B, say B_1, leading to a merged entity, say C. Stand-alone competitors are called A_2 in market A and B_2 in market B.

Data is generated in market B and can be used in market A for personalization. The set of consumers in market A whose data is available is called firm C's target segment, and a consumer in the target segment, a targeted consumer. By personalization, we refer to firm C's ability to charge a personalized price for a tailored product that better matches a targeted consumer's taste than the firm's standard product, with the improved matching value increasing in the firm's data analytics quality. For non-targeted consumers, firm C offers the standard product at a uniform price. Personalization in market B is too costly so we ignore that possibility. For example, in the market for wearable devices, hardware reconfiguration necessary for personalization can be too costly to be practicable.[6] But the two markets are linked through some complementarity. We model the linkage by assuming that consumers derive extra benefits from buying firm C's product in market B and its personalized product in market A. We call this the consumption synergy. In case of Google/Fitbit, Google can incorporate the wearable device into its ecosystem, which it can leverage to enhance user experience in the digital health sector.

In market A, the market for data application, personalization following the merger has two primary effects. First, it has a potential to benefit targeted consumers thanks to the improved matching value and the consumption synergy. But firm C can extract much of these benefits by using personalized prices except for those who are sufficiently far away from its location and for whom firm C has to compete hard. As a result, targeted consumers closer to firm C can be worse off than before the merger, which may be called the consumer exploitation effect. Second, exploitation of targeted consumers has a salutary effect of intensifying competition for non-targeted consumers. It is because personalization allows firm C to delink its pricing policies for targeted and non-targeted consumers. This shifts the battleground for Hotelling competition outside firm C's target segment, which intensifies competition in uniform price and benefits non-targeted consumers. This also limits firm C's ability to exploit its targeted consumers, whose alternative option is to choose firm A_2's product.

[6]Lausell and Resende (2020) provide examples of product personalization, which are predominantly through software reconfiguration in service industries such as e-commerce, hospitality, media and entertainment, and health. They also mention Tesla's personalized dashboard. But this is also mainly through software interface, rather than through personalizing physical components of the automobile.

On balance, total consumer surplus in market A may increase or decrease depending on the post-merger equilibrium. In what we call the accommodation equilibrium I, firm A_2 remains active after the merger and firm C serves some non-targeted consumers in addition to all targeted consumers. This equilibrium arises when the consumption synergy is relatively small. In this case, the intensified competition for non-targeted consumers pushes down uniform prices, which in turn reduces personalized prices. As a result, total consumer surplus increases after the merger. As the consumption synergy increases, firm C expands its target segment because the larger consumption synergy implies more consumer surplus that can be extracted through personalization. When firm C's target segment is sufficiently large, firm C serves only targeted consumers and firm A_2 serves the rest of the market. We call this the accommodation equilibrium II. In this equilibrium, the merger results in a higher uniform price charged by firm A_2 mainly because its market share is smaller than before the merger. The higher uniform price by firm A_2 allows firm C to raise all personalized prices above its pre-merger uniform price. As a result, consumers are worse off. When the consumption synergy is large enough, firm C monopolizes market A, which we call the monopolization equilibrium. In this case, firm A_2, albeit inactive, remains in the market, which makes the market contestable.

In market B, the market for data collection, competition intensifies unambiguously because of firm C's incentives to expand its target segment in market A. When the consumption synergy is large enough, firm C chooses below-cost pricing. The large enough consumption synergy implies that firm C can use personalization to extract surplus from market A that can more than offset the loss in market B caused by below-cost pricing. Firm C's incentives for below-cost pricing increase in the consumption synergy, which eventually leads firm C to monopolize market B, hence market A as well. Yet in both markets, monopolization does not mean immediate abuse of monopoly power by firm C, because the presence of competitors, albeit inactive, makes both markets contestable. As a result, the merger increases total consumer surplus in market B in the short run. But in the long run when competitors exit following monopolization, consumers in both markets are worse off than before the merger.

A number of clear welfare implications of data-driven mergers emerge from our analysis. First, thanks to the competitive edge derived from the consumption synergy and personalization, merging parties are better off at the cost of their stand-alone competitors. Second, in market B, consumers gain in the short run because of the intensified competition. Third, in market A, changes in consumer surplus depend on different equilibria: consumer surplus increases if firm C serves some non-targeted consumers after the merger, which is possible only when the consumption synergy is relatively small; otherwise, it decreases. Fourth, the long-run effect is unambiguously more detrimental to consumers than the short-run effect. If stand-alone competitors exit the market in the long run following monopolization, then the monopolization equilibrium turns into the monopoly equilibrium, making consumers in both markets worse off. Thus there is a trade-off where potential dynamic costs can outweigh any static benefits.

In view of the above welfare implications, we examine some policy remedies relevant to data-driven mergers. For example, in clearing the acquisition of Fitbit by Google in December, 2020, the European Commission mentioned three main remedies that pertain to the use of health data for Google Ads, access to the Fitbit Web API, and competition in the market for wearable devices.[7] We discuss the second and third remedies as they are directly relevant to our paper. First, we consider the case where firm C is compelled to share data with firm A_2. Such data sharing reduces the value of data to firm C as it allows firm A_2 to also use personalization. This softens competition and hurts consumers in market B, but benefits consumers in market A. In addition, data sharing makes monopolization less likely, hence mitigates the dynamic trade-off. Second, we discuss the effect of banning below-cost pricing in market B. In the equilibria where the ban becomes binding, prices rise and consumer surplus decreases in market B. In market A, firm C's target segment contracts after the binding ban. This allows firm A_2 to serve more consumers by charging a lower price, which in turn lowers firm C's personalized prices, benefiting consumers in market A. Thus the ban has differing effects on the markets for data collection and data application, although both firms A_2 and B_2 are better off at the cost of firm C. In addition, the ban prevents monopolization, hence also mitigates the dynamic trade-off. A general conclusion we can draw is that these remedies can mitigate the dynamic trade-off, although short-run effects on consumers vary depending on policies and markets.

Our paper makes several novel contributions to the literature on tech mergers and the literature on price discrimination. First, we develop a new model for the analysis of data-driven mergers that captures two key features of such mergers: personalization and cross-market interaction due to complementarity. While there is a growing body of literature on personalization and some new papers on conglomerate mergers such as Chen and Rey (2020), the combination of these two features leads us to several novel findings relevant to tech mergers. For example, the differing effects of the merger on consumer surplus in the two markets due to the role of data have not been pointed out in the existing literature. Likewise, the mechanism whereby the merger creates externalities between stand-alone competitors across the two markets is novel. Finally, our paper identifies the dynamic trade-off as one of the key issues in assessing tech mergers and shows that the trade-off is at the heart of various merger remedies. To the best of our knowledge, these issues are yet to be formally analyzed in published works.

Second, our paper provides a new perspective and clear policy implications relevant to data-driven tech mergers. Conventional merger assessments weigh possible costs due to lessening competition against merger-specific efficiency gains that can be passed on to consumers, which are often associated with lower prices.[8] But lower prices are not a good indicator of consumer

[7] https://ec.europa.eu/commission/presscorner/detail/en/ip_20_2484

[8] See, for example, the symposium on horizontal mergers and antitrust in the *Journal of Economic Perspectives*, Fall 1987. The general guidelines for horizontal mergers extend to non-horizontal mergers such as Google/Fitbit with suitably defined potential competition. For this, see Section 4 of the Department of Justice's Merger Guidelines (1984) in the US, Section 5 of the ACCC Merger Guidelines (2008) in Australia, or "Guidelines on the assessment of non-horizontal mergers under the Council Regulation on the control of concentrations between undertakings" (2008) in the European Union.

benefits in tech mergers because they can be transitory as the firm tries to increase market penetration through price cuts.[9] When the firm gains market dominance in the long run, all prices can rise. In addition, the price decrease is not due to efficiency gains passed on to consumers; it is due to the merged firm's incentives to expand data scale that it can leverage in the market for data application. That is, although prices fall in the market for data collection, they generally rise in the market for data application where the efficiency gains exist thanks to the consumption synergy and product personalization. Thus, there is little sense in which the efficiency gains are passed on to consumers. In sum, even based on the conventional merger assessment, data-driven mergers do not present a convincing case. The case becomes even weaker if one considers the dynamic trade-off.

If blocking the merger is not an option for whatever reasons, however, then competition authorities need to look for policies that can help preserve consumer benefits, albeit temporary, while minimizing long-run consumer harm. The policies we discuss mitigate the dynamic trade-off, implying that some sacrifice to short-term consumer benefits is inevitable. An alternative is to allow consecutive mergers that can level the playing field. For instance, Apple's expansion into the digital health following the Google/Fitbit merger will have pro-competitive effects without sacrificing the efficiency gains from data-enabled personalization. Needless to say, the success of policy depends on effective monitoring and enforcement, which can be a daunting task in complex digital industries. This presents a dilemma to competition authorities: blocking a merger can prevent long-term harm, while also preventing potential benefits from being realized; approving a merger with remedies presupposes an effective system of monitoring and enforcement, without which problems can be amplified after the merger has been approved and cannot be undone.

Third, we enrich the literature on price discrimination by introducing a new innovation. The existing literature considers either pure personalized pricing or perfect product personalization. Our key innovation is to distinguish between the firm's ability to use personalized pricing and its ability to process consumer data for product personalization. The former depends on the size of market segment in which the firm has consumer data, which we call the firm's data scale. But the data scale alone does not allow the firm to tailor its product to better match an individual consumer's taste. To improve the matching value, the firm should be able to process and learn from consumer data. We call this the firm's data analytics. We allow the quality of data analytics to vary, with perfect product personalization possible only with the perfect data analytics. Separating the data scale from the data analytics in this way generates new insight. For example, the data scale has a non-monotonic effect on consumer surplus, but consumer surplus is nondecreasing in the quality of data analytics.

The rest of the paper is organized as follows. After a review of the related literature below, Section 2 presents our model. Section 3 analyzes the effect of personalization in market A. Section 4 studies the cross-market effects from the merger. Section 5 discusses policy implications

[9] This point is made emphatically by Khan (2017), Chair of the US Federal Trade Commission confirmed by the US Senate on June 15, 2021.

and Section 6 provides the analysis of various extensions of the baseline model. Section 7 concludes the paper. Appendix provides proofs of results in Sections 3 and 4. Online Appendix contains all other proofs, a brief account of Google's interest in and expansion into health care, and some information on how big data and personalization are affecting the healthcare industry.

Related Literature

While our work shares common interest with the large literature on the digital economy, we review only those studies that are most closely related to the main focus of this paper, namely, data-driven mergers and the use of data for personalization. For general discussions on the digital economy and the relevant policy issues, see Australian Competition & Consumer Commission (2019), Crémer et al. ("EU Report", 2019), Furman et al. ("Furman Report", 2019), or Scott Morton et al. ("Stigler Report", 2019). For reviews of the academic literature on the digital economy, see Goldfarb and Tucker (2019), or Calvano and Polo (2021).

There is a growing body of literature on mergers in digital industries. Evidence on the scale and scope of tech mergers is documented in Argentesi et al. (2019) and Gautier and Lamesch (2020). They evaluate several hundred acquisitions made by the Big Five tech firms (Google, Amazon, Facebook, Apple, and Microsoft) and find that most acquisitions are in areas where the acquirer's and the target's products and services are complementary to each other, a majority of targets are young or start-up companies, and that "killer acquisitions" are not common.

In the digital economy, network effects and economies of scale can lead to market tipping so that a successful firm attains temporary market dominance until it is replaced by a more successful entrant, with success crucially depending on innovation. Cabral (2021), Kamepalli et al. (2020), Katz (2021), and Motta and Peitz (2021) study the effects of merger policy on innovation incentives by the incumbent and/or entrant. de Cornière and Taylor (2020) adopt the competition-in-utility-space approach (Armstrong and Vickers, 2001) and study general conditions for a data-driven merger to be pro- or anti-competitive.[10] These studies adopt a reduced-form approach and do not go into the details of how data is used by the merged firm. In contrast, we provide a micro foundation by focusing on the specific use of data. We also study cross-market effects of data-driven mergers.[11]

Although not related to mergers, several studies analyze how data can be used for learning and affect market dynamics.[12] Hagiu and Wright (2020b) study a model of dynamic duopoly where a firm's data from past sales can be used for learning and augment the value of its product to current consumers. They analyze various types of data-enabled learning and their implications

[10] For merger policy governing multi-sided platforms, see, for example, Jullien and Sand-Zantman (2021) and the references therein.

[11] Somewhat related to our cross-market effects, Condorelli and Padilla (2020) use a reduced-form approach to study how a monopolist can use the data from one market for entry deterrence in another market.

[12] For a non-technical discussion on various conditions for data-enabled learning to provide competitive advantage, see Hagiu and Wright (2020a).

for competitive dynamics. Prüfer and Schottmüller (2020) study a dynamic duopoly where a firm's cost of investment in quality of its product decreases in the amount of data or sales in the previous period and the demand is an increasing function of quality. They show how network effects can lead to market tipping through a positive feedback loop. Farboodi et al. (2019) study market dynamics in a competitive industry in which heterogeneous price-taking firms can use data to improve efficiency.

The primary use of data in our model is for personalization of product and pricing. Personalized pricing has been the focus of many studies (Thisse and Vives, 1988; Chen and Iyer, 2002; Shaffer and Zhang, 2002; Choudhary et al., 2005; Ghose and Huang, 2009; Matsumura and Matsushima, 2015; Choe et al., 2018; Chen et al., 2020).[13] Zhang (2011) and Laussel and Resende (2020) consider product personalization in addition to personalized pricing. General findings from this literature can be summarized as follows. First, competition in personalized pricing is more intense than competition in other types of price discrimination unless consumers can take actions to bypass personalized pricing.[14] Second, competition becomes increasingly more intense as firms move from pure personalized pricing to personalized pricing combined with product personalization. Our work adds to this literature in several ways. First, unlike most studies that focus on a symmetric duopoly, our model is in the context of merger where the merged firm can employ data-driven personalization while its stand-alone competitor cannot, hence an asymmetric duopoly arises naturally. Second, we allow the merged firm to delink product personalization and personalized pricing, if it wishes to. Finally, we show how the merged firm's personalization strategy changes when cross-market effects are taken into account.

2 The Model

Consider two markets A and B with correlated demands. Consumer data is harvested in market B and can be used in market A thanks to correlated demands. Since our model can be best understood with help of a concrete example, we will refer to market B as the market for wearable devices such as Fitbit watch and market A as the market for complementary services such as the digital health care. Needless to say, our model applies to any pair of related markets where data is collected in one market for use in the other market. For example, market B can be the market for professional services network and market A can be the market for productivity software, as in Microsoft/LinkedIn merger.

Each market is represented by a Hotelling line with uniform distribution on $[0, 1]$. Two firms serve each market. In market A (B, resp.), firm A_1 (B_1, resp.) is located at 0 and firm A_2

[13] For a comprehensive survey of the literature, see Fudenberg and Villas-Boas (2006, 2012). Ezrachi and Stucke (2016) provide discussions and examples of personalized pricing.

[14] Choe et al. (2018) show competition is more intense when it is in personalized pricing than when it is in third-degree price discrimination, as in Fudenberg and Tirole (2000). Chen et al. (2020) show consumers' identity management can soften competition in personalized pricing and even lead to a collusive outcome.

(B_2, resp.) is located at 1. We normalize the marginal cost of production to zero and treat prices as profit margins. In each market, a consumer demands one unit of product and derives gross utility v_i ($i = A, B$) when the product in market i perfectly matches her taste. But a consumer's taste is private information, without which firms cannot offer a perfectly matched product to each consumer. In the absence of consumer information, firms can offer only one standard product. The utility consumers derive from the standard product varies depending on the market and the consumer's location, as explained below.

Firms are symmetric in market A. If both firms offer a standard product, then a consumer located at x derives utility $v_A - x$ from purchasing a product from firm A_1 and utility $v_A - (1-x)$ by patronizing firm A_2. Thus a consumer's location is a taste parameter that represents the degree of mismatch between her taste and each firm's standard product. We assume $v_A > 3$, which simplifies analysis and also ensures that the market is fully covered even if it is served by a monopoly supplier. Before the merger, market A has a symmetric Hotelling equilibrium with prices $\alpha_1^0 = \alpha_2^0 = 1$, profits $\Pi_{A_1}^0 = \Pi_{A_2}^0 = 1/2$, and firm A_1's market share given by $[0, 1/2]$.

Firms in market B are also symmetric but we allow sequential moves where firm B_1 is the first mover.[15] As in market A, a consumer located at x derives utility $v_B - x$ from firm B_1's product and $v_B - (1 - x)$ from firm B_2's product, where $v_B > 3$. Solving the sequential game, we obtain equilibrium prices $\beta_1^0 = 3/2$ and $\beta_2^0 = 5/4$, hence firm B_1 serves $[0, x^0]$ where $x^0 = 3/8$. Then firms earn profits equal to $\Pi_{B_1}^0 = 9/16$ and $\Pi_{B_2}^0 = 25/32$.

We consider the merger between firms A_1 and B_1, leading to a merged entity to be called firm C. Alternatively, one may also consider the scenario in which firm B_1 is acquired by a dominant digital platform C that enters market A in partnership with firm A_1. The primary use of consumer data collected in market B is for personalization in market A, which we will explain shortly. We assume that the cost of using consumer data for personalization in market B is prohibitively high. For example, personalizing hardware such as wearable devices can be too costly.[16] Thus post-merger competition in market B continues to be in uniform price.

In market A, consumer data can be used for two types of personalization. Suppose firm C knows exact locations of all consumers in $[0, \delta_A]$. We call this firm C's target segment and δ_A, its *data scale*. Knowing each targeted consumer's exact location enables firm C to offer a personalized price to each targeted consumer. Moreover, firm C can utilize its data analytics

[15]This is partly to reflect reality. For example, Fitbit sold its first fitness tracker at the end of 2009 whereas the first Apple Watch was released in April 2015. In addition, assuming sequential moves in market B limits possible deviations by the merged firm compared to the case with simultaneous moves, hence simplifies post-merger analysis. Having firm B_2 as the first mover leads to similar qualitative results. That is, there are two types of post-merger equilibria with monopolization more likely when the consumption synergy increases. In the previous version of this paper (Chen et al., 2020), we considered simultaneous moves as well as asymmetric firms in market B.

[16]Allowing software customization may not be too costly. But our focus is on personalization rather than customization. The former is commonly defined as the practice whereby the firm decides what marketing mix is suitable for the individual customer, usually based on previously collected customer data. On the other hand, customization occurs when the customer pro-actively specifies one or more elements of his or her marketing mix (Arora et al., 2008; Zhang, 2011).

and offer a personalized product that has a higher matching value for a targeted consumer than its standard product. We parameterize this by $\phi_A \in (0, 1]$ such that consumer x derives utility $v_A - (1 - \phi_A)x$ from the personalized product, and call ϕ_A, firm C's *data analytics* quality.[17] For simplicity, we assume that firm C can offer a personalized product at no additional cost. In this case, firm C will offer personalized products at personalized prices to all of its targeted consumers, which we simply call *personalization*.[18]

In market A, the merger allows firm C to offer a mix of personalized and uniform prices. The time line of the post-merger game is as follows, which is common in the literature (Thisse and Vives, 1988; Matsumura and Matsushima, 2015; Choe et al., 2018; Chen et al., 2020). In the first stage, firms simultaneously post uniform prices, which are publicly observed. In the second stage, firm C makes private offers to targeted consumers. Consumers make purchasing decisions after observing all available offers. It is important to note that the private offer of personalized prices gives firm C the flexibility in adjusting prices. It can easily change a personalized price offered to a particular customer without adjusting the prices to other customers.[19] Such flexibility in pricing gives firm C a second-mover advantage in responding to the rival's pricing strategy.

We make several simplifying assumptions. First, consumer tastes are perfectly correlated in the two markets. That is, a consumer's location is the same in both markets, implying that her location data collected in market B perfectly reveals her location in market A. Second, firms' locations remain the same before and after the merger so that firm C's position in market A remains at 0. Third, firms A_2 and B_2 remain independent so that firm C is the only merged entity. Fourth, consumers are myopic in that when they make purchase decisions in market B, they do not anticipate how their data will be used in market A.[20] In Section 6, we relax some of these assumptions and show that our main insight pertaining to the implications of data and personalization remains robust.

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[17] We assume δ_A and ϕ_A are independent of each other. In reality, it is conceivable that there may be a positive correlation between the two, for example, thanks to data-enabled learning (Hagiu and Wright, 2020b). A simple way to model the positive correlation is to assume $\phi_A = h + (1 - h)\delta_A$, $h \in [0, 1]$. This modification does not change our qualitative results, the details of which are available from the authors.

[18] In the previous version of this paper (Chen et al., 2020), we considered the case where offering the personalized product incurs a unit cost $c > 0$. This leads to the segmentation of market in which firm C offers the standard product at personalized pricing to targeted consumers close to its location, and personalized products at personalized pricing to the remaining targeted consumers. Other than that, our main insight remains the same.

[19] Pricing algorithms are becoming popular in digital industries. Personalized prices are generated by algorithms rather than by managers, and algorithms can be designed to identify the best response to the rival's prices. See Brown and MacKay (2020) for the analysis of competition with pricing algorithms, and Calvano et al. (2020) who demonstrate that algorithmic pricing can support tacit collusion.

[20] In some cases, such myopia seems plausible: people leave a huge amount of data by using various Google services (emails, maps, search, etc) on a daily basis without thinking too much about how their data will be used; Facebook users may not be that forward-looking as to how their interaction with Facebook can be used by advertisers and retailers. On the other hand, consumer myopia may be less plausible in our motivating example of Google/Fitbit. In this sense, our assumption of consumer myopia is mainly to simplify analysis. That said, the main change we expect from having forward-looking consumers is that competition in market B where data is collected will become more intense than when consumers are myopic. This is akin to the insight from the literature on behavior-based price discrimination (Choe et al., 2018).

Remark 1. In our reference to Google/Fitbit, we refer to market A as the digital health care in general, and at times, the market for health insurance. We offer some justifications for our choice of Hotelling model for market A. The Hotelling model is often used in the analysis of competition in healthcare markets.[21] Health plans are highly differentiated for two reasons. First, health plans cover a broad range of treatments for chronic or acute illnesses, and offer different co-payment rates for different treatments. For instance, insurance plan A_1 may cover 40% costs for the dental treatment and 60% costs for the treatment of knee problems, whereas insurance plan A_2 may cover 60% of dental treatment but 40% of knee treatment. Second, consumers' health conditions vary across individuals. A consumer with a serious dental problem but a good knee condition will value plan A_2 higher than plan A_1, whereas another consumer with a knee problem but a good dental condition will prefer plan A_1. We choose the Hotelling model to capture differentiations described above. Thus market A captures one aspect of health care (product differentiation) but ignores other aspects such as different risk types that could lead to adverse selection. As such, it can be best understood as a segment of the healthcare market with customers of similar risk types. Our intention is to focus squarely on the effect of personalization by abstracting away other issues. In Section 6.2, we discuss the case with two risk types and show that focusing on a single risk type does not alter our main insight unless the costs of serving different risk types are sufficiently different.

Remark 2. The key element of our model is the ability the merged firm has in offering personalization in market A. In the context of Google/Fitbit, this relates to the extent to which healthcare services can be personalized, which warrants some elaboration. The healthcare sector is becoming a new battlefield for personalization due to the unprecedented accumulation of health data.[22] In health and life insurance, the new concept Pay-As-You-Live (PAYL), introduced by Ernst & Young, is becoming popular. Wearable devices are developed to track a policyholder's health information, which is then used to perform risk assessments. Under PAYL, consumers demonstrating healthy lifestyles receive premium discounts and other rewards. This type of insurance model is adopted by not only a small start-up such as Health IQ, but also one of the largest insurance companies such as John Hancock. It is worth noting that Google's subsidiary, Verily, entered the insurance market in 2019 in collaboration with John Hancock, as we explain in the Online Appendix. Personalization based on the use of big data is also becoming more prevalent in other areas of health care such as personalized cancer treatment.[23]

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[21] Olivella and Vera-Hernández (2007) employ the Hotelling model in studying competition among differentiated health plans. Biglaiser and Ma (2003) incorporate vertical differentiation into the Hotelling model and study price and quality competition in health care. Katz (2011) uses the Hotelling model to analyze the price and quality competition in the U.S. hospital markets.

[22] In the Online Appendix, we provide a more detailed account of how the healthcare sector is transformed by big data and personalization.

[23] https://www.clinicalomics.com/topics/oncology/multiple-myeloma/gns-healthcare/

3 Equilibrium Analysis of Personalization

We start by analyzing the equilibrium in market A. The only aspect of the merger relevant to our focus is the consumer data harvested by firm B_1, which can be used by firm C for personalization in market A. Denote firm C's target segment by $[0, \delta_A]$. We treat δ_A as exogenous in this section, but will endogenize it in the next section.

Targeted consumer x enjoys gross utility $v_A - (1-\phi_A)x$ from the personalized product and $v_A - x$ from the standard product. Since product personalization is costless, firm C will offer personalized products to all its targeted consumers for any $\phi_A \geq 0$. Denote firm C's personalized price for targeted consumer $x \in [0, \delta_A]$ by $p_A(x)$. For non-targeted consumers in $[\delta_A, 1]$, firm C charges a uniform price, denoted by α_1. But firm A_2 can only charge a uniform price for all consumers, denoted by α_2. We assume that firm C can prevent targeted consumers from purchasing its standard product at uniform price α_1, for instance, by redirecting the product search from a targeted consumer, a practice dubbed steering or search discrimination.[24] This allows firm C to delink its choice of personalized prices and its choice of uniform price.[25]

3.1 Characterization of equilibria

Before characterizing the equilibrium, we define three cutoff values that will be used in our analysis. First, competition for firm C's non-targeted consumers is in uniform price. Given the uniform prices α_1 and α_2, the marginal consumer's location denoted by $\hat{x}$ is given by $\alpha_1 + \hat{x} = \alpha_2 + (1-\hat{x})$, hence

$$\hat{x} \equiv \frac{1+\alpha_2-\alpha_1}{2}. \tag{1}$$

Firm C can serve all consumers $x \leq \hat{x}$ with uniform price.

Next, consider firm C's target segment. Targeted consumer x prefers firm C's personalized offer to firm A_2's standard product if $p_A(x) + (1-\phi_A)x \leq \alpha_2 + (1-x)$. Assuming that targeted consumers choose personalized offers when they are indifferent, firm C's best response to α_2 is given by $p_A(x) = 1 - (2-\phi_A)x + \alpha_2$. Since firm C can adjust its personalized price for each targeted consumer separately, it can reduce $p_A(x)$ down to 0. This defines the marginal consumer $\bar{x}$ as $p_A(\bar{x}) = 0 = 1 - (2-\phi_A)\bar{x} + \alpha_2$, hence

$$\bar{x} \equiv \frac{1+\alpha_2}{2-\phi_A}. \tag{2}$$

Firm C can serve all targeted consumers $x \leq \bar{x}$ with personalization. In doing so, it will choose

[24] Mikians et al. (2012) find that search discrimination is commonly used in online markets. Essentially, we are assuming that firm C can successfully set access hurdles and execute its price discrimination strategy by preventing arbitrage.

[25] Although firm C's personalized prices and uniform price can be delinked in this way, they are indirectly linked through firm A_2's uniform price. That is, α_1 affects α_2 in competition for non-targeted consumers, and α_2 in turn affects firm C's personalized prices in competition for targeted consumers.

personalized prices that make all targeted consumers indifferent between its personalized offer and its competitor's standard offer. Note that $\bar{x} \geq \hat{x}$, which implies that personalization can serve as a more powerful weapon for firm C than uniform pricing in defending its target segment.

Finally, we define the maximum target segment that firm C can profitably serve. Notice first that firm C will never use the uniform price to serve its targeted consumers. The statement is clearly true for targeted consumers in $[\hat{x}, \bar{x}]$. So consider targeted consumer $x \leq \hat{x}$. Firm C can serve consumer x by choosing $p_A(x) = 1-(2-\phi_A)x+\alpha_2$. Then $x \leq \hat{x}$ implies $p_A(x) \geq 1+\alpha_2 - 2\hat{x}+\phi_A\hat{x} = \alpha_1 + \phi_A\hat{x} \geq \alpha_1$. Thus personalization allows firm C to serve its targeted consumers more profitably than uniform pricing. But the ability to use personalization is constrained by its data scale δ_A and data analytics quality ϕ_A. Even when $\delta_A = 1$, firm C can serve consumers only up to $\bar{x}$ using personalization while competing for the remaining consumers in $[\bar{x}, 1]$ with its rival. Given the marginal consumer's location $\bar{x}$ in (2), firm A_2 can maximize profit $\alpha_2(1-\bar{x})$ by choosing $\alpha_2 = (1-\phi_A)/2$. This leads to $\bar{x} = \bar{\delta}$ where $[0, \bar{\delta}]$ is the maximum market segment that firm C can serve, defined as

$$\bar{\delta} \equiv \frac{3-\phi_A}{2(2-\phi_A)}. \tag{3}$$

It is easy to see $\bar{\delta}$ increases in ϕ_A. Put differently, the above analysis shows how firm C can expand its market reach through personalization. With uniform pricing, firm C can reach the maximum market size $[0, 3/4]$ by choosing $\alpha_1 = 0$. With personalization, this can be expanded to $[0, \bar{\delta}]$ where $\bar{\delta} \in [3/4, 1]$.

We now turn to the characterization of equilibrium. There are three cases to consider.

3.1.1 Equilibrium when $\delta_A < 3/4$

First, on $[\delta_A, 1]$, competition is in uniform price with the marginal consumer's location given by $\hat{x}$ in (1). Thus firm C's profit from this segment is $\alpha_1(\hat{x}-\delta_A)$ and firm A_2's profit is $\alpha_2(1-\hat{x})$. Solving for the Hotelling equilibrium, we obtain the equilibrium uniform prices

$$\alpha_1^* = 1 - \frac{4}{3}\delta_A, \ \alpha_2^* = 1 - \frac{2}{3}\delta_A, \tag{4}$$

which implies $\hat{x} = 1/2+\delta_A/3$. For this equilibrium to exist, we need $\alpha_1^* \geq 0$, which is guaranteed since $\delta_A < 3/4$. Note also that $\delta_A < 3/4$ implies $\hat{x} > \delta_A$.

Next, for $x \in [0, \delta_A]$, firm C offers personalization with price $p_A(x)$ that makes consumer x indifferent between firm C's personalized offer and firm A_2's standard product offered at price α_2^*. Thus the equilibrium personalized price in this segment is given by

$$p_A^*(x) = 1-(2-\phi_A)x+\alpha_2^* = 2 - \frac{2}{3}\delta_A - (2-\phi_A)x. \tag{5}$$

Then firm C's total profit is $\Pi_C^* = \int_0^{\delta_A} p_A^*(x)\,dx + \alpha_1^*(\hat{x}-\delta_A)$. Firm A_2 serves consumers in $[\hat{x}, 1]$ with uniform price α_2^*, hence its profit is $\Pi_{A_2}^* = (1-(2\delta_A)/3)^2/2$.

In sum, when firm C's data scale is relatively small in that $\delta_A < 3/4$, none of firm C's targeted consumers are contestable by firm A_2. Firm C serves all of its targeted consumers in $[0, \delta_A]$ with personalization, and some non-targeted consumers in $[\delta_A, \hat{x}]$ with uniform price, while firm A_2 serves the rest. Thus the two firms' market shares in this case are endogenously determined by $\hat{x}$.

3.1.2 Equilibrium when $3/4 \le \delta_A < \bar{\delta}$

In this case, firm C cannot serve any of its non-targeted consumers. Competition in uniform price on $[\delta_A, 1]$ would lead to prices given in (4). But $3/4 \le \delta_A$ implies a negative price for firm C. Thus firm C chooses $\alpha_1 = 0$, hence $\hat{x} = (1+\alpha_2)/2$. Firm A_2 chooses α_2 to maximize profit $\alpha_2(1-\hat{x})$ subject to $\delta_A \le \hat{x}$. It is easy to see that, given $v_A > 3$, firm A_2 can maximize profit by choosing α_2 so that $\delta_A = \hat{x}$. This leads to the following equilibrium uniform prices:

$$\alpha_1^{**} = 0,\ \alpha_2^{**} = 2\delta_A - 1. \tag{6}$$

Given α_2^{**}, we can determined firm C's personalized price as before.

$$p_A^{**}(x) \quad = \quad 2\delta_A - (2-\phi_A)x \text{ for } x \in [0, \delta_A]. \tag{7}$$

Given the above prices and market shares, firm C's profit is $\Pi_C^{**} = \int_0^{\delta_A} p_A^{**}(x)dx$, and firm A_2's profit is $\Pi_{A_2}^{**} = (2\delta_A - 1)(1-\delta_A)$.

In sum, when firm C's data scale is in the intermediate range in that $3/4 \le \delta_A < \bar{\delta}$, firm C can serve only its targeted consumers with personalization while firm A_2 serves all consumers not targeted by firm C. Thus the two firms' market shares are exogenously determined by δ_A.

3.1.3 Equilibrium when $\bar{\delta} \le \delta_A$

In this case, firm C's target segment is so large that firm A_2 serves firm C's targeted consumers in $[\bar{\delta}, \delta_A]$ in addition to all non-targeted consumers in $[\delta_A, 1]$. As shown previously, we then have the following equilibrium uniform prices:

$$\alpha_1^{***} = 0,\ \alpha_2^{***} = \frac{1-\phi_A}{2}. \tag{8}$$

Then firm C's personalized prices are[26]

$$p_A^{***}(x) \quad = \quad \begin{cases} \frac{3-\phi_A}{2} - (2-\phi_A)x, & \text{for } x \in [0, \bar{\delta}]. \\ \ge 0, & \text{for } x \in [\bar{\delta}, \delta_A]. \end{cases} \tag{9}$$

[26]Firm C cannot profitably serve targeted consumers in $[\bar{\delta}, \delta_A]$. So the only restriction we have on these off-the-equilibrium prices is $p_A^{***}(x) \ge 0$, based on a refinement using trembling-hand perfection. That is, suppose firm A_2 'trembles' and increases its price so that some consumers in $[\bar{\delta}, \delta_A]$ choose firm C. This will cost firm C if it had chosen $p_A^{***}(x) < 0$.

Profits are $\Pi_C^{***} = \int_0^{\bar{\delta}} p_A^{***}(x)dx$ and $\Pi_{A_2}^{***} = (1-\phi_A)^2 / (4(2-\phi_A))$.

To summarize this case, when firm C's data scale is large in that $\bar{\delta} \leq \delta_A$, firm C can serve its targeted consumers only up to $\bar{\delta}$. Firm A_2 poaches firm C's targeted consumers in $[\bar{\delta}, \delta_A]$ in addition to serving all non-targeted consumers. In this case, the two firms' market shares are endogenously determined by $\bar{\delta}$. We summarize the above discussions below.

Proposition 1 *Suppose firm C's target segment is given by* $[0, \delta_A]$.

- *When* $\delta_A < 3/4$, *there exists a unique equilibrium in which firm C serves all targeted consumers with personalization at price* $p_A^*(x)$, *and chooses uniform price* α_1^* *to serve non-targeted consumers in* $[\delta_A, 1/2 + \delta_A/3]$. *Firm* A_2 *serves all remaining consumers with uniform price* α_2^*. *These prices are given in (4) and (5).*
- *When* $3/4 \leq \delta_A < \bar{\delta}$, *there exists a unique equilibrium in which firm C serves all targeted consumers with personalization at price* $p_A^{**}(x)$, *and firm* A_2 *serves all remaining consumers with uniform price* α_2^{**}. *These prices are given in (6) and (7).*
- *When* $\bar{\delta} \leq \delta_A$, *there exists a unique equilibrium in which firm C serves targeted consumers in* $[0, \bar{\delta}]$ *with personalization at price* $p_A^{***}(x)$, *while firm* A_2 *serves all consumers in* $\left[\bar{\delta}, 1\right]$ *with uniform price* α_2^{***}. *These prices are given in (8) and (9).*

3.2 Welfare implications of personalization

Based on the equilibrium characterization in Proposition 1, we now turn to the discussions of how firm C's ability to use personalization following the merger affects welfare. We start by making two observations on how personalization can increase firm C's market power, which can be used to exploit a subset of targeted consumers and harm its stand-alone competitor.

That personalization can lead to consumer exploitation seems intuitive given that firm C can tailor its pricing strategy for each targeted consumer. This is especially true for targeted consumers close to firm C's location since the benefit of improved matching value is small for these consumers. On the other hand, firm C's non-targeted consumers may benefit since more intense competition in uniform price reduces uniform prices below the Hotelling benchmark. In sum, personalization can lead to exploitation of some consumers while benefiting others.

The ability to use personalization expands firm C's pricing arsenal, making it a more effective defender of its target segment and a more aggressive competitor outside of it. The end result is that firm C will be able to enlarge its market share above the Hotelling benchmark. This is true for any value of δ_A since having a target segment $[0, \delta_A]$ shifts the battleground for Hotelling competition from $[0, 1]$ to $[\delta_A, 1]$. This hurts firm A_2 although, except for the case with $\delta_A = \phi_A = 1$, firm A_2 will continue to remain active in the market, albeit with reduced profit and market share. But the market can turn into a monopoly in the long run if there are some fixed costs of staying in the market, which are not covered by firm A_2's short-run profit.

With these observations in mind, let us examine how personalization following the merger affects each firm's profit and consumer surplus.

First, firm C is unambiguously better off after the merger. Given that firm C can always revert to the Hotelling competition, the ability to use personalization at no additional cost following the merger cannot hurt it. This can be verified by checking that firm C's profit in all the three cases in Proposition 1 is larger than 1/2, its pre-merger profit. In contrast, firm A_2's profit decreases unambiguously. Moreover, one can check $\Pi^{***}_{A_2} < \Pi^{**}_{A_2} < 1/8$. Thus the merger can reduce firm A_2's profit to less than 25% of its pre-merger profit if firm C's data set covers more than three quarters of consumers. As discussed previously, this could force firm A_2 to exit the market in the long run if it has a fixed cost greater than 1/8.

Next, personalization harms some consumers but benefits others. Before the merger, a targeted consumer x receives utility $v_A - x - 1$ given the Hotelling price equal to 1. After the merger, consumer x will be given a personalized offer from firm C that leaves her indifferent between choosing firm C and firm A_2. The latter choice gives her utility equal to $v_A-(1-x)-\alpha_2$. Thus consumer x is worse off after the merger if $v_A-(1-x)-\alpha_2 < v_A-x-1$, or $x < \alpha_2/2$. This implies that consumers closer to firm C are more likely to be exploited through personalization. In the equilibrium with $\delta_A < 3/4$, we have $\alpha^*_2/2 = 1/2 - \delta_A/3 > 1/4$. Thus at least one quarter of consumers including those in $[0, 1/4]$ are worse off after the merger. But targeted consumers in $[\alpha_2/2, \delta_A]$ benefit from personalization. In addition, all consumers outside firm C's target segment also benefit from the merger because of lower uniform prices than before the merger. This suggests that personalization following the merger can decrease total consumer surplus if firm C's target segment is sufficiently large and firm C can exploit a large fraction of these targeted consumers through personalization. Otherwise, total consumer surplus increases.

Proposition 2 *Suppose firm C's target segment is given by* $[0, \delta_A]$. *Then personalization following the merger*

- *increases firm C's profit unambiguously;*
- *reduces firm A_2's profit unambiguously;*
- *increases total consumer surplus except when $\phi_A > 2/3$ and $\delta_A \in (7/8, \bar{\delta})$.*

Next, we discuss the comparative statics of profits and consumer surplus with respect to δ_A and ϕ_A. First, suppose firm C has a large data scale in that $\delta_A \geq \bar{\delta}$. In this case, the two firms' market shares are determined by $\bar{\delta}$, which is independent of δ_A; nor do equilibrium prices depend on δ_A. Consequently, an increase in δ_A affects neither firm's profits, implying that an excessive data scale beyond $\bar{\delta}$ has no effect on competition. In contrast, an increase in ϕ_A intensifies competition and reduces firm A_2's uniform price, which in turn reduces firm C's personalized prices. Thus an increase in ϕ_A reduces both firms' profits but benefits all consumers.

Consider next the case $3/4 \leq \delta_A < \bar{\delta}$, when firm C can serve all its targeted consumers while firm A_2 serves the rest. In this case, an increase in δ_A benefits firm C simply because it allows firm C to serve more consumers, but hurts firm A_2 for exactly the same reason. Consumer surplus decreases in δ_A since an increases in δ_A increases firm A_2's uniform price. As for ϕ_A, its increase benefits firm C by allowing it to increase its personalized prices $p_A(x)$, thereby extracting the efficiency gain from the improved matching value. But it has no effect on firm A_2's profit since neither firm A_2's market share nor its equilibrium uniform price depends on ϕ_A. Likewise, it has no effect on consumer surplus since the improved matching value is fully extracted by firm C through personalized pricing.

When $\delta_A < 3/4$, firm C serves some non-targeted consumers in addition to all of its targeted consumers. An increase in δ_A in this case has two countervailing effects: it allows firm C to serve more consumers but it also intensifies competition for non-targeted consumers. As a result, the impact of an increase in δ_A on firm C's profit may not be monotonic. It is easy to check Π_C^* is concave in δ_A and reaches a maximum at $\delta_A = \delta^* \equiv 6/(14 - 9\phi_A)$ where $\delta^* \leq 3/4$ if and only if $\phi_A \leq 2/3$. In contrast, an increase in δ_A unambiguously reduces firm A_2's profit. On the other hand, an increase in ϕ_A benefits firm C by allowing it to increase $p_A(x)$ but it has no effect on firm A_2's profit. As for consumer surplus, an increase in δ_A benefits consumers since it decreases uniform prices, and therefore, personalized prices as well. But an increase in ϕ_A has no effect on consumer surplus as in the previous case.

Proposition 3 *Suppose firm C's target segment is given by* $[0, \delta_A]$.

- *Firm C's profit weakly increases in* δ_A *except when* $\phi_A < 2/3$ *and* $\delta_A \in [\delta^*, 3/4]$ *where* $\delta^* \equiv 6/(14 - 9\phi_A)$. *Firm C's profit increases in* ϕ_A *when* $\delta_A < \bar{\delta}$, *but decreases in* ϕ_A *when* $\delta_A \geq \bar{\delta}$.
- *Firm* A_2*'s profit decreases in* δ_A *up to* $\delta_A = \bar{\delta}$, *but is independent of* δ_A *thereafter. Firm* A_2*'s profit is independent of* ϕ_A *when* $\delta_A < \bar{\delta}$, *but decreases in* ϕ_A *when* $\delta_A \geq \bar{\delta}$.
- *Consumer surplus increases in* δ_A *up to* $\delta_A = 3/4$, *decreases in* δ_A *for* $\delta_A \in [3/4, \bar{\delta}]$, *but is independent of* δ_A *after that. Consumer surplus is independent of* ϕ_A *when* $\delta_A < \bar{\delta}$, *but increases in* ϕ_A *when* $\delta_A \geq \bar{\delta}$.

The main thrust of Proposition 3 is differential effects of data scale vis-à-vis data analytics relevant to personalization. Increasing data scale can benefit firm C but only up to a certain point, because its ability to serve additional targeted consumers is ultimately limited by its data analytics. Insofar as firm C benefits from a larger data scale, its competitor inevitably loses due to a decrease in its market share. In contrast, an improvement in data analytics can benefit firm C without hurting its competitor since the benefit comes from the firm's ability to extract surplus from consumers that firm C already serves, rather than from poaching consumers from its competitor. On the other hand, a further improvement in data analytics coupled with a large data scale can hurt both firms by intensifying competition for consumers firm C cannot serve.

We close this section with a caveat. As our model is essentially static, Proposition 2 simply reiterates the well-known point that data can generally benefit consumers in the short run by intensifying competition. Of course, the effect can be only short-lived if the intensified competition leads to market tipping and drives the competitor out of the market in the long run. Data externalities can further expedite this process. Relevant to Google/Fitbit, Google can correlate health data on Fitbit users with its own data from other Google services, and infer health-related information on Google users even if they do not use Fitbit devices. One way to think about data externalities in our setting is that firm C can use the data from its target segment $[0, \delta_A]$ to infer information on the remaining segment. For example, firm C can expand its target segment to $[0, (1+y)\delta_A]$ where $0 \leq y \leq (1-\delta_A)/\delta_A$. If $y = (1-\delta_A)/\delta_A$, then firm C's target segment covers the entire market. This leads to the monopolization of market A by firm C if $\phi_A = 1$. Then firm C can use personalization to extract consumer surplus uninhibited by competition. This suggests a dynamic trade-off between short-term gains in consumer surplus and possible long-term losses.

4 Data-Driven Mergers with Cross-Markets Effects

One of the concerns that competition authorities have in cases like Google/Fitbit merger is how a dominant firm like Google can leverage advantages from its powerful ecosystem into related markets through the merger. Of course, such concerns make sense only when there are some linkages between the relevant markets. We model such linkages through two channels: data and consumption synergy. First, we have already argued that firm C can use data it harvests in market B for personalization in market A. But data alone establishes only a one-way linkage. So we introduce another element. Specifically, a consumer who purchases firm B_1's product receives extra value $\omega > 0$ by choosing firm C's personalized product in market A. This extra value can be interpreted as a consumption synergy, which may be due to several factors. First, there may be "one-stop shopping" benefits such as reduced transactions costs. Second, there may be benefits from consuming the two products together. For example, some add-on features in the personalized product may have value only when consumed together with firm B_1's product. In case of Google/Fitbit, incorporating the wearable device into Google's ecosystem and packaging it with other existing applications and services can enhance user experience in the market for digital health. Third, the extra value ω may capture a bundling discount in reduced form. Our aim in this section is to understand how data and the consumption synergy affect competition in both markets.[27]

Throughout this section, we assume perfect personalization, i.e., $\phi_A = 1$, primarily to simplify analysis. Also recall our assumption that consumers are not forward looking, so that their purchase decisions in the two markets are separately made. In addition, neither consumers nor firms discount future. The timing of the game is as follows. First, firms A_1 and B_1 decide whether they should merge and create firm C. They choose to merge if and only if their total

[27]The merger is not the only way to make data in market B available in market A. For example, firms A_1 and B_1 can sign a contract for trading data. In the absence of the consumption synergy, one can find non-linear tariffs that can lead to the same outcome as that under the merger. But the consumption synergy is merger-specific in the sense that it can be exploited only through the merger.

profit after the merger is larger than that before the merger. Without the merger, the status quo is maintained. With the merger, we analyze market B first where firm C is the first mover. This determines firm C's target segment in market A. The timing of the pricing game in market A is the same as before. That is, uniform prices are simultaneously chosen, after which firm C makes personalized offers. We solve the game backward.

4.1 Analysis of equilibria

Denote firm C's target segment in market A by $[0, x^*]$ where x^* is the marginal consumer who chose firm B_1's product in market B. Firm C sets personalized prices to leave all targeted consumers indifferent between choosing either firm in market A. Thus $v_A + \omega - p_A(x) = v_A - (1 - x) - \alpha_2$, hence $p_A(x) = 1 + \omega + \alpha_2 - x$ for all $x \in [0, x^*]$. This leads to the following observations. First, since $p_A(1) = \omega + \alpha_2 > 0$, firm C can profitably serve all targeted consumers in market A. Thus data scale has a positive marginal benefit in market A, which makes monopolization an attractive option. Second, the consumption synergy ω increases the marginal benefit to data scale, which makes firm C more aggressive in market B than without the consumption synergy. Thus ω plays two roles: it adds market power to firm C in market A; it links the two markets by creating negative externalities for firm B_2.

From the discussions above, we expect two types of equilibria. If ω is large enough, we expect firm C to monopolize market B, which also implies the monopolization of market A. Otherwise, firm C will accommodate competitors in both markets. In both types of equilibria, we expect the merger to be an equilibrium outcome. This is because firm C obtains market power created by the ability to use personalization and the consumption synergy only through the merger. We now turn to the characterization of each type of equilibrium.

The analysis of market A is the same as that in Section 3 with δ_A replaced by x^*. The only differences are that we now have ω and $\phi_A = 1$. Let us turn to market B. Given β_1, firm B_2 chooses β_2 to maximize $\beta_2(1 - x^*)$ where $x^* = (1 - \beta_1 + \beta_2)/2$. This leads to firm B_2's best response $\beta_2 = (1 + \beta_1)/2$, hence $x^* = (3 - \beta_1)/4$. Then firm C chooses β_1 to maximize total profit from both markets. Based on the analysis in Section 3, we consider two cases.

First, if $x^* \leq 3/4$, then, from Section 3.1.1, we have $\alpha_1^* = 1 - (4x^*)/3$, $\alpha_2^* = 1 - (2x^*)/3$, $\hat{x} = 1/2 + x^*/3$, and $p_A^*(x) = 2 + \omega - x - (2x^*)/3$. Firm C's total profit in this case is

$$\Pi_C = \beta_1 x^* + \int_0^{x^*} p_A^*(x)dx + \alpha_1^*(\hat{x} - x^*) = -\frac{5}{18}(x^*)^2 + \left(\frac{2}{3} + \omega + \beta_1\right) x^* + \frac{1}{2} \tag{10}$$

where $x^* = (3 - \beta_1)/4$. Solving for firm C's optimal uniform price β_1^* and substituting it back to β_2 and x^*, we obtain

$$\beta_1^* = \frac{99 - 36\omega}{77},\ \beta_2^* = \frac{88 - 18\omega}{77},\ x^* = \frac{33 + 9\omega}{77}. \tag{11}$$

Substituting x^* into the prices in market A given above, we have

$$\alpha_1^* = \frac{33 - 12\omega}{77},\ \alpha_2^* = \frac{55 - 6\omega}{77},\ p_A^*(x) = \frac{132 + 71\omega}{77} - x,\ \hat{x} = \frac{9}{14} + \frac{3\omega}{77}. \tag{12}$$

The above prices constitute a local optimum if and only if $x^* = (33 + 9\omega)/77 \le 3/4$, hence $\omega \le 11/4$. We now verify that, given the above prices, firm C's total profit is larger than the sum of the two firms' pre-merger equilibrium profits. Before the merger, firm A_1's profit is $1/2$ and firm B_1's profit is $9/16$, hence the total profit $17/16$. After the merger, firm C's total profit can be calculated from (10): $\Pi_C^* = 3(66 + 22\omega + 3\omega^2)/154 > 17/16$. In addition, Π_C^* increases in ω. In contrast, the merger hurts rival firms in both markets. Their post-merger profits can be calculated as $\Pi_{A_2}^* = \alpha_2^*(1 - \hat{x}) = (55 - 6\omega)^2/11858$ and $\Pi_{B_2}^* = \beta_2^*(1 - x^*) = 2(44 - 9\omega)^2/5929$. It is easy to verify $\Pi_{A2}^* < \Pi_{A2}^0 = 1/2$ and $\Pi_{B2}^* < \Pi_{B2}^0 = 25/32$. Moreover, both profits decrease in ω; in particular, the consumption synergy in market A hurts firm B_2.

To summarize, if $\omega \le 11/4$, then a candidate equilibrium exists in which firm C serves non-targeted consumers in $[x^*, \hat{x}]$ in addition to all targeted consumers in market A, but accommodates rivals in both markets. In this case, the merger allows firm C to increase its market share from $3/8$ to $x^* \ge 3/7$ in market B, and from $1/2$ to $\hat{x} \ge 9/14$ in market A. We call this the accommodation equilibrium I.

Second, if $x^* \in [3/4, 1]$, then, from Section 3.1.2, we have $\alpha_1^* = 0$, $\alpha_2^* = 2x^* - 1$, and $p_A^*(x) = 2x^* + \omega - x$. Firm C's total profit in this case is

$$\Pi_C = \beta_1 x^* + \int_0^{x^*} (1 - x + \omega + (2x^* - 1))dx = \frac{3(x^*)^2}{2} + (\beta_1 + \omega)x^* \tag{13}$$

where $x^* = (3 - \beta_1)/4$. Solving for firm C's optimal uniform price β_1^{**} and substituting it back to $\beta_2 = (1 + \beta_1)/2$ and x^*, we obtain

$$\beta_1^* = \frac{3 - 4\omega}{5},\ \beta_2^* = \frac{4 - 2\omega}{5},\ x^* = \frac{3 + \omega}{5}. \tag{14}$$

Substituting x^* into the prices in market A given above, we obtain

$$\alpha_1^* = 0,\ \alpha_2^* = \frac{1 + 2\omega}{5},\ p_A^*(x) = \frac{6 + 7\omega}{5} - x. \tag{15}$$

The above prices constitute a local optimum if and only if $x^* \in [3/4, 1]$, hence $3/4 \le \omega \le 2$. Once again, one can verify that, given the above prices, firm C's total profit is larger than the sum of the two firms' pre-merger equilibrium profits: $\Pi_C^* = (3 + \omega)^2/10 > 17/16$ since $\omega \ge 3/4$. Likewise, both firms A_2 and B_2 have lower profits after the merger: $\Pi_{A_2}^* = (-2\omega^2 + 3\omega + 2)/25 < 1/2$ and $\Pi_{B_2}^* = 2(2 - \omega)^2/25 < 25/32$.

To summarize, if $3/4 \le \omega \le 2$, then a candidate equilibrium exists in which firm C serves only targeted consumers in market A and accommodates rivals in both markets. In this case, the merger allows firm C to increase its market share to $x^* \ge 3/4$ in both markets. We call this the accommodation equilibrium II.

The above analysis shows that there are two local optima when $3/4 \leq \omega \leq 2$. Thus we need to identify a global optimum by comparing firm C's profits given the two local optimal prices $\beta_1^* = (99-36\omega)/77$ and $\beta_1^* = (3-4\omega)/5$. Comparing the profits for each case, one can verify that $\beta_1^* = (99-36\omega)/77$ is globally optimal if $\omega \leq 3(\sqrt{385}-11)/16 \simeq 1.62$. Thus the accommodation equilibrium I exists in this case. If $3(\sqrt{385}-11)/16 \leq \omega \leq 2$, then $\beta_1^* = (3-4\omega)/5$ is globally optimal, leading to the accommodation equilibrium II.

If $\omega \geq 2$, then it is optimal for firm C to monopolize market B by choosing $\beta_1^* = -1$, and hence market A as well.[28] We call this the monopolization equilibrium. In this equilibrium, firm C prices below cost in market B and serves all consumers in market A using personalized prices $p_A^*(x) = 2 + \omega - x$, earning profit $\Pi_C^* = (1+2\omega)/2$.[29] The monopolization equilibrium can be described as the short-run predatory equilibrium in that firm C prices below cost and monopolizes the market, but without fully utilizing its monopoly power. This is because firm A_2 is lurking in the background, waiting to counter any price increase by firm C. Thus the presence of firm A_2, albeit inactive in equilibrium, makes the market contestable. This situation is likely to prevail only in the short run, however. If competitors exit the market in the long run, then the monopolization equilibrium will turn into the monopoly equilibrium, which will be much more profitable for firm C to the detriment of consumers.[30] In the monopoly equilibrium, firm C can extract full consumer surplus from each consumer in market A with personalized prices $p_A^m(x) = v_A + \omega > p_A^*(x)$ for all $x \in [0,1]$; in market B, it serves the entire market with monopoly price $\beta^m = v_B/2 > 3/2 = \beta_1^0 > \beta_2^0 = 5/4$, resulting in consumer surplus lower than that in the pre-merger equilibrium.

Proposition 4 *There exist three types of equilibria described below, in all of which firms A_1 and B_1 choose to merge.*

- *If $\omega \leq 3(\sqrt{385}-11)/16$, then the accommodation equilibrium I arises with prices given in (11) and (12).*
- *If $3(\sqrt{385}-11)/16 \leq \omega \leq 2$, then the accommodation equilibrium II arises with prices given in (14) and (15).*
- *If $\omega \geq 2$, then the monopolization equilibrium arises.*

[28] When $\omega \in [2, 11/4]$, the accommodation equilibrium I is also possible. But it is easy to see that firm C's profit is higher when it monopolizes both markets.

[29] In the monopolization equilibrium, firm A_2 chooses an off-the-equilibrium price α_2. In this case, we use a refinement in which $\alpha_2 = \lim_{\varepsilon \to 0} \alpha_2(\varepsilon)$ where $\alpha_2(\varepsilon)$ is optimally chosen when $x^*(\varepsilon) = 1 - \varepsilon$. This refinement is in the same spirit as trembling-hand perfection that allows firm C's tremble in market B. Given the monopolization of market B, the only meaningful tremble is when firm C increases its price slightly. This leads to $x^*(\varepsilon) < 1$, whence $\alpha_1(\varepsilon) = 0$ and $\alpha_2(\varepsilon) = 2x^*(\varepsilon) - 1$. Thus $\alpha_2 = \lim_{\varepsilon \to 0} \alpha_2(\varepsilon) = 1$.

[30] This is somewhat reminiscent of the dynamic leverage theory, in which an incumbent monopolist bundles complementary products to extend its monopoly power into related markets by deterring entry of competitors (Carlton and Waldman, 2002; Choi and Stefanadis, 2001). But the main difference is the role of personalization in our paper, without which firm C cannot monopolize market A even if it had acquired full information from market B. That is, data-enabled personalization, rather than tying, is a key to the monopolization of market A.

4.2 Welfare implications of the merger

Our analysis so far has shown that the merger benefits firm C at the cost of its competitors in both markets. The benefits are derived from data-enabled personalization that allows firm C to extract surplus from its targeted consumers, and to expand its market power against the competitor in the market for data application, supported by firm C's aggressive pricing in the market for data collection. To complete the analysis, we now examine how consumer surplus changes after the merger.

Let us start with the accommodation equilibria. Consider market A. Before the merger, price is equal to 1 and firms share the market equally. After the merger, prices and firm C's market share are given in (12) in the accommodation equilibrium I, and they are given in (14) and (15) in the accommodation equilibrium II. Since $\alpha_1^*, \alpha_2^* < 1$, it is immediate that all consumers in $[x^*, 1]$ are better off. On the other hand, firm C's targeted consumers may or may not be better off. All of them pay personalized prices higher than 1 but they benefit from perfectly matched products and the additional consumption synergy. Since personalized prices are higher for consumers whose taste parameter is closer to 0, it follows that there is a threshold value of taste parameter such that consumers are worse off if and only if their taste parameter is below the threshold.[31] Given the uniform distribution, one can show that total consumer surplus in market A increases after the merger in the accommodation equilibrium I, but decreases in the accommodation equilibrium II. The intuition is that consumers pay higher prices in the accommodation equilibrium II than in the accommodation equilibrium I since firm A_2 serves all non-targeted consumers in the former.

In market B, all consumers are better off. Before the merger, prices are $\beta_1^0 = 3/2$, $\beta_2^0 = 5/4$, and the market is divided at $x^0 = 3/8$. After the merger, prices and the marginal consumer are given in (11) and (14) for the respective accommodation equilibrium. It is worth noting that firm C prices below cost, i.e., $\beta_1^* < 0$, for all values of ω that lead to the accommodation equilibrium II. Since equilibrium prices are lower, all consumers in $[0, x^0] \cup [x^*, 1]$ are better off because they pay less while choosing the same firm. For consumer $x \in [x^0, x^*]$ who switches from firm B_2 to firm C after the merger, the change in consumer surplus is $v_B - x - \beta_1^* - \big(v_B - (1-x) - \beta_2^0\big) = 1 - 2x - \beta_1^* + \beta_2^0 > 0$. Thus all consumers in market B are better off after the merger.

In the monopolization equilibrium, changes in consumers surplus are clearer. In market A, consumer $x \in [0, 1/2]$ is worse off after the merger since $(v_A + \omega - p_A^{**}(x)) - (v_A - x - 1) = 2x - 1 \leq 0$. Thus all consumers who purchased from firm A_1 before the merger are worse off. On the other hand, all consumers who purchased from firm A_2 before the merger have the same consumer surplus since $(v_A + \omega - p_A^{**}(x)) - (v_A - (1-x) - 1) = 0$. It follows that total consumer surplus in market A decreases unambiguously after the merger. In market B, the merger benefits all consumers thanks to below-cost pricing, although one needs to exercise caution in interpreting

[31] The threshold value is given by $v_A - x - 1 = v_A + \omega - p_A^*(x)$, hence $x = (55 - 6\omega)/154$ in the accommodation equilibrium I and $x = (1 + 2\omega)/10$ in the accommodation equilibrium II.

this result. The comparison of consumer surplus in this case is in relation to the monopolization equilibrium, rather than the monopoly equilibrium. If the merger leads to the latter in the long run, then firm C will fully exploit its monopoly power. In market A, this implies that firm C will extract entire consumer surplus thanks to data-enabled personalization. In market B, the monopoly price is $\beta^m = v_B/2$, hence total consumer surplus is equal to $(v_B - 1)/2$. As discussed earlier, this consumer surplus is smaller than that in the pre-merger equilibrium.

Put together, these results show clear welfare implications of data-driven mergers. The merging parties are better off at the cost of their stand-alone competitors. In the market for data collection, consumers may gain in the short run thanks to intensified competition. But consumers in the market for data application are better off if the consumption synergy is not large enough so that the merged firm continues to serves some non-targeted consumers. Otherwise, they are worse off since the merged firm uses personalized pricing to extract much of the efficiency gains generated from the consumption synergy and the improved matching value created by product personalization.

Proposition 5 *The merger with cross-markets effects has the following welfare implications.*

- *If* $\omega \leq 3(\sqrt{385} - 11)/16 \simeq 1.62$*, then total consumer surplus is larger in both markets than before the merger.*
- *If* $\omega \geq 3(\sqrt{385} - 11)/16$*, then total consumer surplus is smaller in market* A *but larger in market* B *than before the merger.*
- *If* $\omega \geq 2$*, when firms* A_2 *and* B_2 *exit in the long run following monopolization, total consumer surplus is smaller in both markets than before the merger.*
- *In all three types of equilibria, firms* A_2 *and* B_2 *are worse off than before the merger and their profits decrease in* ω *while firm* C*'s profit increases in* ω*.*

5 Policy Implications

In conventional merger assessments, possible costs due to lessening of competition are weighed against potential benefits from the merger-specific efficiency gains that can be passed on to consumers. We have discussed two types of efficiency gains in data-driven mergers: consumption synergy (ω) and product personalization (ϕ_A) with the total efficiency gains for consumer x measured by $\omega + \phi_A x$. As shown in Section 4, however, firm C can extract the efficiency gains through personalized prices, $p_A(x) = 1 - 2x + \alpha_2 + \omega + \phi_A x$. Thus possible consumers benefits in the form of lower prices are not an indication that the efficiency gains are passed on to consumers; rather, they are driven by firm C's strategic motives for market dominance and, therefore, are likely to be temporary. This also implies that firm C becomes more aggressive as the efficiency gains increase: as Proposition 5 shows, the market is more likely to be monopolized as ω increases. In short, the very source of potential benefits from the merger can be the reason for the market to tip in the merged firm's favor, and the efficiency gains cannot be a plausible reason for approving a data-driven tech merger.

In addition, even if stand-alone competitors do not exit the market in the short run, there is risk of market tipping in the long run due to data externalities and network effects, as we have discussed previously. Indeed, digital markets often face a trade-off where the potential dynamic costs of concentration outweigh any static benefits (Furman et al., 2019). This trade-off has been one of the main concerns for competition authorities. To quote Crémer et al. (2019, p. 76), "Because of the innovative and dynamic nature of the digital world, and because its economics are not yet completely understood, it is extremely difficult to estimate consumer welfare effects of specific practices."

In view of these concerns, we consider possible remedies that are often discussed in relation to tech mergers.[32] Particularly relevant to the Google/Fitbit merger are remedies that relate to the use of health data for Google Ads, access to the Fitbit Web API in relation to the digital health, and competition in the market for wearable devices.[33] As the first one is not directly relevant to our model, we consider the other two. Specifically, we first analyze the effect of data sharing between firms C and A_2. Then we examine the effect of banning below-cost pricing in market B. This is followed by a brief discussion on the case of blocking the merger. We continue to assume $\phi_A = 1$ and denote the marginal consumer in market B by $\tilde{x}$ to facilitate comparison with x^* in Section 4.

5.1 Data sharing

Suppose firm C is compelled to share data with firm A_2, based on which firm A_2 can also make personalized offers. We assume firm A_2's personalization technology is identical to firm C's. Given data sharing, firms C and A_2 compete under symmetric information, which intensifies competition in the target segment and reduces the value of data. This dampens firm C's incentives to collect consumer data, hence softens competition in market B. Thus the effect of data sharing in market B is clear: firm B_2 is better off but consumers are worse off due to higher uniform prices. But the effect in market A is more complex and we need to examine all possible equilibria.

Before describing possible equilibria, we first note that, even with data sharing, firm C can serve all targeted consumers thanks to the consumption synergy, which firm A_2 cannot offer to its consumers. With this in mind, we now describe three possible equilibria given data sharing. Let $[0, \tilde{x}]$ be the target segment and $\hat{x}$ be the marginal consumer in market A when competition is in uniform price. First, when ω is relatively small in that $\omega \leq 3$, there is an equilibrium in

[32] For example, see Bourreau et al. (2020).

[33] These are discussed in the decision made by the European Commission in approving the Google/Fitbit merger (https://ec.europa.eu/commission/presscorner/detail/en/ip_20_2484) and in the statement by the ACCC in Australia (https://www.accc.gov.au/media-release/accc-rejects-google-behavioural-undertakings-for-fitbit-acquisition).

which firm C serves all consumers in $[0, \tilde{x}]$ with personalization, those in $[\tilde{x}, \hat{x}]$ with uniform price, while firm A_2 serves the rest with uniform price. This equilibrium has the same structure as the accommodation equilibrium with accommodation I in Section 4, but with several key differences: (i) personalized prices are lower due to more intense competition in the target segment; (ii) the target segment is smaller because of (i); (iii) uniform prices are higher in both markets because of (ii). Second, If $\omega \in [3, 5]$, then there is an equilibrium where firm C serves only targeted consumers while firm A_2 serves the rest, as in the accommodation equilibrium II. Finally, if $\omega \geq 5$, then firm C monopolizes both markets.

Table 1: Equilibria with or without data sharing

ω	$[0, 2]$	$[2, 3]$	$[3, 5]$	$5 \leq \omega$
No data sharing	Accommodation I, II	Monopolization	Monopolization	Monopolization
Data sharing	Accommodation I	Accommodation I	Accommodation II	Monopolization

Table 1 shows various types of equilibria with or without data sharing for different ranges of ω. Comparing the equilibria for the given range of ω, we can show that total consumer surplus in market A increases after data sharing, primarily because of lower personalized prices. In addition, data sharing sustains equilibria with accommodation for a wider range of values for ω than without data sharing, as shown in Table 1. In this sense, data sharing can be pro-competitive. To summarize, data sharing benefits stand-alone competitors at the cost of merging firms, and in the process, hurts consumers in the market for data collection but benefits consumers in the market for data application. It can be also pro-competitive by intensifying competition where data is used and by making monopolization harder to achieve. The following proposition summarizes the key implications of data sharing.

Proposition 6 *Suppose firm C is compelled to share data with firm A_2.*

- *Firm C is worse off but both firms A_2 and B_2 are better off than without data sharing.*
- *In market A, total consumer surplus is larger in all equilibria than without data sharing.*
- *In market B, total consumer surplus is strictly smaller in all equilibria when $\omega < 5$ than without data sharing, but remains unchanged if $\omega \geq 5$.*
- *Monopolization is less likely with data sharing in the sense that the monopolization equilibrium arises for $\omega \geq 5$ whereas, without data sharing, the monopolization equilibrium arises for $\omega \geq 2$.*

5.2 Restriction on below-cost pricing

Our analysis in Section 4 shows that firm C will engage in below-cost pricing in market B in the accommodation equilibrium II and the monopolization equilibrium. Clearly, the reason is to harvest a large set of consumer data that firm C can use in market A. If the benefit from market

A more than offsets the loss in market B, then below-cost pricing is profitable. What happens if the competition authority bans below-cost pricing? We discuss its implications below.

Given the restriction $\beta_1 \geq 0$, firm C cannot monopolize the market and the accommodation equilibria remain the only possibility. Consider first the accommodation equilibrium I, which is possible when $\tilde{x} \leq 3/4$, hence $\omega \leq 11/4$. Since $\beta_1^* \geq 0$ in this case as shown in (11), the restriction does not affect the accommodation equilibrium I. Consider next the accommodation equilibrium II, which is possible when $\tilde{x} \geq 3/4$. In this case, we have $\beta_1^* = (3 - 4\omega)/5$, as shown in (14). Thus the restriction is binding if $\omega \geq 3/4$, when firm C chooses $\beta_1 = 0$, to which firm B_2's best response is $\beta_2 = 1/2$. Since both accommodation equilibria are possible when $\omega \in [3/4, 11/4]$, we need to compare the profits to find the global optimum. It is easy to see that firm C's profit is higher in the accommodation equilibrium I. Thus we can conclude that the accommodation equilibrium I arises when $\omega \leq 11/4$ and the accommodation equilibrium II arises when $\omega \geq 11/4$. The accommodation equilibrium I is the same as that without the restriction. In the accommodation equilibrium II, we have $\beta_1^* = 0$, $\alpha_2^* = \beta_2^* = 1/2$, different from those without the restriction.

The analysis above shows that the restriction has two main effects. First, it expands the range of ω that leads to the accommodation equilibrium I from $[0, 3(\sqrt{385} - 11)/16]$ to $[0, 11/4]$. Second, it eliminates the possibility of the monopolization equilibrium. Recall that, without the restriction, we have the monopolization equilibrium when $\omega \geq 2$. Table 2 shows various types of equilibria with or without the restriction for different ranges of ω.

Table 2: Equilibria with or without the restriction on below-cost pricing

ω	$[0, 3(\sqrt{385} - 11)/16]$	$[3(\sqrt{385} - 11)/16, 2]$	$[2, 11/4]$	$11/4 \leq \omega$
No restriction	Accommodation I	Accommodation II	Monopolization	Monopolization
Restriction	Accommodation I	Accommodation I	Accommodation I	Accommodation II

From Table 2, we can make the following observations. When $\omega \leq 3(\sqrt{385} - 11)/16$, the restriction has no effect. In all other cases, the restriction unambiguously hurts consumers in market B by raising prices, hurts firm C by decreasing its market share, and benefits firms A_2 and B_2 as a result. In what follows, we discuss only the comparison of consumer surpluses in market A. When $\omega \in [3(\sqrt{385} - 11)/16, 2]$, we compare the accommodation equilibrium I under the restriction with the accommodation equilibrium II without the restriction. Firm A_2's price is higher in the latter because firm C's target segment is larger and firm C does not serve any non-targeted consumers. This also means that firm C's personalized prices are higher in the latter. The combined effects from these dominate the lower uniform price charged by firm C in the latter. As a result, total consumer surplus is higher in the accommodation equilibrium I. When $\omega \in [2, 11/4]$, the comparison is between the accommodation equilibrium I under the restriction and the monopolization equilibrium without the restriction. Since all prices decrease under the restriction, consumers are better off. The same argument applies when $\omega \geq 11/4$.

Proposition 7 *Suppose firm C is not allowed to engage in below-cost pricing. The restriction has no impact when $\omega \leq 3(\sqrt{385} - 11)/16$. If $\omega \geq 3(\sqrt{385} - 11)/16$, then*

- *both firms A_2 and B_2 benefit at the cost of firm C;*
- *consumer surplus increases in market A, but decreases in market B;*
- *the ban prevents monopolization so all consumers can benefit in the long run compared to when below-cost pricing is allowed.*

5.3 Blocking the merger

Merger remedies require continuous and effective monitoring and enforcement to have intended effects. But this can be a daunting task in complex and rapidly changing digital industries, which may leave blocking the merger as the only alternative. As discussed in Proposition 5, the key welfare implications of blocking the merger hinge on the consumption synergy, which makes the merging parties more aggressive. Thus, if the consumption synergy is significant, then allowing a merger is more likely to lead to monopolization of both markets. In this case, blocking the merger is a convincing policy option to consider.

6 Extensions and Discussions

6.1 Imperfect preference correlation

One of our simplifying assumptions is that consumer preferences are perfectly correlated across the two markets. We now discuss a case where preferences are imperfectly correlated. Imperfect correlation implies that consumer data collected in market B is less valuable in market A than the case with perfect correlation. This reduces firm C's incentives for data collection and hence softens competition in market B. This in turn softens competition in market A since firm C's target segment is smaller and, in addition, firm C's personalized prices cannot be precisely matched to its targeted consumers. Thus, compared to the case with perfectly correlated preferences, we expect firm C to be worse off while its stand-alone competitors are better off. Reduced competition in market B implies consumers are worse off whereas changes in consumer surplus in market A depend on the way imperfect correlation is modelled.

We consider a simple case of imperfectly correlated preferences in Armstrong and Vickers (2010). Suppose that a fraction $\rho \in [0, 1)$ of consumers in market B have exactly the same preferences in market A whereas the remaining consumers have independent preferences, which is common knowledge. The parameter ρ measures the preference link across the two markets, with $\rho = 1$ corresponding to our main model and $\rho = 0$ implying independent preferences. In addition, we assume that, once firm C has collected data on the segment $[0, x^*]$ in market B, it can recognize the exact locations of the fraction ρ of these consumers in market A, for whom it can offer personalization. For the remaining fraction, it can offer only a uniform price based on the belief that consumers are uniformly distributed on $[0, 1]$.

With this modification, one can show that there continue to exist the accommodation equilibria and the monopolization equilibrium. But, compared to the case with $\rho = 1$, prices in market B in the accommodation equilibria are higher and the monopolization equilibrium is possible for larger values of ω. This is intuitively clear since consumer data has now less value than when $\rho = 1$. Thus competition is softened in market B and monopolization is less likely as a result. This also means that firm C is worse off while firm B_2 is better off. Imperfect preference correlation also benefits firm A_2 because firm C's target segment is smaller and its personalization is less effective than when $\rho = 1$. While consumers in market B are worse off due to softened competition, the comparison of consumer surplus in market A is not as straightforward since it involves changes in equilibrium prices and consumers' purchase decisions, where only the fraction ρ of consumers in the target segment pay the personalized price.

As an example, denote firm C's share of market B by $[0, x(\rho)]$ and its uniform prices in market A by $\alpha_1(\rho)$ and $\alpha_2(\rho)$ in the accommodation equilibrium for some ω and $\rho < 1$. Suppose the same ω leads to the accommodation equilibrium I when $\rho = 1$, with the corresponding market share and prices denoted by x^*, α_1^*, and α_2^*. In the Online Appendix, we show $x(\rho) = (3(9 + 2\rho + 3\rho\omega))/(72 + 9\rho - 4\rho^2) < x^*$. Thus $\alpha_1(\rho) = 1 - (4\rho x(\rho))/3 > \alpha_1^* = 1 - (4x^*)/3$, and $\alpha_2(\rho) = 1 - (2\rho x(\rho))/3 > \alpha_2^* = 1 - (2x^*)/3$. In this case, consumer surplus in market A is smaller when $\rho < 1$. We can verify that the equilibrium prices in market B are also higher when $\rho < 1$. In this sense, imperfect preference correlation softens competition in both markets. The complete analysis is provided in the Online Appendix.

Proposition 8 *Suppose a fraction $\rho \in [0, 1)$ of consumers in market B have exactly the same preferences in market A while the remaining consumers have independent preferences.*

- *Firm C is worse off but firms A_2 and B_2 are better off compared to when $\rho = 1$.*
- *The monopolization equilibrium arises when $\omega \geq (15 - 16\rho + 5\rho^2)/(3\rho(1 - \rho)) > 2$, hence is less likely than when $\rho = 1$.*
- *Compared to when $\rho = 1$, consumer surplus in market B is larger, but consumer surplus in market A is smaller if $\omega < 3(\sqrt{385} - 11)/16$.*

6.2 Heterogeneous consumer types in market A

We have represented each market in our model by a horizontally differentiated Hotelling line. Given that our motivating example is Google/Fitbit, our choice of a Hotelling line for market A was intended to capture one aspect of health care, namely, product differentiation, as we have explained in Section 2. Nevertheless, this ignores other aspects of health care such as different risk types into which consumers can be segmented into. In this section, we extend the model in Section 3 by considering a simple case of two risk types with different costs of service, and show that our analysis of the baseline model continues to be valid if the cost difference is not large.

We also show that, when the cost difference is large, cream skimming can arise where firm C uses data to screen out some high-cost consumers, who are then served by firm A_2. Thus market A in our baseline model can be best understood as representing a segment of health care where the costs of serving different types of consumers are not very different.

Suppose there are two types of consumers in market A with equal proportion, indexed by $\theta = L$ (low-risk) or $\theta = H$ (high-risk). The cost of serving a type H consumer is $c > 0$ and that of serving a type L consumer is normalized to zero. Each type is represented by a unit-length Hotelling line, exactly the same as in our baseline model. For a targeted consumer $x \in [0, \delta_A]$, firm C's data covers (x, θ). Since types differ only in the cost of serving them, while personalized prices depend on the rival's uniform price and consumers' locations only, firm C will continue to choose the same personalized price for both types of consumers with the same location. Assuming $\phi_A = 1$, we then have $p_A(x) = 1 - x + \alpha_2$ for all $x \in [0, \delta_A]$ and $\theta = H, L$. For all consumers outside its target segment, firm C chooses a single uniform price α_1 for both types. Likewise, firm A_2 chooses the same uniform price α_2 for all consumers of either type.

With the above modification, it is easy to see that the equilibrium outcome of Section 3 continues to obtain for each type when c is not large enough. To see this, note that the Hotelling competition on $[\delta_A, 1]$ is now modified so that each firm has the expected cost $c/2$ of serving a consumer. Thus firm C chooses α_1 to maximize $(\alpha_1 - c/2)(\hat{x} - \delta_A)$ and firm A_2 chooses α_2 to maximize $(\alpha_2 - c/2)(1 - \hat{x})$ where $\hat{x} = (1 + \alpha_2 - \alpha_1)/2$. This leads to the equilibrium uniform prices in Section 3 augmented by $c/2$. On the other hand, since firm C can identify consumer types in its target segment, it will serve all type-H consumers in $[0, \delta_A]$ if and only if $p_A(\delta_A) \geq c$. In this case, we have qualitatively the same outcome for each type as in Section 3. But if $p_A(\xi) = c$ for some $\xi \in [0, \delta_A)$, then firm C will stop serving consumers in $(\xi, \delta_A]$ since $p_A(x) < c$ for all $x \in (\xi, \delta_A]$. Firm A_2 cannot identify these consumers and will make a loss from these consumers since $\alpha_2 < c$. In this cream-skimming equilibrium, firm C serves all type-L targeted consumers, type-H targeted consumers in $[0, \xi]$, and some non-targeted consumers. Thus the set of type-H consumers served by firm C is not contiguous. The following proposition provides sufficient conditions for the two types of equilibria described above.[34]

Proposition 9 *Suppose there are two types of consumers (H, L) in market A with equal proportion and only a type-H consumer incurs cost of service c.*

- *If $c \leq 3/2$, then the equilibrium is qualitatively the same for each type as in Section 3.*
- *If $c \in (3/2, 5]$ and $\delta_A \in [1/2, 4/5]$, then a cream-skimming equilibrium exists with $\xi \in (0, \delta_A)$ and $\hat{x} \in (\delta_A, 1)$ such that firm C serves all type-L consumers in $[0, \delta_A]$, type-H consumers in $[0, \xi]$, and both types of consumers in $[\delta_A, \hat{x}]$, while firm A_2 serves type-H consumers in $[\xi, \delta_A]$ and both types of consumers in $[\hat{x}, 1]$.*

[34] Characterizing the complete set of equilibria in the context of merger is beyond the scope of the current paper, which we leave for future work.

6.3 Successive merger

After firms A_1 and B_1 merge, would stand-alone competitors choose to merge if they have an opportunity to do so? How does such a successive merger affect consumer surplus? Intuitively, firms A_2 and B_2 have incentives to merge (and create, say, firm D) because the successive merger can level the playing field. This will make market A more competitive as both merged entities will use personalization in competition. But the effect on market B is less clear since the successive merger makes it more difficult for firm C to monopolize the market, which may soften competition. In this section, we analyze the firms' incentives for successive merger and its welfare effect. To make the comparison with the baseline case meaningful, we assume firm C moves first in market B after the successive merger, personalization is perfect and costless for both firms C and D, but the consumption synergy exists only for firm C.

Let us analyze the equilibrium given the successive merger. First, in market A with firm C's target segment given by $[0, x^*]$, firm D's target segment is $[x^*, 1]$. Each firm uses personalization and serves all consumers in its target segment, which leads to equilibrium personalized prices $p_C(x) = 1 - x + \omega$, $p_D(x) = x$, resulting in profits $\pi_C = \int_0^{x^*}(1 - x + \omega)dx$ and $\pi_D = \int_{x^*}^1 xdx$. Next, in market B, firm C chooses β_1 to maximize $\Pi_C = \pi_C + \beta_1 x^*$ and firm D chooses β_2 to maximize $\Pi_D = \pi_D + \beta_2(1 - x^*)$ where $x^* = (1 - \beta_1 + \beta_2)/2$. This leads to two possible outcomes: (i) if $\omega \leq 7$, then we have an equilibrium with $x^* = (\omega + 4)/11 \in (0, 1)$; (ii) if $\omega \geq 7$, then we have an equilibrium where firm C monopolizes the market by choosing $\beta_1^* = -2$.

The above shows that the successive merger has two main effects. First, it makes monopolization less likely since the monopolization equilibrium obtains when $\omega \geq 2$ without the successive merger. Second, it makes monopolization more costly for firm C since the price it chooses to monopolize market B is $\beta_1 = -2$ instead of $\beta_1 = -1$ as in the baseline model. As a result, consumers in market A benefit from the successive merger. But in market B, the effect is less clear when $\omega \in (2, 7)$: without the successive merger, the market is monopolized by firm C with $\beta_1 < 0$ but, with the successive merger, both firms are active, implying that prices can rise. Given that firm C chooses below-cost pricing in the accommodation equilibrium II in the baseline model, we expect that the successive merger may decrease consumer surplus for some range of ω that supports the accommodation equilibrium II. Comparing profits and consumer surpluses with or without the successive merger, we obtain the following results.

Proposition 10 *Suppose firms A_2 and B_2 can choose to merge following the merger between firms A_1 and B_1.*

- *If $\omega < 7$, then they prefer merger to remaining independent.*
- *If $\omega \geq 7$, then they are indifferent between merger and remaining independent.*
- *Firm C's profit is smaller after the successive merger.*
- *Consumer surplus is larger in market A after the successive merger. In market B, it is larger after the successive merger except when $\omega \in [3(\sqrt{385} - 11)/16,\ (11\sqrt{21} - 41)/2]$.*

6.4 Personalization without personalized pricing

Although personalization can benefit consumers by increasing matching value, personalized pricing can be used as a tool to extract the improved matching value. Then, would consumers benefit when firm C offers personalization but is not allowed to use personalized pricing? Clearly, this would hurt firm C by limiting its ability to extract surplus from its targeted consumers. On the other hand, firm C continues to enjoy a competitive advantage over firm A_2 because only it can offer personalized products. To analyze this problem, we consider a case where firm C uses two uniform prices, one for its targeted consumers denoted by p_C, and the other for non-targeted consumers denoted by α_2 as before. Consistent with the timeline in the baseline model, we assume p_C is chosen after the other uniform prices are chosen. To simplify analysis, we focus on the case $\omega > 1$.[35]

Although firm C cannot use personalized pricing, it can still serve all its targeted consumers thanks to its competitive advantage. To see this, let $x_C \in [0, x^*]$ be the marginal consumer defined by $v_A + \omega - p_C = v_A - (1 - x_C) - \alpha_2$, hence $p_C = 1 + \omega + \alpha_2 - x_C$. On $[0, x^*]$, firm C chooses p_C to maximize $p_C x_C$. Given $\omega > 1$, the solution obtains at the boundary, i.e., $x_C = x^*$ and $p_C = 1 + \omega + \alpha_2 - x^*$. Compared to the case without the restriction, firm C chooses the lowest personalized price that makes consumer x^* indifferent, rather than choosing different personalized prices for all targeted consumers. Thus the restriction limits firm C's ability to extract consumer surplus. Nevertheless, firm C continues to serve all its targeted consumers, which implies that the equilibrium structure is the same as that in the baseline model. That is, as ω increases, the equilibrium changes from accommodation to monopolization.

The main effect of the restriction is to soften competition in market B since consumer data has less value in market A due to firm C's reduced ability for surplus extraction. It then follows that the restriction benefits firm B_2 but harms consumers in market B. In market A, targeted consumers clearly benefit from the restriction. But the restriction reduces firm C's target segment, hence softens competition for non-targeted consumers. Thus the restriction raises uniform prices and benefits firm A_2, but harms non-targeted consumers. But the first effect dominates the second and, as a result, consumer surplus in market A increases after the restriction. Finally, the restriction makes monopolization less likely than without the restriction.

Proposition 11 *Suppose firm C can use only uniform pricing for its targeted consumers.*

- *The accommodation equilibrium I arises when $\omega < 3(\sqrt{129} - 5)/8 \simeq 2.384$, the accommodation equilibrium II arises when $3(\sqrt{129} - 5)/8 \leq \omega < 3$, and the monopolization equilibrium arises when $\omega \geq 3$.*
- *Compared to when firm C can use personalized pricing, firm C is worse off, but firms A_2 and B_2 are better off.*

[35] Since the equilibrium in the baseline model has cutoff values $\omega = 3(\sqrt{385} - 11)/16 > 1$ and $\omega = 2$, this assumption is innocuous for the purpose of comparison.

- *Compared to when firm C can use personalized pricing, consumer surplus is larger in market A but smaller in market B.*

6.5 Repositioning by the merged firm

In Section 4, we assumed that the merged firm continues to market the same standard product in market A. But the availability of customer data may help firm C to optimally reposition its standard product. Since firm C can serve all consumers in its target segment given $\phi_A = 1$, it may have incentives to move the Hotelling battleground further to the right by repositioning its standard product closer to firm A_2's location. This can allow firm C to serve more non-targeted consumers at a higher uniform price, which is the benefit from repositioning. But such repositioning will intensify competition for non-targeted consumers and decrease firm A_2's uniform price, which in turn decreases firm C's personalized prices. Thus firm C's profit from its target segment decreases, which is the cost of repositioning. This discussion suggests that firm C's repositioning decision hinges on its data scale δ_A. If δ_A is small, then the benefit from repositioning can outweigh the cost. In this case, firm C will choose an interior location after repositioning. If δ_A is large, then the cost of repositioning can outweigh the benefit, hence firm C will choose not to reposition its standard product.

To elaborate on the above discussion, let $\hat{x}$ be the marginal consumer given the uniform prices (α_1, α_2) when firm C does not reposition. Suppose now firm C chooses to reposition at $z \in (0, \delta_A]$ and denote the corresponding prices and marginal consumer by (α'_1, α'_2) and $\hat{x}'$. Since $z > 0$, we have $\alpha'_1 > \alpha_1$, $\alpha'_2 < \alpha_2$ and $\hat{x}' > \hat{x}$. Then the change in firm C's profit can be decomposed into the following three components.

$$\Delta\pi_C = \underbrace{(\alpha'_2 - \alpha_2)\delta_A}_{\text{(-) targeted consumers}} + \underbrace{\alpha'_1(\hat{x}' - \hat{x})}_{\text{(+) new non-targeted consumers}} + \underbrace{(\alpha'_1 - \alpha_1)(\hat{x} - \delta_A)}_{\text{(+) old non-targeted consumers}} . \tag{16}$$

That firm C chooses $z > 0$ implies $\Delta\pi_C \geq 0$, which in turn can be shown to imply $z \geq 14\delta_A - 6$. Moreover, $\Delta\pi_C$ is increasing in z when $z \geq 14\delta_A - 6$. The main reason for this is that the losses in (16) are linear in z while the gains are quadratic in z. Thus we can conclude that firm C will optimally reposition at $z = \delta_A$ if $14\delta_A - 6 \leq z \leq \delta_A$, or if $\delta_A \leq 6/13$. Clearly, firm C's repositioning hurts firm A_2. But consumers benefit because both firm C's personalized prices and firm A_2's uniform price decrease, although firm C's uniform price increases. The following proposition formalizes our discussions above.[36]

Proposition 12 *Suppose firm C can reposition its standard product in market A at z given its target segment* $[0, \delta_A]$.

[36] We only present the analysis of market A. The full analysis of both markets does not alter the main insight provided in Proposition 12. But it is rather messy and available from the authors.

- *If $\delta_A \leq 6/13$, then firm C chooses $z = \delta_A$, which decreases firm A_2's profit but increases consumer surplus.*
- *If $\delta_A > 6/13$, then firm C does not reposition its standard product, i.e., $z = 0$.*

7 Conclusion

This paper has studied data-driven tech mergers where data-enabled personalization and the consumption synergy are two key elements that link the market for data collection and the market for data application. As our motivating example is the Google's acquisition of Fitbit, we recapitulate our main findings in that context. In doing so, we choose the two relevant markets as the market for wearable devices and the digital health market, for which we have provided justification and evidence.

First, the merger harms stand-alone competitors in both markets. Second, the merger intensifies competition and, in the short run, benefits consumers in the market for wearable devices. These benefits stem from lower prices due to Google's incentives to gather a large amount of consumer data that it can leverage in the digital health market. Third, in the digital health market, the merger can increase consumer surplus if the consumption synergy is not large enough, but decreases it otherwise. The increase in consumer surplus is not driven by efficiency gains that are passed on to consumers since the efficiency gains are extracted away through personalized pricing; rather, it is the result of intensified competition for consumers for whom Google does not have data. Fourth, markets can tip in Google's favor when the consumption synergy is sufficiently large, which harms consumers in both markets in the long run. In sum, data-driven tech mergers may generate short-term consumer benefits in the form of lower prices. But they are driven not by the efficiency gains being passed on to consumers but by Google's pricing strategies to increase its data scale. Consequently, the long-term consumer harm due to market tipping is likely to be more substantial than short-term benefits.

We have examined the effects of blocking the merger as well as policy remedies such as data sharing and a ban on below-cost pricing. A general conclusion we can draw is that these remedies can reverse short-run effects of the merger on firms and mitigate the dynamic trade-off, although short-run effects on consumers vary depending on policies and markets. Needless to say, the effectiveness of merger remedies assumes the effectiveness of monitoring and enforcement, which can be a tall order in complex digital industries. We have also shown that allowing consecutive mergers can benefit consumers. For example, if the Google/Fitbit merger is approved, then allowing Apple's expansion into the digital health market can have pro-competitive effects.[37]

[37] Apple's ambition in health care is commonly known, as shown by the development of various software frameworks such as HealthKit, ResearchKit, and CareKit. In 2016, the ResearchKit apps began incorporating genetic data, via a module designed by the consumer genetics company, 23andMe. The Google/Fitbit merger can increase the likelihood of Apple's expansion into the healthcare industry. For more details, see https://www.apple.com/healthcare/. Sharon (2016) provides detailed discussions on Google's and Apple's interest in health care.

Finally, we have assumed away issues such as adverse selection, moral hazard, and privacy concerns in health care, which we have chosen as the market for data application. Personalization in this market can help screen consumers and ameliorate adverse selection, although it could amplify privacy concerns. Competition between firms with asymmetric information and the use of personalization by a better informed firm may also lead to cream skimming, as we have briefly touched upon in Section 6.2. We leave these issues for future research.

Appendix: Proofs

Proof of Proposition 1

In the main text leading up to Proposition 1, our argument establishes that the outcome stated in Proposition 1 characterizes the only possible equilibrium for each case. This takes care of uniqueness. So it suffices to show that there are no profitable deviations by either firm from the equilibrium outcome characterized in Proposition 1.

First, since firm A_2 chooses only a uniform price, it is clear that α_2 given in Proposition 1 is uniquely optimal for firm A_2, hence firm A_2 has no incentive for unilateral deviation. Second, firm C's choice of personalized prices is subgame-perfect given the equilibrium α_2, hence there is no reason for deviation when firm A_2 does not deviate. Third, firm C's choice of α_1 is its best response to the equilibrium α_2, hence there is no reason for unilateral deviation. Finally, firm C will never use a uniform price to serve targeted consumers. Putting all these together, we only need to consider a global deviation that includes both the uniform and personalized prices. In what follows, we show that firm C cannot benefit from the global deviation.

Let us start with the case $\delta_A < \bar{\delta}$. Then firm C serves all targeted consumers in $[0, \delta_A]$ with personalized prices optimally chosen in response to firm A_2's equilibrium uniform price. Insofar as firm C serves all its targeted consumers and firm A_2's equilibrium uniform price remains fixed, no deviation can benefit firm C in its target segment. Thus the only possible deviation is in uniform price, which was ruled out already. So there is no profitable global deviation.

Next, when $\bar{\delta} \leq \delta_A$, firm C concedes some of its targeted consumers in $[\bar{\delta}, \delta_A]$ to its rival. Since firm C's personalized price for its marginal consumer $\bar{\delta}$ is equal to 0, and so is its uniform price, firm C cannot profitably deviate by reducing these prices. The only way it may deviate is to increase personalized prices and/or the uniform price. But the increase in the uniform price does not have any effect since firm C does not serve any non-targeted consumers. Then, as discussed previously, an increase in personalized prices alone cannot be profitable given firm A_2's equilibrium uniform price. Once again, there is no profitable global deviation. ∎

Proof of Proposition 2

Let us start with firm C. Recall that firm A_1's pre-merger profit is 1/2. First, when $\delta_A < 3/4$, firm C's profit is $\Pi_C^* = -\left((14 - 9\phi_A)/18\right)\delta_A^2 + \frac{2}{3}\delta_A + 1/2 > 1/2$. When $3/4 \leq \delta_A < \bar{\delta}$, firm C's profit is $\Pi_C^{**} = ((2+\phi_A)/2)\,\delta_A^2$. It is easy to see that Π_C^{**} increases in δ_A for $\delta_A > 3/4$. Thus we have $\Pi_C^{**}(\delta_A) > \Pi_C^{**}(3/4) = 1/2 + (9\phi_A+2)/32 > 1/2$. Finally, when $\delta_A \geq \bar{\delta}$, firm C's profit is $\Pi_C^{***} = (3-\phi_A)^2/(8(2-\phi_A))$. Differentiating Π_C^{***} with respect to ϕ_A, we can show $\partial\Pi_C^{***}/\partial\phi_A < 0$. Moreover, we have $\Pi_C^{***} = 1/2$ when $\phi_A = 1$. Thus $\Pi_C^{***} \geq 1/2$ always holds.

Consider next firm A_2. When $\delta_A \leq 3/4$, $\Pi_{A_2}^{*} = (1-(2\delta_A)/3)^2/2 < 1/2$, and the profit is decreasing in δ_A. When $3/4 < \delta_A < \bar{\delta}$, firm A_2's profit is $\Pi_{A_2}^{**} = 3\delta_A - 1 - 2\delta_A^2$, which is decreasing in δ_A and is less than $\Pi_{A_2}^{**}(3/4) = 1/8$. Finally, when $\delta_A > \bar{\delta}$, it is straightforward to check $\Pi_{A_2}^{***} = (1-\phi_A)^2/(4(2-\phi_A)) < 1/2$. Thus firm A_2 is worse off after the merger.

We now turn to the total consumer surplus. Before the merger, it is given by $S_0 \equiv \int_0^{1/2}(v_A - x - 1)dx + \int_{1/2}^{1}(v_A-(1-x)-1)dx = v_A - 5/4$. After the merger, targeted consumers receive the same surplus as when they choose firm A_2, hence $v_A - (1-x) - \alpha_2$. First, when $\delta_A < 3/4$, we have $\alpha_2^* = 1-(2\delta_A)/3$, hence the post-merger total consumer surplus is $S_1 \equiv \int_0^{\delta_A}(v_A - (1-x) - \alpha_2^*)dx + \int_{\delta_A}^{\hat{x}}(v_A - x - \alpha_1^*)dx + \int_{\hat{x}}^{1}(v_A-(1-x)-\alpha_2^*)\,dx = v_A - 5/4 + (4\delta_A^2)/9 > S_0$. Next, when $3/4 \leq \delta_A < \bar{\delta}$, we have $\alpha_2^{**} = 2\delta_A - 1$, so the post-merger consumer surplus is $S_1 = \int_0^1 (v_A - (1-x) - \alpha_2^{**})\,dx = v_A + 1/2 - 2\delta_A$. Thus $S_1 \geq S_0$ if $\delta_A \leq 7/8$. Notice that $\bar{\delta} \leq 7/8$ if and only if $\phi_A \leq 2/3$. It then follows that $S_1 < S_0$ only if $\phi_A > 2/3$ and $\delta_A \in (7/8, \bar{\delta})$. Finally, when $\delta_A > \bar{\delta}$, we have $\alpha_2^{***} = (1-\phi_A)/2$, and the total consumer surplus is $S_1 = \int_0^1 (v_A - (1-x) - \alpha_2^{***})\,dx = v_A - 1/2 - (1-\phi_A)/2 > v_A - 5/4$. ∎

Proof of Proposition 3

We make use of the expressions derived in the proof of Proposition 2. Consider first firm C. When $\delta_A < 3/4$, Π_C^* is concave in δ_A and reaches a maximum when $\delta_A = \delta^* = 6/(14-9\phi_A)$ where $\delta^* \leq 3/4$ if and only if $\phi_A \leq 2/3$. Differentiating Π_C^* with respect to ϕ_A, we have $\partial\Pi_C^*/\partial\phi_A = \delta_A^2/2 \geq 0$. When $3/4 \leq \delta_A < \bar{\delta}$, one can verify that $\partial\Pi_C^{**}/\partial\delta_A \geq 0$ and $\partial\Pi_C^{**}/\partial\phi_A \geq 0$. When $\delta_A > \bar{\delta}$, Π_C^{***} is independent of δ_A, but one can verify $\partial\Pi_C^{***}/\partial\phi_A \leq 0$. Consider next firm A_2. Clearly, both $\Pi_{A_2}^{*}$ and $\Pi_{A_2}^{**}$ are decreasing in δ_A but independent of ϕ_A. But $\Pi_{A_2}^{***}$ is decreasing in ϕ_A but independent of δ_A. Finally, consider consumer surplus. When $\delta_A < 3/4$, the consumer surplus is $S_1 = v_A - (5/4) + (4\delta_A^2)/9$. Clearly, S_1 increases in δ_A but is independent of ϕ_A. When $3/4 \leq \delta_A < \bar{\delta}$, we have $S_1 = v_A - 2\delta_A + 1/2$, which is decreasing in δ_A but independent of ϕ_A. When $\delta_A > \bar{\delta}$, we have $S_1 = v_A - 1/2 - (1-\phi_A)/2$, which is increasing in ϕ_A but independent of δ_A. ∎

Proof of Proposition 5

In the main text, we have already explained how profits change after the merger. It remains to show changes in consumer surplus. For completeness, we provide full comparison of consumer surplus in both markets.

Consider first the pre-merger equilibrium. In market A, the prices are $\alpha_1^0 = \alpha_2^0 = 1$ and the marginal consumer is at $1/2$. The resulting consumer surplus is $CS_A^0 = \int_0^{1/2}(v_A - x -$

$1)dx + \int_{1/2}^{1}(v_A - (1-x) - 1)dx = v_A - 5/4$. In market B, the prices are $\beta_1^0 = 3/2$ and $\beta_2^0 = 5/4$ and the marginal consumer is at $3/8$. The resulting consumer surplus is $CS_B^0 = \int_0^{3/8}(v_B - x - \beta_1^0)dx + \int_{3/8}^{1}\left(v_B - (1-x) - \beta_2^0\right)dx = v_B - 103/64$.

It is straightforward to see that total consumer surplus in market B after the merger is larger than that before the merger in all post-merger equilibria. This follows largely from the fact that post-merger prices are lower than pre-merger prices. So we consider only market A. In the accommodation equilibrium I, using (11) and (12), one can calculate the consumer surplus in market A as $CS_A^I = v_A + (36\omega^2)/5929 + (24\omega)/539 - 229/196$. In the accommodation equilibrium II, from (14) and (15), we obtain $CS_A^{II} = v_A - (2\omega)/5 - 7/10$. In the monopolization equilibrium, we have $CS_A^M = v_A - 3/2$. From these follow $\max\{CS_A^{II}, CS_A^M\} \leq CS_A^0 \leq CS_A^I$. Finally, in the monopoly equilibrium when $\omega > 2$, total consumer surplus is zero in market A. In market B, total consumer surplus is $(v_B - 1)/2$, which is smaller than CS_B^0 since $v_B > 3$. ∎

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Online Appendix for Data-Driven Mergers and Personalization

■ Proof of Proposition 6

We use notation $p_C(x)$ to denote firm C's personalized price to distinguish it from $p_A(x)$ used in Section 4. We also denote the marginal consumer in market B by $\tilde{x}$ to facilitate comparison with x^* in the previous section. Given firm C's target segment $[0, \tilde{x}]$, let $\hat{x}$ be the marginal consumer in market A when competition is in uniform price. Given data sharing, Bertrand competition for each $x \in [0, \tilde{x}]$ leads to $p_{A_2}(x) = 0$, whence $p_C(x) = \omega$. Clearly $p_C(x) = \omega < p_A(x) = 1 + \omega + \alpha_2 - x$, the latter being firm C's personalized price without data sharing. So all targeted consumers benefit from data sharing. For non-targeted consumers, we need to consider different types of equilibria.

1. Analysis of market A

We divide analysis to two cases. First, suppose $\tilde{x} \leq \hat{x} \leq 1$. In this case, competition in uniform price in the segment $[\tilde{x}, \hat{x}]$ is identical to the case without data sharing. Thus we have $\alpha_1^* = 1 - (4\tilde{x})/3$, $\alpha_2^* = 1 - (2\tilde{x})/3$, and $\hat{x} = 1/2 + \tilde{x}/3$. As before, we need $\alpha_1^* \geq 0$, hence $\tilde{x} \leq 3/4$.

Next, suppose $\hat{x} < \tilde{x} \leq 1$. In this case, firm C cannot serve any non-targeted consumers, implying $\alpha_1 = 0$. This leads to $\hat{x} = (1 + \alpha_2)/2$, and firm A_2 serves all $[\tilde{x}, 1]$ with $\alpha_2 = 2\tilde{x} - 1$. It is easy to check that firm C has no incentive to deviate and firm A_2 has no incentive to deviate to a lower price. Suppose now firm A_2 deviates by raising its price to $\alpha_2^d > 2\tilde{x} - 1$. Then its deviation profit is $\alpha_2^d \left(1 - (1 + \alpha_2^d)/2\right)$. Thus the deviation is not profitable if $2\tilde{x} - 1 \geq 1/2$, or $\tilde{x} \geq 3/4$. Thus this equilibrium is possible if $\tilde{x} \geq 3/4$.

2. Analysis of market B

Based on the analysis of market A, we consider two separate cases. First, consider the case $\tilde{x} \leq 3/4$. Then firm C chooses β_1 to maximize profit

$$\begin{aligned}
\Pi_C &= \beta_1 \tilde{x} + \int_0^{\tilde{x}} p_C(x) dx + \left(1 - \frac{4\tilde{x}}{3}\right)\left(\frac{1}{2} + \frac{\tilde{x}}{3} - \tilde{x}\right) \\
&= -\frac{10}{36}\beta_1^2 + \frac{1}{2}\left[\frac{4}{3} - \omega + \frac{1}{9}(1 + \beta_2)\right]\beta_1 + \frac{2}{9}(1 + \beta_2)^2 + \frac{1}{2}\left(\omega - \frac{4}{3}\right)(1 + \beta_2) + \frac{1}{2}.
\end{aligned}$$

Firm B_2 chooses β_2 to maximize its profit $\Pi_{B_2} = \beta_2(1 - \tilde{x})$. This leads to the best response $\beta_2 = (1 + \beta_1)/2$, hence $\tilde{x} = (3 - \beta_1)/4$. The condition $0 \leq \tilde{x} \leq 3/4$ is equivalent to $0 \leq \beta_1 \leq 3$. Substituting firm B_2's best response to Π_C and solving for firm C's optimal β_1, we obtain $\beta_1 = 9(3 - \omega)/14$ if $\omega \leq 3$, and $\beta_1 = 0$, otherwise.

Consider next the case $\tilde{x} \geq 3/4$. As before, firm B_2's best response is $\beta_2 = (1 + \beta_1)/2$ and $\tilde{x} = (3 - \beta_1)/4$. Thus the condition $3/4 \leq \tilde{x} \leq 1$ is equivalent to $-1 \leq \beta_1 \leq 0$. Firm C chooses β_1 to maximize

$$\Pi_C = \beta_1 \tilde{x} + \int_0^{\tilde{x}} p_C(x)\, dx = (\beta_1 + \omega)\, \tilde{x}.$$

This gives us $\beta_1 = 0$ if $\omega \le 3$, $\beta_1 = (3-\omega)/2$ if $\omega \in [3,5]$, and $\beta_1 = -1$ if $\omega \ge 5$.

Comparing profits from the two cases to find a global optimum for the given range of ω, we obtain the following. If $\omega \le 3$, then the equilibrium prices are

$$\beta_1^* = \frac{9(3-\omega)}{14},\ \beta_2^* = \frac{41-9\omega}{28},\ \tilde{x} = \frac{15+9\omega}{56},\ \alpha_1^* = \frac{9-3\omega}{14},\ \alpha_2^* = \frac{23-3\omega}{28},\ \hat{x} = \frac{33+3\omega}{56}.$$

This is the accommodation equilibrium I. Profits in this case are

$$\Pi_C^* = \frac{9\omega^2+30\omega+81}{112},\ \Pi_{A_2}^* = \frac{1}{2}\left(\frac{23-3\omega}{28}\right)^2,\ \Pi_{B_2}^* = \frac{1}{2}\left(\frac{41-9\omega}{28}\right)^2.$$

If $3 \le \omega \le 5$, then the equilibrium prices are

$$\beta_1^* = \frac{3-\omega}{2},\ \beta_2^* = \frac{5-\omega}{4},\ \tilde{x} = \frac{3+\omega}{8},\ \alpha_1^* = 0,\ \alpha_2^* = \frac{\omega-1}{4}.$$

This is the accommodation equilibrium II where profits are

$$\Pi_C^* = \frac{(3+\omega)^2}{16},\ \Pi_{A_2}^* = \frac{(\omega-1)(5-\omega)}{32},\ \Pi_{B_2}^* = \frac{(5-\omega)^2}{32}.$$

When $\omega \ge 5$, we have the monopolization equilibrium with prices $\beta_1^* = -1$ and $\beta_2^* = 0$, and profits $\Pi_C^* = \omega - 1,\ \Pi_{A_2}^* = \Pi_{B2}^* = 0$.

From the profits derived above, it is straightforward to verify that firm C's profit with data sharing is smaller than that without data sharing, and firms A_2 and B_2 have larger profits under data sharing for all values of $\omega \le 5$. When $\omega \ge 5$, then both markets are monopolized with or without data sharing, so the profit comparison is trivial.

3. Comparison of consumer surpluses

Total consumer surplus without data sharing can be calculated as as follows. When $\omega \le \frac{3(\sqrt{385}-11)}{16}$, $CS_A^{NSI} = v_A + \frac{36}{5929}\omega^2 + \frac{24}{539}\omega - \frac{229}{196}$, $CS_B^{NSI} = v_B - \left(\frac{143}{98} - \frac{81}{5929}\omega^2 - \frac{180}{539}\omega\right)$ where the superscript "NSI" indicates "no sharing accommodation I". When $\frac{3(\sqrt{385}-11)}{16} \le \omega < 2$, $CS_A^{NSII} = v_A - \frac{2}{5}\omega - \frac{7}{10}$, $CS_B^{NSII} = v_B - \left(\frac{47}{50} - \frac{1}{25}\omega^2 - \frac{16}{25}\omega\right)$ where the superscript "NSII" indicates "no sharing accommodation II". When $\omega \ge 2$, $CS_A^{NSM} = v_A - \frac{3}{2}$, $CS_B^{NSM} = v_B + \frac{1}{2}$ where the superscript "NSM" indicates "no sharing monopolization".

With data sharing, total consumer surplus can be calculate as follows. When $\omega \le 3$,

$$\begin{aligned}
CS_A^{DSI} &= \int_0^{\tilde{x}} (v_A + \omega - p_C(x))dx + \int_{\tilde{x}}^{\frac{1}{2}+\frac{\tilde{x}}{3}} (v_A - x - \alpha_1^*)dx + \int_{\frac{1}{2}+\frac{\tilde{x}}{3}}^{1} (v_A - (1-x) - \alpha_2^*)dx \\
&= v_A - \frac{13}{18}(\tilde{x})^2 + 2\tilde{x} - \frac{5}{4} \\
&= v_A - \frac{117}{6272}\omega^2 + \frac{813}{3136}\omega - \frac{4805}{6272},
\end{aligned}$$

$$
\begin{aligned}
CS_B^{DSI} &= \int_0^{\tilde{x}} (v_B - x - \beta_1^*)dx + \int_{\tilde{x}}^1 (v_B - (1-x) - \beta_2^*)dx \\
&= \int_0^{\frac{15+9\omega}{56}} \left(v_B - x - \frac{9(3-\omega)}{14}\right) dx + \int_{\frac{15+9\omega}{56}}^1 \left(v_B - (1-x) - \frac{41-9\omega}{28}\right) dx \\
&= v_B + \frac{81}{3136}\omega^2 + \frac{639}{1568}\omega - \frac{5935}{3136},
\end{aligned}
$$

where the superscript "DSI" indicates "data sharing accommodation I". When $3 \leq \omega \leq 5$,

$$
\begin{aligned}
CS_A^{DSII} &= \int_0^{\tilde{x}} (v_A + \omega - p_C(x))dx + \int_{\tilde{x}}^1 (v_A - (1-x) - \alpha_2^{**})dx \\
&= \int_0^{\frac{3+\omega}{8}} (v_A + \omega - \omega)dx + \int_{\frac{3+\omega}{8}}^1 (v_A - (1-x) - \frac{\omega-1}{4})dx \\
&= v_A + \frac{3}{128}\omega^2 - \frac{7}{64}\omega - \frac{5}{128},
\end{aligned}
$$

$$
\begin{aligned}
CS_B^{DSII} &= \int_0^{\tilde{x}} (v_B - x - \beta_1^{**})dx + \int_{\tilde{x}}^1 (v_B - (1-x) - \beta_2^{**})dx \\
&= \int_0^{\frac{3+\omega}{8}} \left(v_B - x - \frac{3-\omega}{2}\right) dx + \int_{\frac{3+\omega}{8}}^1 \left(v_B - (1-x) - \frac{5-\omega}{4}\right) dx \\
&= v_B + \frac{1}{64}\omega^2 + \frac{11}{32}\omega - \frac{103}{64},
\end{aligned}
$$

where the superscript "DSII" indicates "data sharing accommodation II". When $\omega \geq 5$,

$$
CS_A^{DSM} = \int_0^1 (v_A + \omega - p_C(x))dx = v_A, \; CS_B^{DSM} = \int_0^1 (v_B - x - \beta_1^{***})dx = v_B + \frac{1}{2},
$$

where the superscript "DSM" indicates "data sharing monopolization".

Based on the above, we can verify that data sharing always increases total consumer surplus in market A. In market B, total consumer surplus strictly decreases when $\omega < 5$, but does not change when $\omega \geq 5$ when the market is monopolized with or without data sharing. ∎

■ Proof of Proposition 8

As described in the main text, a fraction $\rho \in [0, 1)$ of consumers in market B have exactly the same preferences in market A whereas the remaining fraction of consumers have independent preferences, which is common knowledge. In addition, once firm C has collected data on $[0, x^*]$ in market B, it can recognize the exact locations of the fraction ρ of these consumers in market A, for whom it can offer personalized prices. For the remaining fraction, it can offer only a uniform price.

1. Analysis of market A

As before, let $\hat{x} = (1 - \alpha_1 + \alpha_2)/2$ be the marginal consumer when competition is in uniform price. We divide the analysis into two cases: $\hat{x} > x^*$ and $\hat{x} \leq x^*$. For its targeted consumers, firm C's personalized prices are given by $p_A(x) = 1 - x + \omega + \alpha_2$. Clearly, firm C can serve all of its targeted consumers since $p_A(x) > 0$ when $\alpha_2 = 0$. We proceed as follows. For each case, we first identify the candidate equilibrium by solving best response functions simultaneously. This candidate equilibrium prescribes locally optimal prices for each firm within each case only. Thus we check the possibilities of deviations across the two cases.

(i) $\hat{x} > x^*$

Firm C chooses α_1 to maximize $\alpha_1[(1-\rho)x^* + \hat{x} - x^*]$, which leads to the best response $\alpha_1 = (1+\alpha_2)/2 - \rho x^*$. Firm A_2 chooses α_2 to maximize $\Pi_{A_2} = \alpha_2(1 - \hat{x})$, hence the best response is $\alpha_2 = (1+\alpha_1)/2$. Solving them together gives us uniform prices

$$\alpha_1^* = 1 - \frac{4}{3}\rho x^*, \quad \alpha_2^* = 1 - \frac{2}{3}\rho x^*, \tag{1}$$

and the marginal consumer $\hat{x} = 1/2 + (\rho x^*)/3$. The resulting profits for firms C and A_2 are $(3 - 4\rho x^*)^2/18$ and $(3 - 2\rho x^*)^2/18$ respectively. For this equilibrium to exist, we need $\alpha_1^* \geq 0$ and $\hat{x} > x^*$, which are equivalent to

$$x^* < \frac{3}{6 - 2\rho}. \tag{2}$$

(ii) $\hat{x} \leq x^*$

In this case, firm C chooses α_1 to maximize $\alpha_1(1-\rho)\hat{x}$, which leads to the best response $\alpha_1 = (1+\alpha_2)/2$. Firm A_2 chooses α_2 to maximize $\Pi_{A_2} = \alpha_2\left[(1-\rho)(x^* - \hat{x}) + (1 - x^*)\right]$, hence its best response is $\alpha_2 = (1 - \rho x^*)/(1-\rho) - (1 - \alpha_1)/2$. Solving them together gives us uniform prices[38]

$$\alpha_1^{**} = 1 + \frac{2\rho(1 - x^*)}{3(1-\rho)}, \quad \alpha_2^{**} = 1 + \frac{4\rho(1-x^*)}{3(1-\rho)}, \tag{3}$$

and the marginal consumer $\hat{x} = (1 - \rho x^*)/(3(1-\rho)) + 1/6$. The resulting profits for firms C and A_2 are $(3 - \rho - 2\rho x^*)^2/(18(1-\rho))$ and $(3 + \rho - 4\rho x^*)^2/(18(1-\rho))$ respectively.

The condition $\hat{x} \leq x^*$ is equivalent to $x^* \geq \frac{3-\rho}{6-4\rho}$. We also need the marginal consumer to obtain non-negative utility, i.e., $v_A - \hat{x} - \alpha_1^{**} \geq 0$, which is equivalent to $x^* \geq \frac{1+2\rho}{3\rho} - \frac{(v_A - \frac{7}{6})(1-\rho)}{\rho}$. We focus on the case $\rho \leq \frac{6v_A - 9}{6v_A - 3}$ so that this condition always holds, which is reproduced below:

$$x^* \geq \frac{3 - \rho}{6 - 4\rho}. \tag{4}$$

We now check deviation incentives across the two cases, starting from deviations from case

[38]When $\rho = 1$, firm C cannot serve any consumers with uniform price. Firm A_2's profit function becomes $\Pi_{A_2} = \alpha_2(1 - x^*)$. Then the equilibrium uniform prices are $\alpha_1 = 0$ and $\alpha_2 = 2x^* - 1$ and $\hat{x} = x^*$. Thus the equilibrium prices are discontinuous at $\rho = 1$.

(i) to case (ii). First, we check the condition that firm C does not deviate from α_1^* in (1) to the locally optimal α_1 in case (ii). Given α_2^* in (1), the optimal deviation price is $\alpha_1^{d*} = 1 - \rho x^*/3$, which satisfies $\hat{x}^d \le x^*$ if and only if $x^* > 3/(6+\rho)$. The resulting deviation profit for firm C is $\pi_1^{d*} = (1-\rho)(3-\rho x^*)^2/18$, which is smaller than $(3-4\rho x^*)^2/18$ if and only if $x^* < (3(3+\rho-3\sqrt{1-\rho}))/(\rho(15+\rho))$. Second, we check the condition that firm A_2 does not deviate from α_2^* in (1) to the locally optimal α_2 in case (ii). Given α_1^* in (1), the optimal deviation price is $\alpha_2^{d*} = (3-\rho(5-2\rho)x^*)/(3(1-\rho))$, which satisfies $\hat{x}^d \le x^*$ if and only if $x^* > 3/(6-5\rho+2\rho^2)$. The resulting deviation profit for firm A_2 is $\pi_2^{d*} = (3-\rho(5-2\rho)x^*)^2/(18(1-\rho))$, which is smaller than $(3-2\rho x^*)^2/18$ if and only if $x^* > (3(3-\sqrt{9-21\rho+16\rho^2-4\rho^3}))/(\rho(21-16\rho+4\rho^2))$. The latter is satisfied whenever $\hat{x}^d \le x^*$ holds.

From the above discussion, we can conclude that the prices in (1) constitute equilibrium if and only if

$$x^* < \min\left\{\frac{3}{6-2\rho}, \frac{3(3+\rho-3\sqrt{1-\rho})}{\rho(15+\rho)}\right\} = \frac{3(3+\rho-3\sqrt{1-\rho})}{\rho(15+\rho)}. \tag{5}$$

Then firm C's personalized prices are given by $p_A^*(x) = 2 - (2\rho x^*)/3 - x + \omega$. Firm C's profit in market A is

$$\pi_C^* = \rho \int_0^{x^*} p_A^*(x)dx + \alpha_1^*[(1-\rho)x^* + \hat{x} - x^*].$$

Next, we check the possibilities of deviations from case (ii) to case (i). First, we check the condition that firm C does not deviate from α_1^{**} in (3) to the locally optimal α_1 in case (i). Given α_2^{**} in (3), the optimal deviation price is $\alpha_1^{d**} = (3-\rho-\rho(5-3\rho)x^*)/(3(1-\rho))$, which satisfies $\hat{x}^d \ge x^*$ if and only if $x^* < (3-\rho)/(6-7\rho+3\rho^2)$. The resulting deviation profit for firm C is $\pi_1^{d**} = (3-\rho-\rho(5-3\rho)x^*)^2/(18(1-\rho)^2)$, which is smaller than $(3-\rho-2\rho x^*)^2/(18(1-\rho))$ if and only if $x^* > (3-\rho)(3-\rho-3(1-\rho)\sqrt{1-\rho})/(\rho(21-26\rho+9\rho^2))$.

Second, we check the condition that firm A_2 does not deviate from α_2^{**} in (3) to the locally optimal α_2 in case (i). Given α_1^{**} in (3), the optimal deviation price, denoted by α_2^{d**}, can be described as follows. When $\rho \le 3/4$, we have $\alpha_2^{d**} = (3-2\rho-\rho x^*)/(3(1-\rho))$, which satisfies $\hat{x}^d \ge x^*$ if and only if $x^* < (3-4\rho)/(6-7\rho)$s. In this case, firm A_2's deviation profit is $\pi_2^{d**} = (3-2\rho-\rho x^*)^2/(18(1-\rho)^2)$. This deviation profit is smaller than firm A_2's equilibrium profit $(3+\rho-4\rho x^*)^2/(18(1-\rho))$ if and only if $x^* < (9-6\rho-4\rho^2-9(1-\rho)\sqrt{1-\rho})/(\rho(15-16\rho))$, which holds whenever $\hat{x}^d \ge x^*$ holds.

When $\rho > 3/4$, we have $\alpha_2^{d**} = ((6-8\rho)x^* + 2\rho)/(3(1-\rho))$, which makes $\hat{x}^d = x^*$. In this case, firm A_2's deviation profit is $\pi_2^{d**} = ((6-8\rho)x^* + 2\rho)(1-x^*)/(3(1-\rho))$. The deviation profit is always smaller than firm A_2's equilibrium profit.

From the above discussion, we can conclude that the prices in (3) constitute equilibrium if and only if

$$x^* \ge \max\left\{\frac{3-\rho}{6-4\rho}, \frac{(3-\rho)(3-\rho-3(1-\rho)\sqrt{1-\rho})}{\rho(21-26\rho+9\rho^2)}\right\} = \frac{(3-\rho)(3-\rho-3(1-\rho)\sqrt{1-\rho})}{\rho(21-26\rho+9\rho^2)}. \tag{6}$$

and $\rho \le \min\{\frac{3}{4}, \frac{6v_A-9}{6v_A-3}\}$.

Firm C's personalized prices are $p_A^{**}(x) = 1 - x + \omega + \alpha_2^{**}$ and its profit in market A is

$$\pi_C^{**} = \rho \int_0^{x^*} p_A^{**}(x)dx + \alpha_1^{**}(1-\rho)\hat{x}.$$

Notice that $\frac{3(3+\rho-3\sqrt{1-\rho})}{\rho(15+\rho)} < \frac{(3-\rho)(3-\rho-3(1-\rho)\sqrt{1-\rho})}{\rho(21-26\rho+9\rho^2)}$ holds for any $\rho \in (0,1)$. When $\frac{3(3+\rho-3\sqrt{1-\rho})}{\rho(15+\rho)}$ $< x^* < \frac{(3-\rho)(3-\rho-3(1-\rho)\sqrt{1-\rho})}{\rho(21-26\rho+9\rho^2)}$, we do not find a pure-strategy equilibrium in market A.

(iii) Mixed strategy equilibrium

Since a pure strategy equilibrium does not exist if

$$\frac{3(3+\rho-3\sqrt{1-\rho})}{\rho(15+\rho)} < x^* < \frac{(3-\rho)(3-\rho-3(1-\rho)\sqrt{1-\rho})}{\rho(21-26\rho+9\rho^2)},$$

we solve for a mixed strategy equilibrium below.

The non-existence of pure strategy equilibrium stems from firm C's deviation incentives. So we examine firm C's best response in more detail. Firm C prefers choosing $(1+\alpha_2)/2$ to choosing $(1+\alpha_2)/2 - \rho x^*$ if $\alpha_2 \le \bar{\alpha}_2 = -1 + 2(1+\sqrt{1-\rho})x^*$; it prefers choosing $(1+\alpha_2)/2 - \rho x^*$ to choosing $(1+\alpha_2)/2$ if $\alpha_2 \ge \bar{\alpha}_2$. This implies that both $\alpha_1 = (1+\bar{\alpha}_2)/2 - \rho x^*$ and $\alpha_1 = (1+\bar{\alpha}_2)/2$ are firm C's best response to $\alpha_2 = \bar{\alpha}_2$. So, we consider the following mixed strategy: firm C chooses $\alpha_1 = (1+\bar{\alpha}_2)/2 - \rho x^*$ with probability g and $\alpha_1 = (1+\bar{\alpha}_2)/2$ with probability $1-g$. We solve for g such that $\alpha_2 = \bar{\alpha}_2$ is firm A_2's best response to firm C's mixed strategy $(g, 1-g)$.

Given $(g, 1-g)$, there are three possibilities for α_2: (i) α_2 satisfies $\hat{x} < x^*$ regardless of the realized α_1; (ii) α_2 satisfies $\hat{x} \ge x^*$ if the realized α_1 is $\alpha_1 = (1+\bar{\alpha}_2)/2 - \rho x^*$ and α_2 satisfies $\hat{x} < x^*$ if the realized α_1 is $\alpha_1 = (1+\bar{\alpha}_2)/2$; (iii) α_2 satisfies $\hat{x} \ge x^*$ regardless of the realized α_1. Thus we can consider α_2 in three cases: (i) $\alpha_2 < -1 + (3-\rho+\sqrt{1-\rho})x^*$, (ii) $-1 + (3-\rho+\sqrt{1-\rho})x^* \le \alpha_2 < -1 + (3+\sqrt{1-\rho})x^*$, (iii) $-1 + (3+\sqrt{1-\rho})x^* \le \alpha_2$.

The A_2's profit for the three cases can be calculated as

$$\begin{cases} g\alpha_2\left((1-\rho)(1-\frac{1-((1+\bar{\alpha}_2)/2-\rho x^*)+\alpha_2}{2})+\rho(1-x^*)\right) \\ +(1-g)\alpha_2\left((1-\rho)(1-\frac{1-((1+\bar{\alpha}_2)/2)+\alpha_2}{2})+\rho(1-x^*)\right) & \text{in case (i)}, \\ g\alpha_2\left(1-\frac{1-((1+\bar{\alpha}_2)/2-\rho x^*)+\alpha_2}{2}\right) \\ +(1-g)\alpha_2\left((1-\rho)(1-\frac{1-((1+\bar{\alpha}_2)/2)+\alpha_2}{2})+\rho(1-x^*)\right) & \text{in case (ii)}, \\ g\alpha_2\left(1-\frac{1-((1+\bar{\alpha}_2)/2-\rho x^*)+\alpha_2}{2}\right) \\ \qquad +(1-g)\alpha_2\left(1-\frac{1-((1+\bar{\alpha}_2)/2)+\alpha_2}{2}\right) & \text{in case (iii)}. \end{cases}$$

From the above, it is easy to find $\alpha_2 = \bar{\alpha}_2 = -1 + 2(1 + \sqrt{1-\rho})x^*$ in case (ii). First, we check the optimal α_2 in case (ii). Then we find g that makes the optimal α_2 equal to $\bar{\alpha}_2$. Solving the first-order condition, we have

$$\alpha_2 = \frac{1 + \rho + (1 - 3\rho + (1-\rho)\sqrt{1-\rho})x^* + \rho(-1 + (2 + \sqrt{1-\rho})x^*)g}{2(1 - \rho + \rho g)}.$$

Then setting α_2 derived above equal to $\bar{\alpha}_2$, we can derive

$$g = \frac{3 - \rho - (3(1 + \sqrt{1-\rho}) - \rho(1 + 3\sqrt{1-\rho}))x^*}{\rho(-1 + (2 + 3\sqrt{1-\rho})x^*)}.$$

It is easy to check that firm A_2's profit monotonically increases in α_2 in case (i) and monotonically decreases in α_2 in case (iii). Thus firm A_2 does not deviate from α_2 derived above. In sum, we have found the following mixed strategy equilibrium: Firm C chooses

$$\alpha_1^{***} = \begin{cases} \dfrac{1+\bar{\alpha}_2}{2} - \rho x^* & \text{with probability } g^* \\ \dfrac{1+\bar{\alpha}_2}{2} & \text{with probability } 1 - g^*\text{, where} \\ g^* = \dfrac{3 - \rho - (3(1 + \sqrt{1-\rho}) - \rho(1 + 3\sqrt{1-\rho}))x^*}{\rho(-1 + (2 + 3\sqrt{1-\rho})x^*)}; \end{cases} \tag{7}$$

Firm A_2 chooses

$$\alpha_2^{***} = \bar{\alpha}_2 = -1 + 2(1 + \sqrt{1-\rho})x^* \tag{8}$$

with probability 1. This equilibrium exists, i.e., $g^* \in [0, 1]$, if and only if

$$\frac{3(3 + \rho - 3\sqrt{1-\rho})}{\rho(15 + \rho)} \leq x^* \leq \frac{(3-\rho)(3 - \rho - 3(1-\rho)\sqrt{1-\rho})}{\rho(21 - 26\rho + 9\rho^2)}.$$

The threshold values perfectly coincide with the threshold values for which there is no pure strategy equilibrium. By the nature of mixed strategy, the firm C's expected profit is equivalent to that when firm A_2 chooses α_2^{***} with probability 1 and firm C chooses $\alpha_1 = (1 + \bar{\alpha}_2)/2$ with probability 1. Therefore, firm C's equilibrium profit of is

$$\frac{(1 + \alpha_2^{***})}{2}(1-\rho)\frac{(1 - (1 + \alpha_2^{***})/2 + \alpha_2^{***})}{2} = \frac{(1-\rho)(1 + \sqrt{1-\rho})^2(x^*)^2}{2}.$$

In addition, firm C obtains profits from personalized prices, $p_A^{***}(x) = 1 - x + \omega + \alpha_2^{***}$:

$$\rho \int_0^{x^*} (1 - x + \omega + \alpha_2^{***})dx = \frac{\rho x^*(2\omega + (3 + 4\sqrt{1-\rho})x^*)}{2}.$$

Notice that firm C's profit is continuous in $x^* \in [0, 1]$. This can be checked by substituting the threshold value of x^* in (5) (resp. x^* in (6)) into the profit functions in cases (i) and (iii) (resp. (ii) and (iii)) and verifying that their values are the same.

2. Analysis of market B

Firm C chooses β_1 anticipating firm B_2's best response $\beta_2(\beta_1) = (1+\beta_1)/2$. We proceed with analysis in the following sequence: i) $\hat{x} > x^*$, (ii) mixed strategy equilibrium, (iii) $\hat{x} \le x^*$.

(i) $\hat{x} > x^*$, or equivalently, $x^* < (3(3+\rho-3\sqrt{1-\rho}))/(\rho(15+\rho))$

Firm C chooses β_1 to maximize total profit from both markets

$$\begin{aligned}\Pi_C &= \beta_1 x^* + \rho\int_0^{x^*} p_A^*(x)dx + \alpha_1^*[(1-\rho)x^* + \hat{x} - x^*] \\ &= \left(\frac{2}{9}\rho^2 - \frac{1}{2}\rho\right)(x^*)^2 + \left(\beta_1 + \frac{2}{3}\rho + \rho\omega\right)x^* + \frac{1}{2}.\end{aligned}$$

Differentiating Π_C with respect to β_1, we obtain

$$\beta_1 = \frac{3(36+\rho-4\rho^2-12\rho\omega)}{72+9\rho-4\rho^2}, \tag{9}$$

$$\beta_2 = \frac{90+6\rho-8\rho^2-18\rho\omega}{72+9\rho-4\rho^2}, \tag{10}$$

and the marginal consumer's location related to the above β_1

$$x^* = \frac{3(9+2\rho+3\rho\omega)}{72+9\rho-4\rho^2}. \tag{11}$$

One can check that the above uniform prices are higher than their counterparts when $\rho = 1$ ($\beta_1^* = (99-36\omega)/77$ when $x^* < 3/4$; $\beta_1^{**} = (3-4\omega)/5$ when $3/4 < x^* < 1$). Thus, price competition in market B is softened when consumers preferences are imperfectly correlated, which benefits firm B_2.

Firm C's price β_1 given in (9) is the local optimum when $x^* < 3(3+\rho-3\sqrt{1-\rho})/(\rho(15+\rho))$, which is equivalent to

$$\omega < \frac{2(36-6\rho-7\rho^2-\rho^3)-(72+9\rho-4\rho^2)\sqrt{1-\rho}}{\rho^2(15+\rho)} \equiv \hat{\omega}_1, \tag{12}$$

otherwise, the corner solution, $\beta_1 = \frac{3(12\sqrt{1-\rho}-(1-\rho)(12+\rho))}{\rho(15+\rho)}$ is the local optimum in case (i).

To summarize case (i), the equilibrium prices and the marginal consumer in market B are given by (9), (10), and (11). In market A, the equilibrium prices are given by (1) and the marginal consumer is $\hat{x} = 1/2 + (\rho x^*)/3$. Firm C's personalized prices are $p_A^*(x) = 2 - (2\rho x^*)/3 - x + \omega$.

Then the equilibrium profits are

$$\Pi_C^* = \left(\frac{2}{9}\rho^2 - \frac{1}{2}\rho\right)(x^*)^2 + \left(\beta_1^* + \frac{2}{3}\rho + \rho\omega\right)x^* + \frac{1}{2}, \tag{13}$$

$$\Pi_{B_2}^* = \beta_2^*(1 - x^*), \tag{14}$$

$$\Pi_{A_2}^* = \alpha_2^*(1 - \hat{x}) = \left(1 - \frac{2}{3}\rho x^*\right)\left(\frac{1}{2} - \frac{\rho x^*}{3}\right). \tag{15}$$

One can verify that firm C's total profit is smaller than when $\rho = 1$. But both firms B_2 and A_2 benefit when preferences are imperfectly correlated since their prices are higher and market shares are larger.

(ii) Mixed strategy equilibrium, or equivalently, $(3(3+\rho-3\sqrt{1-\rho}))/(\rho(15+\rho)) \le x^* \le (3-\rho)(3-\rho-3(1-\rho)\sqrt{1-\rho})/(\rho(21-26\rho+9\rho^2))$

Firm C chooses β_1 to maximize total profit from both markets

$$\begin{aligned}\Pi_C &= \beta_1 x^* + \rho\int_0^{x^*} p_A^{***}(x)dx + \frac{(1-\rho)(1+\sqrt{1-\rho})^2(x^*)^2}{2} \\ &= (\rho\omega + \beta_1)x^* + \frac{(\rho(3+4\sqrt{1-\rho}) + (1-\rho)(1+\sqrt{1-\rho})^2)}{2}(x^*)^2.\end{aligned}$$

Differentiating Π_C with respect to β_1, we obtain

$$\beta_1 = \frac{6 - 3\rho^2 - 6(1+\rho)\sqrt{1-\rho} - 4\rho\omega}{6 - \rho^2 - 2(1+\rho)\sqrt{1-\rho}}, \tag{16}$$

$$\beta_2 = \frac{2(3 - \rho^2 - 2(1+\rho)\sqrt{1-\rho} - \rho\omega)}{6 - \rho^2 - 2(1+\rho)\sqrt{1-\rho}}, \tag{17}$$

and the marginal consumer's location related to the above β_1

$$x^* = \frac{3 + \rho\omega}{6 - \rho^2 - 2(1+\rho)\sqrt{1-\rho}}. \tag{18}$$

The requirement $x^* \ge (3(3+\rho-3\sqrt{1-\rho}))/(\rho(15+\rho))$ is equivalent to

$$\omega \ge \frac{3(3 - \rho - \rho^2 - (5+2\rho)\sqrt{1-\rho})}{\rho(3+\rho+3\sqrt{1-\rho})} \equiv \hat{\omega}_{2a}. \tag{19}$$

If this inequality does not hold, then the corner solution, $\beta_1 = \frac{3(12\sqrt{1-\rho}-(1-\rho)(12+\rho))}{\rho(15+\rho)}$, is the local optimum in case (ii). Also, the requirement $x^* \le (3-\rho)(3-\rho-3(1-\rho)\sqrt{1-\rho})/(\rho(21-26\rho+9\rho^2))$ is equivalent to

$$\omega \le \frac{9 - 3\rho - 3\rho^2 + \rho^3 - (15 - 5\rho - 2\rho^2)\sqrt{1-\rho}}{\rho(3 - \rho + 3(1-\rho)\sqrt{1-\rho})} \equiv \hat{\omega}_{2b}. \tag{20}$$

If this inequality does not hold, then the corner solution

$$\beta_1 = \frac{-3+\rho+9(1-\rho)\sqrt{1-\rho}}{3-\rho+3(1-\rho)\sqrt{1-\rho}} \tag{21}$$

is the local optimum in case (ii), when the marginal consumer in market B is

$$x^* = \frac{(3-\rho)(3-\rho-3(1-\rho)\sqrt{1-\rho})}{\rho(21-26\rho+9\rho^2)}. \tag{22}$$

Firm C's price β_1 given in (16) is the local optimum in case (ii) if and only if

$$\hat{\omega}_{2a} \leq \omega \leq \hat{\omega}_{2b}. \tag{23}$$

To summarize case (ii), the equilibrium prices and the marginal consumer in market B are given by (16), (17), and (18). In market A, the equilibrium uniform prices are given by (7) and (8), and the marginal consumer is $\hat{x} = \frac{1-\rho x^*}{3(1-\rho)} + \frac{1}{6}$ with probability g^* and $\hat{x} = 1/2 + (\rho x^*)/3$ with probability $1-g^*$. Firm C's personalized prices are $p_A^{***}(x) = -x+\omega+2(1+\sqrt{1-\rho})x^*$.

(iii) $\hat{x} \leq x^*$, or equivalently, $(3-\rho)(3-\rho-3(1-\rho)\sqrt{1-\rho})/(\rho(21-26\rho+9\rho^2)) \leq x^* \leq 1$

Firm C chooses β_1 to maximize total profit from both markets

$$\begin{aligned}\Pi_C &= \beta_1 x^* + \rho\int_0^{x^*} p_A^{**}(x)dx + \alpha_1^{**}(1-\rho)\hat{x} \\ &= -\frac{11\rho^2+9\rho}{18(1-\rho)}(x^*)^2 + \left(\beta_1+\rho\omega+\frac{-4\rho^2+12\rho}{9(1-\rho)}\right)x^* + \frac{1}{3} + \frac{1-\rho}{6} + \frac{\rho(3-\rho)}{9(1-\rho)}.\end{aligned}$$

Differentiating Π_C with respect to β_1, we obtain

$$\beta_1 = \frac{108-129\rho+49\rho^2-36\rho(1-\rho)\omega}{72-63\rho+11\rho^2}, \tag{24}$$

$$\beta_2 = \frac{6(15-16\rho+5\rho^2-3\rho(1-\rho)\omega)}{72-63\rho+11\rho^2}, \tag{25}$$

and the marginal consumer's location related to the above β_1

$$x^* = \frac{27-15\rho-4\rho^2+9\rho(1-\rho)\omega}{72-63\rho+11\rho^2}. \tag{26}$$

The requirement $x^* \geq \frac{(3-\rho)(3-\rho-3(1-\rho)\sqrt{1-\rho})}{\rho(21-26\rho+9\rho^2)}$ is equivalent to

$$\omega \geq \frac{2(6\rho^5+7\rho^4-113\rho^3+261\rho^2-261\rho+108)-(3-\rho)(1-\rho)(11\rho^2-63\rho+72)\sqrt{1-\rho}}{3\rho^2(1-\rho)(21-26\rho+9\rho^2)} \equiv \hat{\omega}_3. \tag{27}$$

If this inequality does not hold, then the corner solution, $\beta_1 = \frac{-3+\rho+9(1-\rho)\sqrt{1-\rho}}{3-\rho+3(1-\rho)\sqrt{1-\rho}}$, is the local optimum in case (iii). Also, the requirement $x^* \leq 1$ is equivalent to

$$\omega \leq (15 - 16\rho + 5\rho^2)/(3\rho(1-\rho)) \equiv \hat{\omega}_M.$$

If this inequality does not hold, then the corner solution, $\beta_1 = -1$, is the local optimum in case (iii). Thus, this case holds if and only if

$$\hat{\omega}_3 \leq \omega \leq \hat{\omega}_M. \tag{28}$$

To summarize case (iii), the equilibrium prices and the marginal consumer in market B are given by (24), (25), and (26). In market A, the equilibrium uniform prices are given by (3) and the marginal consumer is $\hat{x} = \frac{1-\rho x^*}{3(1-\rho)} + \frac{1}{6}$. Firm C's personalized prices are $p_A^{**}(x) = 2 + \frac{4\rho(1-x^*)}{3(1-\rho)} - x + \omega$.

As mentioned before, when $\omega \geq \frac{15-16\rho+5\rho^2}{3\rho(1-\rho)}$, the equilibrium prices are

$$\beta_1^{***} = -1, \quad \beta_2^{***} = 0. \tag{29}$$

In this case, we have $x^* = 1$, i.e., firm C monopolizes both markets. It is straightforward to check that $\frac{15-16\rho+5\rho^2}{3\rho(1-\rho)} > 2$, implying that accommodation is possible for larger values of ω under imperfect preference correlation. In market A, firm C serves a fraction ρ of all consumers with personalized prices $p_A^{***}(x) = 2 + \omega - x$. For the remaining fraction $1 - \rho$ of consumers, the equilibrium uniform prices are $\alpha_1^{***} = \alpha_2^{***} = 1$, and the marginal consumer is $\hat{x} = 1/2$.

In Figure 1, we plot the range of (ω, ρ) that leads to different equilibria. The figure on the left-hand side summarizes the threshold values of $\hat{\omega}$ that correspond to the various cases discussed above with interior local optima. The figure on the right-hand side shows these threshold values for global optima.

3. Welfare implications

For each pair of equilibria corresponding to ω, it is straightforward to check that firm C has smaller profit but firms A_2 and B_2 have larger profits when $\rho < 1$. Given that the equilibrium uniform prices are higher in market B when $\rho < 1$, imperfect correlation reduces consumer surplus in market B.

The comparison of consumer surplus in market A is not as straightforward since it involves changes in equilibrium prices and consumers' purchase decisions, where the fraction $1 - \rho$ of consumers in the target segment pay the uniform price when $\rho < 1$. So we calculate consumer surplus directly. In case (i), i.e., $\hat{x} > x^*$, consumer surplus in market A is

$$CS_A^{(i)} = v_A - \frac{5}{4} + \left(\rho - \frac{5}{9}\rho^2\right)(x^*)^2,$$

where x^* is given in (11) and the superscript (i) indicates case (i). In case (ii), i.e., mixed

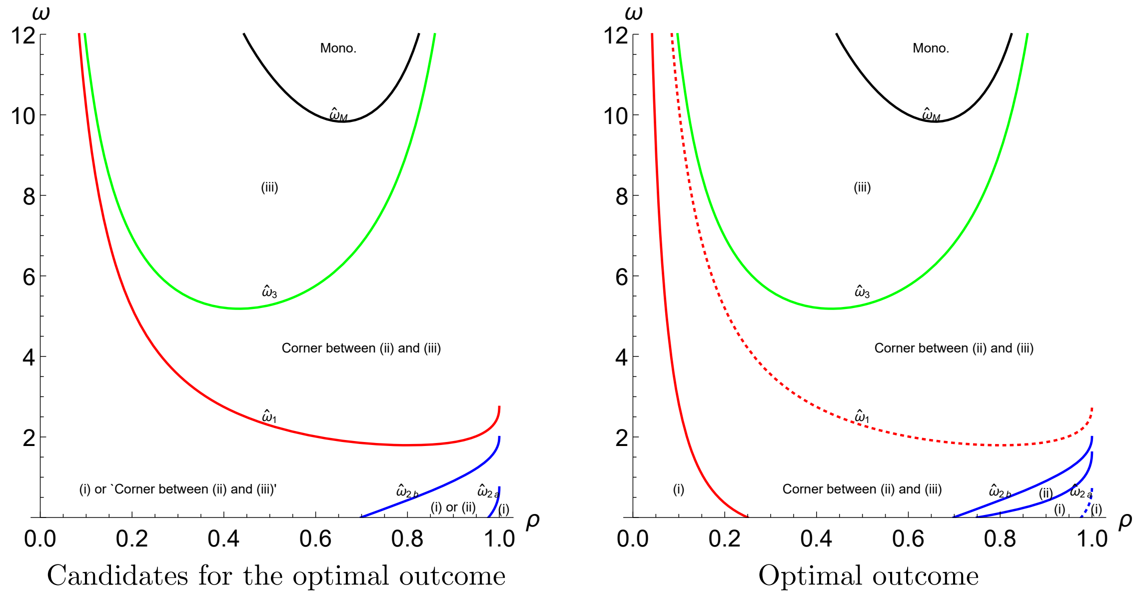

Figure 1: The threshold values of ω

strategy equilibrium, expected consumer surplus in market A is

$$CS_A^{(ii)} = v_A + \frac{1}{2} - 2(1+\sqrt{1-\rho})x^* + \frac{(1-\rho)(2-\rho+2\sqrt{1-\rho}+4\rho g^*)}{4}(x^*)^2,$$

where g^* and x^* are as in (7) and (18) and the superscript (ii) indicates case (ii). In case (iii), i.e., $\hat{x} \leq x^*$, or the corner case between cases (ii) and (iii), consumer surplus in market A is

$$CS_A^{(iii)} = v_A - \frac{45-\rho^2}{36(1-\rho)} + \frac{\rho(9+\rho)x^* + \rho^2(x^*)^2}{9(1-\rho)}.$$

where x^* is given in (22) in the corner case and in (26) in case (iii). In the monopolization equilibrium, consumer surplus in market A is

$$CS_A^{(M)} = v_A - \frac{5}{4} - \frac{1}{4}\rho.$$

Comparing the above with consumer surplus in market A when $\rho = 1$, one can show that imperfect preference correlation decreases consumer surplus in market A when (a) $\omega < 3(\sqrt{385}-11)/16$ or (b) $3(\sqrt{385}-11)/16 \leq \omega$ and ρ is larger than a threshold value that depends on ω. The threshold value is smaller than $3/10$ for $\omega \leq 5$. ∎

■ Proof of Proposition 9

In Hotelling competition on $[\delta_A, 1]$, firm C chooses α_1 to maximize $(\alpha_1 - c/2)(\hat{x} - \delta_A)$ and firm A_2 chooses α_2 to maximize $(\alpha_2 - c/2)(1-\hat{x})$ where $\hat{x} = (1+\alpha_2-\alpha_1)/2$. This leads to the following equilibrium uniform prices: $\alpha_1^* = 1-(4\delta_A)/3+c/2$, $\alpha_2^* = 1-(2\delta_A)/3+c/2$ if $\delta_A \leq 3/4$; $\alpha_1^* = c/2$, $\alpha_2^* = (2\delta_A - 1) + c/2$ if $\delta_A > 3/4$. Then firm C's personalized prices are given by $p_A^*(x) = 1 - x + \alpha_2^*$. Clearly, firm C serves all type-L targeted consumers since $p_A^*(x) \geq 0$. Firm C will also serve all type-H targeted consumers if $p_A^*(\delta_A) \geq c$. First, if $\delta_A \leq 3/4$, then $p_A^*(\delta_A) = 2 - (5\delta_A)/3 + c/2$. So we have $p_A^*(\delta_A) \geq c$ if $c \leq 3/2$. Second, if $\delta_A \geq 3/4$, then $p_A^*(\delta_A) = \delta_A + c/2 \geq c$ if $c \leq 3/2$. Thus if $c \leq 3/2$, then the equilibrium is qualitatively the same for each type as that in Section 3.

Next, suppose $p_A(\xi) = 1-x+\alpha_2 = c$ for some $\xi \in (0, \delta_A)$. Then $p_A(x) < c$ for all $x \in (\xi, \delta_A]$. Below we find sufficient conditions for an equilibrium in which firm C serves all type-L consumers in $[0, \delta_A]$, type-H consumers in $[0, \xi]$, and both types of non-targeted consumers in $[\delta_A, \hat{x}]$, while firm A_2 serves type-H consumers in $[\xi, \delta_A]$ in addition to both types of consumers in $[\hat{x}, 1]$. In this equilibrium, firm C chooses α_1 to maximize $(\alpha_1 - c/2)(\hat{x} - \delta_A)$ and firm A_2 chooses α_2 to maximize $\pi_2 = (\alpha_2 - c/2)(1 - \hat{x}) + (\alpha_2 - c)(\delta_A - \xi)/2$ where $\hat{x} = (1 + \alpha_2 - \alpha_1)/2$. Solving them for an interior solution, we obtain $\alpha_1^* = 4/7 - \delta_A + (9c)/14, \alpha_2^* = 1/7 + (11c)/14$, hence $\hat{x}^* = 2/7 + \delta_A/2 + c/14$, $\xi^* = 8/7 - (3c)/14$, and firm A_2's profit denoted by π_{A2}^*. These prices constitute equilibrium if $0 < \xi^* < \delta_A < \hat{x}^* < 1$ and $\pi_{A2}^* \geq 0$. One can verify that all of these inequalities are satisfied if $c \in (3/2, 5]$ and $\delta_A \in [1/2, 4/5]$. ∎

■ Proof of Proposition 10

1. Equilibrium following the successive merger

Let us start with market A. Let firm C's target segment be $[0, x^*]$ so that firm D's target segment is $[x^*, 1]$. It is easy to see each firm serves all its targeted consumers using personalized prices $p_C^*(x) = \omega + 1 - x + \alpha_2$ and $p_D^*(x) = x + \alpha_1$. Given that they cannot serve non-targeted consumers, we can set uniform prices $\alpha_1 = \alpha_2 = 0$. This leads to each firm's profit in market A given by $\pi_C = \int_0^{x^*} (\omega + 1 - x)dx$ and $\pi_D = \int_{x^*}^1 xdx$.

In market B, firm D chooses β_2 to maximize $\Pi_D = \pi_D + \beta_2(1 - x^*)$ where $x^* = (1 - \beta_1 + \beta_2)/2$, leading to its best response $\beta_2(\beta_1)$ and $x^*(\beta_1)$. Then firm C chooses β_1 to maximize $\Pi_C = \pi_C + \beta_1 x^*(\beta_1)$. From this, we obtain the following. First, if $\omega < 7$, then we have an accommodation equilibrium with

$$\beta_1^* = \frac{13 - 5\omega}{11}, \; \beta_2^* = \frac{10 - 3\omega}{11}, \; x^* = \frac{4 + \omega}{11}.$$

Second, if $\omega \geq 7$, then we have a monopolization equilibrium with $\beta_1^* = -2$ and $\beta_2^* = -1$. Total profits are then

$$\begin{aligned} &\Pi_C^{SM} = \frac{(4 + \omega)^2}{22}, \; \Pi_D^{SM} = \frac{5(7 - \omega)^2}{242} \text{ in the accommodation equilibrium,} \\ &\Pi_C^{SM} = \omega - \frac{3}{2}, \; \Pi_D^{SM} = 0 \text{ in the monopolization equilibrium,} \end{aligned}$$

where the superscript ‘SM’ denotes the successive merger.

2. Merger decision and profits

Without the successive merger, we have the following total equilibrium profits:

- When $\omega \le \frac{3(\sqrt{385}-11)}{16}$, $\Pi_C^* = \frac{9}{154}\omega^2 + \frac{3}{7}\omega + \frac{9}{7}$, $\Pi_{A_2}^* + \Pi_{B_2}^* = \frac{1}{2}\left(\frac{37-6\omega}{59}\right)^2 + 2\left(\frac{26-9\omega}{59}\right)^2$.
- When $\frac{3(\sqrt{385}-11)}{16} \le \omega < 2$, $\Pi_C^* = \frac{1}{10}(\omega+3)^2$, $\Pi_{A_2}^* + \Pi_{B_2}^* = \frac{-2\omega^2+3\omega+2}{25} + \frac{2(2-\omega)^2}{25}$.
- When $\omega \ge 2$, $\Pi_C^* = \omega + \frac{1}{2}$, $\Pi_{A_2}^* + \Pi_{B_2}^* = 0$.

Comparing the profits above, we find that $\Pi_{A_2}^* + \Pi_{B_2}^* < \Pi_D^{SM}$ when $\omega < 7$, and $\Pi_{A_2}^* + \Pi_{B_2}^* = \Pi_D^{SM} = 0$, otherwise. Thus firms A_2 and B_2 prefer merger to remaining independent when $\omega < 7$, and are indifferent, otherwise. It is easy to see $\Pi_C^{SM} < \Pi_C^*$ is always true.

3. Consumer surplus

Without the successive merger, consumer surplus in each market is given by

- When $\omega \le \frac{3(\sqrt{385}-11)}{16}$, $CS_A = v_A + \frac{36\omega^2}{5929} + \frac{24\omega}{539} - \frac{229}{196}$, $CS_B = v_B + \frac{81\omega^2}{5929} + \frac{180\omega}{539} - \frac{143}{98}$.
- When $\frac{3(\sqrt{385}-11)}{16} \le \omega < 2$, $CS_A = v_A - \frac{2\omega}{5} - \frac{7}{10}$, $CS_B = v_B + \frac{\omega^2}{25} + \frac{16\omega}{25} - \frac{47}{50}$.
- When $\omega \ge 2$, $CS_A = v_A - \frac{3}{2}$, $CS_B = v_B + \frac{1}{2}$.

After the successive merger, consumer surplus can be calculated as follows. First, consider the equilibrium with accommodation that arises when $\omega < 7$. In market A, consumers $[0, x^*]$ pay $p_C^*(x) = \omega + 1 - x$ and consumers $[x^*, 1]$ pay $p_D^*(x) = x$ where $x^* = (4+\omega)/11$. So total consumer surplus in market A is

$$CS_A = \int_0^{x^*} (v_A + \omega - p_C^*(x))dx + \int_{x^*}^1 (v_A - p_D^*(x))dx = v_A + \frac{1}{121}\omega^2 - \frac{3}{121}\omega - \frac{177}{242}.$$

In market B, total consumer surplus is

$$\begin{aligned} CS_B &= \int_0^{x^*} (v_B - x - \beta_1^*)dx + \int_{x^*}^1 (v_B - (1-x) - \beta_2^*)dx \\ &= \int_0^{\frac{4+\omega}{11}} (v_B - x - \frac{13-5\omega}{11})dx + \int_{\frac{4+\omega}{11}}^1 (v_B - (1-x) - \frac{10-3\omega}{11})dx \\ &= v_B + \frac{1}{121}\omega^2 + \frac{41}{121}\omega - \frac{309}{242}. \end{aligned}$$

Next, consider the monopolization equilibrium when $\omega \ge 7$. In market A, all consumers pay $p_C^*(x) = \omega + 1 - x$ and in market B, all consumers pay $\beta_1^* = -2$. Thus hence

$$CS_A = \int_0^1 (v_A + \omega - p_C^*(x))dx = v_A - \frac{1}{2},\ CS_B = \int_0^1 (v_B - x - \beta_1^*)dx = v_B + \gamma + \frac{3}{2}.$$

Based on the above, we can verify the following. First, for all values of ω, consumer surplus in market A without the successive merger is smaller than under the successive merger. Second, consumer surplus in market B is smaller under the successive merger if and only if $3(\sqrt{385}-11)/16 \leq \omega \leq (11\sqrt{21}-41)/2$. ∎

■ Proof of Proposition 11

1. Equilibrium in market A

Denote firm C's uniform price for consumers in its target segment $[0, x^*]$ by p_C. Given firm A_2's price α_2, the marginal consumer $x_C \in [0, x^*]$ is defined by $v_A + \omega - p_C = v_A - (1 - x_C) - \alpha_2$, or $x_C = 1 + \omega + \alpha_2 - p_C$. On $[0, x^*]$, firm C chooses p_C to maximize $p_C x_C$. Suppose we have an interior solution so that the first-order condition is satisfied with equality, $1 + \omega + \alpha_2 - 2p_C = 0$. This leads to $x_C = (1+\omega+\alpha_2)/2$. But this would imply $x_C > 1$ if $\omega > 1$, an impossibility. Thus the boundary solution is the only possibility, $x_C = x^*$. In sum, on $[0, x^*]$, firm C chooses uniform price $p_C(\alpha_2) = 1 + \omega + \alpha_2 - x^*$ to serve all its targeted consumers and earns profit $p_C(\alpha_2)x^*$. On $[x^*, 1]$, firms choose α_1 and α_2. But we have already solved this problem in Section 3. The equilibrium prices and profits are

$$\alpha_1 = \begin{cases} \dfrac{3-4x^*}{3} & \text{if } x^* < \dfrac{3}{4}, \\ 0 & \text{if } x^* \geq \dfrac{3}{4}. \end{cases} \qquad \pi_C = \begin{cases} \dfrac{(3-4x^*)^2}{18} & \text{if } x^* < \dfrac{3}{4}, \\ 0 & \text{if } x^* \geq \dfrac{3}{4}. \end{cases}$$

$$\alpha_2 = \begin{cases} \dfrac{3-2x^*}{3} & \text{if } x^* < \dfrac{3}{4}, \\ 2x^*-1 & \text{if } x^* \geq \dfrac{3}{4}. \end{cases} \qquad \pi_{A2} = \begin{cases} \dfrac{(3-2x^*)^2}{18} & \text{if } x^* < \dfrac{3}{4}, \\ (2x^*-1)(1-x^*) & \text{if } x^* \geq \dfrac{3}{4}. \end{cases}$$

Putting together, firm C's profit in market A is

$$\pi_{C,A} = \begin{cases} \dfrac{9+6(2+3\omega)x^* - 14(x^*)^2}{18} & \text{if } x^* < \dfrac{3}{4}, \\ (\omega + x^*)x^* & \text{if } x^* \geq \dfrac{3}{4}. \end{cases}$$

2. Equilibrium in market B

Given firm B_2's best response $\beta_2(\beta_1) = (1+\beta_1)/2$, firm C chooses β_1 to maximize $\Pi_C = \beta_1 x^* + \pi_{C,A}$, which can be expressed as

$$\Pi_C = \begin{cases} \dfrac{1}{2} + \left(\beta_1 + \omega + \dfrac{2}{3}\right) x^* - \dfrac{7}{9}(x^*)^2 & \text{if } x^* < \dfrac{3}{4}, \\ (\beta_1 + \omega + x^*)x^* & \text{if } x^* \geq \dfrac{3}{4}, \end{cases}$$

where $x^* = \frac{1+\beta_2(\beta_1)-\beta_1}{2} = \frac{3-\beta_1}{4}$. The first-order derivative is given by

$$\frac{d\Pi_C}{d\beta_1} = \begin{cases} \dfrac{9(7-2\omega)-43\beta_1}{72} & \text{if } x^* < \dfrac{3}{4}, \\ \dfrac{3-2\omega-3\beta_1}{8} & \text{if } \dfrac{3}{4} \le x^* \le 1. \end{cases}$$

Solving for the equilibrium prices, we obtain three different types of equilibria, the same as in the baseline model except for the parameter regions.

First, the accommodation equilibrium I is possible when $x^* < 3/4$. The interior solution from the first-order condition, $\beta_1^* = 9(7-2\omega)/43$, is optimal if $\omega < 7/2$. In this case, firm C's total profit is $\Pi_C^* = 3(69+22\omega+3\omega^2)/172$ with $x^* = (9\omega+33)/86$, and firm B_2's price is $\beta_2^* = (53-9\omega)/43$. Second, the accommodation Equilibrium II is possible when $3/4 \le x^* < 1$. The optimal price is the interior solution $\beta_1^* = (3-2\omega)/3$ when $3/2 \le \omega \le 3$. Firm C's profit is $\Pi_C^{**} = (3+\omega)^2/12$ with $x^* = (3+\omega)/6$, and firm B_2's price is $\beta_2 = (3-\omega)/3$. Third, the monopolization equilibrium obtains when $\omega \ge 3$. In this case, firm C will optimally set $\beta_1 = -1$ and its equilibrium profit is $\Pi_C^{***} = \omega$.

From the above, both accommodation equilibria are possible when $\omega \in [3/2, 3]$ and the accommodation equilibrium II and the monopolization equilibrium are possible when $\omega \in [3, 7/2]$. For each case, we need to compare firm C's profits to find firm C's global optimum. This leads to $\Pi_C^* > \Pi_C^{**}$ if and only if $\omega < 3(\sqrt{129}-5)/8 \simeq 2.384$, and $\Pi_C^* < \Pi_C^{***}$ if and only if $\omega \ge (53-\sqrt{946})/9 \simeq 2.471$. Thus we can conclude that the accommodation equilibrium I exists when $\omega < 3(\sqrt{129}-5)/8$, the accommodation equilibrium II exists when $3(\sqrt{129}-5)/8 \le \omega < 3$, and the monopolization equilibrium arises when $\omega \ge 3$.

The equilibrium prices in market B are summarized as follows

$$\beta_1 = \begin{cases} \dfrac{9(7-2\omega)}{43} & \text{if } \omega < \dfrac{3(\sqrt{129}-5)}{8}, \\ \dfrac{3-2\omega}{3} & \text{if } \dfrac{3(\sqrt{129}-5)}{8} \le \omega < 3, \\ -1 & \text{if } 3 \le \omega. \end{cases}$$

$$\beta_2 = \begin{cases} \dfrac{53-9\omega}{43} & \text{if } \omega < \dfrac{3(\sqrt{129}-5)}{8}, \\ \dfrac{3-\omega}{3} & \text{if } \dfrac{3(\sqrt{129}-5)}{8} \le \omega < 3, \\ 0 & \text{if } 3 \le \omega. \end{cases}$$

This leads to the following equilibrium profits

$$\Pi_C = \begin{cases} \dfrac{3(69+22\omega+3\omega^2)}{172} & \text{if } \omega < \dfrac{3(\sqrt{129}-5)}{8}, \\ \dfrac{(3+\omega)^2}{12} & \text{if } \dfrac{3(\sqrt{129}-5)}{8} \leq \omega < 3, \\ \omega & \text{if } 3 \leq \omega. \end{cases}$$

$$\pi_{B2} = \begin{cases} \dfrac{(53-9\omega)^2}{3698} & \text{if } \omega < \dfrac{3(\sqrt{129}-5)}{8}, \\ \dfrac{(3-\omega)^2}{18} & \text{if } \dfrac{3(\sqrt{129}-5)}{8} \leq \omega < 3, \\ 0 & \text{if } 3 \leq \omega. \end{cases}$$

$$\pi_{A2} = \begin{cases} \dfrac{1}{2}\left(\dfrac{32-3\omega}{43}\right)^2 & \text{if } \omega < \dfrac{3(\sqrt{129}-5)}{8}, \\ \left(\dfrac{9\omega-10}{43}\right)\left(\dfrac{53-9\omega}{86}\right) & \text{if } \dfrac{3(\sqrt{129}-5)}{8} \leq \omega < 3, \\ 0 & \text{if } 3 \leq \omega. \end{cases}$$

Based on the above, the comparison of profits is straightforward. Given the restriction, firm C is worse off while firms A_2 and B_2 are better off than without the restriction.

3. Comparison of consumer surpluses

Recall that firm C's market share without the restriction is given by

$$x^* = \begin{cases} \dfrac{33+9\omega}{77} & \text{if } \omega < \dfrac{3(\sqrt{385}-11)}{16} \simeq 1.617, \\ \dfrac{3+\omega}{5} & \text{if } \dfrac{3(\sqrt{385}-11)}{16} \leq \omega < 2, \\ 1 & \text{if } 2 \leq \omega, \end{cases}$$

whereas the market share given the restriction becomes (subscript R for “restriction”)

$$x_R^* = \begin{cases} \dfrac{9\omega+33}{86} & \text{if } \omega < \dfrac{3(\sqrt{129}-5)}{8} \simeq 2.384, \\ \dfrac{3+\omega}{6} & \text{if } \dfrac{3(\sqrt{129}-5)}{8} \leq \omega < 3, \\ 1 & \text{if } 3 \leq \omega. \end{cases}$$

Without the restriction, consumer surplus in market A can be written as

$$CS_A = \begin{cases} v_A - \dfrac{5}{4} + \dfrac{4}{9}(x^*)^2 & \text{if } \omega < \dfrac{3(\sqrt{385}-11)}{16}, \\ v_A + \dfrac{1}{2} - 2x^* & \text{if } \dfrac{3(\sqrt{385}-11)}{16} \leq \omega < 2, \\ v_A - \dfrac{3}{2} & \text{if } 2 \leq \omega, \end{cases}$$

whereas, given the restriction, consumer surplus in market A is

$$CS_A^R = \begin{cases} v_A - \dfrac{5}{4} + \dfrac{17}{18}(x_R^*)^2 & \text{if } \omega < \dfrac{3(\sqrt{129}-5)}{8}, \\ v_A + \dfrac{1}{2} - 2x_R^* + \dfrac{1}{2}(x_R^*)^2 & \text{if } \dfrac{3(\sqrt{129}-5)}{8} \leq \omega < 3, \\ v_A - 1 & \text{if } 3 \leq \omega. \end{cases}$$

Comparing the total consumer surpluses given above, we obtain

$$CS_A^R - CS_A = \begin{cases} \dfrac{41\,625}{87\,701\,768}(3\omega+11)^2 > 0 & \text{if } \omega < \dfrac{3(\sqrt{385}-11)}{16}, \\ \dfrac{153}{14\,792}\omega^2 + \dfrac{17\,597}{36\,980}\omega - \dfrac{30\,393}{73\,960} > 0 & \text{if } \dfrac{3(\sqrt{385}-11)}{16} < \omega < 2 \\ \dfrac{153}{14\,792}\omega^2 + \dfrac{561}{7\,396}\omega + \dfrac{5\,755}{14\,792} > 0 & \text{if } 2 \leq \omega < \dfrac{3(\sqrt{129}-5)}{8} \\ \dfrac{(9-\omega)^2}{72} > 0 & \text{if } \dfrac{3(\sqrt{129}-5)}{8} < \omega < 3 \\ \dfrac{1}{2} > 0 & \text{if } 3 \leq \omega. \end{cases}$$

Thus consumer surplus in market A increases after the restriction.

In market B, the restriction softens competition and reduces total consumer surplus in the accommodation equilibria, but it does not affect the consumer surplus in the monopolization equilibrium. Without the restriction, consumer surplus in market B can be expressed as

$$CS_B = \begin{cases} v_B - \dfrac{5}{2} + (x^*)^2 + 2x^* & \text{if } \omega < \dfrac{3(\sqrt{385}-11)}{16}, \\ v_B - \dfrac{5}{2} + (x^*)^2 + 2x^* & \text{if } \dfrac{3(\sqrt{385}-11)}{16} \leq \omega < 2, \\ v_B + \dfrac{1}{2} & \text{if } 2 \leq \omega. \end{cases}$$

Under the restriction, total consumer surplus in market B is given by

$$CS_B^R = \begin{cases} v_B - \dfrac{5}{2} + (x_R^*)^2 + 2x_R^* & \text{if } \omega < \dfrac{3(\sqrt{129}-5)}{8}, \\ v_B - \dfrac{5}{2} + (x_R^*)^2 + 2x_R^* & \text{if } \dfrac{3(\sqrt{129}-5)}{8} \leq \omega < 3, \\ v_B + \dfrac{1}{2} & \text{if } 3 \leq \omega. \end{cases}$$

Comparing the total consumer surpluses given above leads to

$$CS_B^R - CS_B = \begin{cases} -\dfrac{27(11+3\omega)(18623+1467\omega)}{43\,850\,884} < 0 & \text{if } \omega < \dfrac{3(\sqrt{385}-11)}{16}, \\ -\dfrac{(93+41\omega)(1283+131\omega)}{184\,900} < 0 & \text{if } \dfrac{3(\sqrt{385}-11)}{16} < \omega < 2 \\ -\dfrac{3(97+3\omega)(53-9\omega)}{7\,396} < 0 & \text{if } 2 \leq \omega < \dfrac{3(\sqrt{129}-5)}{8} \\ -\dfrac{(21+\omega)(3-\omega)}{36} < 0 & \text{if } \dfrac{3(\sqrt{129}-5)}{8} < \omega < 3 \\ 0 & \text{if } 3 \leq \omega. \end{cases}$$

Thus the restriction reduces consumer surplus in market B. ∎

■ Proof of Proposition 12

Given firm C's target segment $[0, \delta_A]$, let z be the location chosen by firm C. Then the consumer who is indifferent when competition is in uniform price is given by $\hat{x} = (1 + z + \alpha_2 - \alpha_1)/2$. To find firm C's optimal choice of z, we consider two cases.

1. $\hat{x} \leq \delta_A$

Since $\phi_A = 1$, firm C serves all consumers in $[0, \delta_A]$ using personalization, and firm A_2 serves all consumers in $[\delta_A, 1]$ by the definition of $\hat{x}$. This leads to equilibrium uniform prices $\alpha_1 = 0$ and $\alpha_2 = 2\delta_A - 1 - z$. Given that firm C's profit is entirely from its targeted consumers and its personalized prices increase in α_2, firm C's optimal choice of z is $z = 0$. Thus, this case leads to $z = 0$, $\alpha_1^* = 0$, $\alpha_2^* = 2\delta_A - 1$, and $\hat{x} = \delta_A$.

Given the above prices, firm C has no incentives for deviation. But firm A_2 may deviate that leads to $\hat{x}^d > \delta_A$. The deviation price is $\alpha_2^d = 2\hat{x}^d - 1$ with the deviation profit given by $\alpha_2^d(1 - \hat{x}^d)$. Such a deviation is not profitable if and only if $\delta_A \geq 3/4$, when we have an equilibrium described above.

2. $\hat{x} > \delta_A$

When $\delta_A < \hat{x}$, firm C serves non-targeted consumers in $[\delta_A, \hat{x}]$ in addition to all its targeted consumers. Notice that we cannot have $z > \hat{x}$ by the definition of $\hat{x}$. Thus we only need to consider $z \leq \hat{x}$. Solving for the equilibrium uniform prices, we obtain

$$\alpha_1^* = \frac{3+z-4\delta_A}{3},\ \alpha_2^* = \frac{3-z-2\delta_A}{3},\ \hat{x} = \frac{3+z+2\delta_A}{6}$$

and firm C's personalized prices, $p_A^*(x) = 1+\omega+\alpha_2^* - x$. Thus firm C's profit in market A is

$$\begin{aligned}
\pi_C(z) &= \int_0^{\delta_A} p_A^*(x)dx + \alpha_1^*(\hat{x}-\delta_A) \\
&= \frac{1}{18}z^2 + \left(\frac{1}{3} - \frac{7}{9}\delta_A\right) z + \left(2 - \frac{2}{3}\delta_A + \omega\right)\delta_A - \frac{1}{2}(\delta_A)^2 + \frac{1}{2}\left(1 - \frac{4}{3}\delta_A\right)^2 \\
&= \pi_C + \left(\frac{z}{3}\right)\left(\frac{z}{6} - \frac{7\delta_A}{3} + 1\right) \equiv \pi_C + F(z)
\end{aligned}$$

where π_C is firm C's profit in market A when its location is 0, hence is independent of z.

Firm C's problem is to choose z to maximize $F(z)$ subject to $z \leq \hat{x}$, or equivalently, $z \leq (3+2\delta_A)/5$. Solving the problem, we obtain the following: (i) when $\delta_A \in [0, 6/13]$, we have $z = \delta_A$ with $\alpha_1^* = \alpha_2^* = 1-\delta_A$ and $\hat{x} = (1+\delta_A)/2$; (ii) when $\delta_A \in (6/13, 3/4]$, we have $z = 0$ with $\alpha_1^* = 1-(4\delta_A)/3, \alpha_2^* = 1-(2\delta_A)/3$ and $\hat{x} = (3+2\delta_A)/6$. Combining these with the case where $\hat{x} \leq \delta_A$ proves the derivation of optimal z.

It remains to show that firm A_2's profit is smaller but consumer surplus is larger when $z = \delta_A$. Clearly, firm A_2's profit decreases because it serves less consumers at lower uniform price when firm C chooses $z = \delta_A$. The consumer surplus when $z = \delta_A$ is given by

$$\begin{aligned}
CS_A^R &= \int_0^{\delta_A} [v_A + \omega - p_A^*(x)]dx + \int_{\delta_A}^{\hat{x}} [v_A - \alpha_1^* - (x-z)]dx + \int_{\hat{x}}^{1} [v_A - \alpha_2^* - (1-x)]dx \\
&= v_A - \frac{5}{4} + \frac{\delta_A^2}{4} + \frac{\delta_A}{2}.
\end{aligned}$$

When $z = 0$, it is $CS_A = v_A - 5/4 + (4\delta_A^2)/9$. It is straightforward to check $CS_A^R > CS_A$. ∎

■ Google's Ambition in Health Care

Google and its parent company Alphabet have made significant investments in life sciences and health care. Alphabet started two independent subsidiaries in these areas: Verily was founded in 2015 with focus on research in life sciences; Calico was founded in 2013 with focus on health, well-being, and longevity. Alphabet's venture capital arm, GV, invested \$21 billion or 36% of its funds in health care and life sciences in 2014, up from 9% in 2012 and 2013.[39] Since its founding in 2009, GV has invested in nearly 60 life sciences companies.[40] In 2018, Google re-established Google Health as an integrated health department, reporting to Google AI. Google's \$2.1 billion bid for Fitbit is in continuation of this strategic direction. Sundar Pichai, the CEO of Alphabet

[39] https://money.cnn.com/2014/12/16/smallbusiness/google-ventures-funding/index.html

[40] https://www.cnbc.com/2018/03/30/alphabet-gv-life-sciences-and-health-investments-going-public.html

and Google, said health care offers the biggest potential for Alphabet to use artificial intelligence to improve outcomes over the next five to ten years.[41]

Google Health

Google's interests in health care date back to 2006, when it started a repository of health records and data. Google Health, back then, aimed to link doctors and hospitals and help consumers aggregate their medical data.[42] But the early experiments failed and Google terminated the "Google Health" product in 2012. Google's new health service projects were re-organized in 2018, under the lead of David Feinberg, the former CEO of Geisinger Health System. Under Feinberg, a major task of Google Health is to develop a specific search engine for medical records and improve the quality of health-related search results.[43]

Project Nightingale and Google's access to health data

Project Nightingale is Google's attempt to gain a foothold in the healthcare industry on a large scale.[44] It is a joint project secretly initiated in 2018 by Google Cloud and Ascension, one of the largest private healthcare systems in the U.S. The two companies signed the Health Insurance Portability and Accountability Act (HIPAA) business associate agreement, under which Ascension would transfer patient data to Google Cloud, and Google would be barred from using this data for purposes other than providing services to Ascension. The data sharing would allow Google access to almost complete electronic health records on millions of Americans.[45] The partnership is currently under investigation by the Department of Health and Human Services for its implications for patient privacy under the HIPAA.

In September 2019, Google announced a ten-year deal with Mayo Clinic to store the hospital system's genetic, medical and financial records.[46] In 2019, Google also made a generous proposal to Cerner Corp, a health-data company, for a storage of 250 million health records, although Cerner eventually chose Amazon. According to a report in *The Wall Street Journal*, Google has struck partnerships with some of the largest hospital systems and most-renowned healthcare providers in the U.S., and it is able to view or analyze tens of millions of patient records in at least three-quarters of the U.S. states.[47]

[41] https://www.cnbc.com/2020/02/11/google-health-has-more-than-500-employees.html

[42] https://www.cnbc.com/2020/02/11/google-health-has-more-than-500-employees.html

[43] https://www.cnbc.com/2019/11/02/google-healths-david-feinberg-focus-on-search-for-doctors-consumers.html

[44] https://en.wikipedia.org/wiki/Project_Nightingale

[45] https://www.wsj.com/articles/google-s-secret-project-nightingale-gathers-personal-health-data-on-millions-of-americans-11573496790

[46] https://www.wsj.com/articles/google-s-secret-project-nightingale-gathers-personal-health-data-on-millions-of-americans-11573496790

[47] https://www.wsj.com/articles/paging-dr-google-how-the-tech-giant-is-laying-claim-to-health-data-

Google/Fitbit merger

The global market for wearable devices was worth $23 billion in 2018, and is projected to grow to $54 billion by 2023 ("Wearable Technology in Healthcare, August 2019, GlobalData).[48] According to a Gallup poll in 2019, about one in three Americans report at some point having worn a fitness tracker such as a Fitbit or smartwatch (34%) or having tracked their health statistics on a phone or tablet app (32%).[49] The growing adoption of mobile platforms, increasing adoption of AI and 5G, and the growing awareness and preference for home health care is expected to boost the growth of the market.[50] While wearable technologies have been employed in various fields, they have the greatest potential in healthcare field. Combined with AI and machine learning, the market for wearable technologies is becoming more personalized and disease-specific ("Wearable Technology in Healthcare, August 2019, GlobalData).

Fitbit was founded in 2007 and filed an IPO in 2015. If offers a suite of fitness trackers, smartwatches, and wristbands. Fitbit's revenue in 2019 was $1.42 billion with profit $234 million. Google's $2.1 billion bid for Fitbit is under regulatory probe in multiple jurisdictions at the time of writing this article. If successful, the acquisition will enhance Google's ability to produce wearable devices and enable Google to have access to personal health tracking data of around 30 million Fitbit users.[51]

According to the IDC Worldwide Quarterly Wearable Device Tracker, Fitbit's global market share in wearable devices market was 4.7% in 2019, down from 7.8% in 2018.[52] Although Google will be initially a minor player in the fitness-tracker/wearable device market after the acquisition of Fitbit, "the concern is Google would use this data to help reinforce its dominance in other segments," said Maurice Stucke, an antitrust law professor at the University of Tennessee, a concern shared by the European Competition Commission.[53]

An ostensible reason for Google's bid for Fitbit is Google's intention to gain a toehold in the market for wearable devices. But the merger would also allow Google to add sensitive health data to users' personal profiles it aggregates from other services, which can then be used to improve its online advertising. In a bid to allay these concerns raised by antitrust regulators in Australia and Europe, Rick Osterloh, senior vice president for Google's devices and services, said the deal

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[48]Wearable devices include earwear, basic watch, smartwatch, wristband, clothing and others. According to IDC (https://www.idc.com/promo/wearablevendor), smartwatch accounts for 20% to 30% of the market, while wristband has around 22% to 30% of the market share.

[49]https://news.gallup.com/poll/269096/one-five-adults-health-apps-wearable-trackers.aspx

[50]https://www.marketsandmarkets.com/Market-Reports/wearable-medical-device-market-81753973.html

[51]https://www.bloomberg.com/news/articles/2020-02-10/google-fitbit-deal-poses-test-for-merger-cops-eyeing-data-giants

[52]https://www.idc.com/getdoc.jsp?containerId=prUS46122120

[53]https://www.bloomberg.com/news/articles/2020-02-10/google-fitbit-deal-poses-test-for-merger-cops-eyeing-data-giants

was “about devices, not data”, and that Fitbit data would not be used for Google ads.[54] On the other hand, Google will be able to harvest users' detailed health data 24/7 by selling wearable devices. Indeed, Fitbit users and the European Commission express concern that the health data tracked by Fitbit would be combined with Google's other data and can be used to exploit consumers. “This takeover is likely to be a worrying game changer for how consumers' health and wellness data is used,” Monique Goyens, the director general of the European Consumer Organization, said in a statement.[55]

With Google Health (medical search engine), Google Cloud and Project Nightingale (massive medical records), Fitbit (wearable devices tracking health data), and Google AI (data analytics), Google will be in a formidable position to become a major player in the digital health industry. Although Google has not offered many healthcare products directly in the market, its subsidiary, Verily, has already begun to venture into health care and insurance, which we discuss below.

Verily's business in health care and insurance

Verily was established in 2015 as an independent subsidiary of Alphabet with focus on research in health care and life sciences. In 2017, Verily initiated an ambitious four-year health project, called Project Baseline, to comprehensively study human health around the globe. In doing so, Verily created its own smartwatch, called Study Watch, with electrocardiogram technology built-in to track participants' health data. The eventual goal, according to Jessica Mega, Verily's chief medical officer, is to “create a map of human health”.[56] Over the past few years, Verily has been quietly expanding in healthcare and insurance industries leveraging its strength in digital health technology. The overarching theme for its new business is opportunities in the cross field of the health and technology sectors.

Verily has collaborated with various health systems, including Atrius Health, the Palo Alto Veterans Affairs healthcare system, and other providers on initiatives to tackle major health challenges. Verily has also partnered with Blue Cross Blue Shield Association and Walgreens for diabetes care.[57] Its main role in these collaborations is to analyze medical data for data-driven prescriptions. For example, in the cooperation with Atrius, Verily will analyze patient health information to better detect the interventions that might work for heart failure patients.

Verily entered the insurance market in 2019 by collaborating with life insurer John Hancock. The two companies cooperate to offer a life insurance solution and digital wellness programs to help people with diabetes manage and improve their condition.[58] Brooks Tingle, president

[54] https://www.nytimes.com/2020/08/04/business/google-fitbit-europe.html

[55] https://www.nytimes.com/2020/08/04/business/google-fitbit-europe.html

[56] https://www.cnbc.com/2017/04/18/alphabet-verily-project-baseline-longitudinal-health-study.html

[57] https://www.fiercehealthcare.com/tech/verily-and-onduo-collaborating-john-hancock-to-offer-life-insurance-disease-management-for

[58] https://www.fiercehealthcare.com/payer/alphabet-s-verily-breaks-into-stop-loss-health-insurance-market-backed-by-swiss-re

and CEO of John Hancock Insurance, said the company saw an opportunity to work with Google to leverage a personalized approach to disease management and make life insurance more personalized and engaging.[59]

In August 2020, Verily and Swiss Re Corporate Solutions, the commercial insurance unit of the Swiss Re Group, established a new subsidiary, called Coefficient Insurance Company, with a focus on employer stop-loss health insurance, a market valued approximately \$20 billion. Departing from the traditional stop-loss health insurance, the partnership would leverage Verily's core strengths integrating hardware, software and data science to provide a data-driven solution to self-funded employers for more predictable protection and cost control.[60] "We're hoping to be more personalized in the way we offer health solutions," said Vivian Lee, Verily's President of Health Platforms.[61] Once Coefficient Insurance finds its footing, Verily would want to integrate its suite of health devices in tracking employees' health to provide tech-driven interventions. Given the smartwatch Verily already used in its Project Baseline and the pending acquisition of Fitbit, it is plausible to expect that Verily would be able offer more personalized health insurance products that utilize health/fitness tracking and data analytics.

■ Big Data and Personalization in Health Care

The digital health sector can be defined as the segment of health care heavily reliant on digital technologies, including wireless health, mobile health, electronic health record, telehealth, etc. The global digital health sector is estimated to be worth around \$100 billion in 2019, and is poised to grow at 28.5% annually.[62] It is becoming a new battlefield for personalization due to the unprecedented accumulation of health data. According to an estimate by the McKinsey Global Institute, big-data applications could generate up to \$100 billion in value annually across the US healthcare system.[63] We give a brief review on the trend of personalization and use of big data in health care.

Data processing has always been the core of insurance business. With more data emerging from digitization, new datasets, including internet of things (IoT) data, online footprints and mobile devices data, and new data analytics tools (e.g., machine learning and artificial intelligence) are increasingly incorporated into insurance business. According to the survey of European Insurance and Occupational Pensions Authority (EIOPA), many insurance companies have developed their own big data analytics (BDA) strategies or have included many BDA

[59]https://www.fiercehealthcare.com/tech/verily-and-onduo-collaborating-john-hancock-to-offer-life-insurance-disease-management-for

[60]https://www.fiercehealthcare.com/payer/alphabet-s-verily-breaks-into-stop-loss-health-insurance-market-backed-by-swiss-re

[61]https://www.cnbc.com/2020/08/25/alphabet-verily-enters-stop-loss-insurance-market.html

[62]https://www.statista.com/statistics/1092869/global-digital-health-market-size-forecast/

[63]https://www.mckinsey.com/industries/pharmaceuticals-and-medical-products/our-insights/how-big-data-can-revolutionize-pharmaceutical-r-and-d

projects in their business plans. Among the 222 insurance companies in the survey, 50 companies already use IoT data and another 75 companies anticipate to use it within the next three years. A smaller number of health insurers in the survey use wearable devices and smartphone apps to track their customers' real-time health information.[64]

Insurance companies typically pool customers with similar risk profiles, and premiums are based on the average risk across the pool. The insurer's ability to distinguish the riskiness of different customers determines the size of the pool. BDA significantly improves the insurer's ability to segment customers based on their risk profiles and fine-tune insurance premium accordingly. Out of the 222 insurers that participated in EIOPA's survey, most of them consider that BDA has had a biggest impact in the pricing and underwriting stage of the insurance value chain, and many of them have begun to adopt more sophisticated BDA-driven pricing models in order to optimize profits.[65]

Usage-based insurance (UBI) in motor and health insurance are the most common products that apply BDA. The UBI products measure a consumer's behavior and environment to perform risk assessments, based on which premiums and discount rewards are determined.[66] In health insurance, Pay-As-You-Live (PAYL) is gaining popularity. It uses wearable devices tracking the policyholder's health information such as blood pressure, glucose level, number of steps walked, calories consumed, etc., and the tracking data is used to perform risk assessments and determine insurance premium. Under PAYL, policyholders demonstrating healthy lifestyles receive premium discounts and other types of rewards.

South African insurance company Discovery's Vitality program is considered the pioneer of personalized wellness program and PAYL product. With the help of wearable devices and smartphone apps, Vitality creates mini challenges related to shopping for healthy food, sporting activities, medical checkups, and motivates clients to accomplish these challenges with rewards (e.g., cash-back, discounts) or other types of incentives. The use of connected devices gives Discovery precious data on people's lifestyle and health condition.[67]

A leading insurance company John Hancock employs the wealth of data collected by wearable devices, including Fitbit bands and Apple Watch, to reward their customers with healthy lifestyle. In April 2015, John Hancock cooperated with Vitality to launch a new PAYL life insurance product that offers up to a 15% premium discount to clients who track their healthy habits and share the information with the company. New clients even get free Fitbit bands or

[64] See EIOPA report "Big Data Analytics in Motor and Health Insurance: A Thematic Review", page 12.

[65] Figure 11 in EIOPA report "Big Data Analytics in Motor and Health Insurance: A Thematic Review".

[66] There are two main types of UBI products in motor insurance. The first kind is Pay-As-You-Drive (PAYD) product in which the premiums are based on the number of kilometers driven by the consumer. The other kind is Pay-How-You Drive (PHYD) product. The consumer receives a driving score based on his/her driving behavior and the score directly affects the premium paid by the consumer. In either product, drivers that show safe driving behavior receive lower premium. The UBI motor insurance, in most cases, requires the tracking data of telematics devices.

[67] https://www.discovery.co.za/vitality/how-vitality-works

other wearable devices to begin tracking.[68] In 2018, John Hancock announced it would stop offering traditional life insurance altogether, and only sell interactive life insurances that track fitness and health data through wearable devices and smartphones.[69] In 2020, John Hancock further announced it would streamline the life insurance buying experience through cooperation with Human API, a leading health data platform, offering a simple, digital way consumers can share access to their electronic health records in real time.[70]

Similar strategies are adopted by Oscar Health, an insurance technology startup, which announced in 2014 that it would begin offering members a free Misfit fitness wearable for those who met individualized, algorithmically determined step-targets. Since discriminatory pricing is illegal under the Patient Protection and Affordable Care Act 2010 (Obama Care), Mario Schlosser, the co-founder of Oscar, said the investment in wearable devices and clients' information is for risk reduction. As an another example, Health IQ, an American insurance startup, rewards clients with healthy lifestyles. The company works with partners in healthcare, pharmaceuticals and medical devices to collect clients' current health condition, health literacy and lifestyle. The clients get personalized pricing discounts up to 41%.[71]

In addition to the insurance industry, more personalized products/services are emerging in other health-related industries. The GNS healthcare, a precision medicine company leveraging artificial intelligence to model individual patients' response to drug treatment, utilizes a range of data streams including the EHR (electronic health record) clinical data, claims data, and lab results to better match therapeutics or procedures to individual patients. In 2020, GNS unveiled the *in silico* patient called Gemini, the world's most accurate computer model of multiple myeloma disease progression and drug response. Gemini leverages broad datasets of molecular, genomic, and clinical and include the most common drug types used to treat multiple myeloma. "We are reaching a tipping point where patient data is becoming rich and multi-layered enough to power AI models that can help predict patient response at the individual level. [...] a true step forward in personalizing cancer treatment," said Dr. Ravi Parikh, an Oncologist at the University of Pennsylvania.[72] The use of big data is becoming more prevalent in personalized health care at all stages of prevention, diagnosis, and treatment.

[68] https://www.the-digital-insurer.com/dia/john-hancock-redefines-life-insurance-with-vitality-program/

[69] https://www.reuters.com/article/us-manulife-financi-john-hancock-lifeins/strap-on-the-fitbit-john-hancock-to-sell-only-interactive-life-insurance-idUSKCN1LZ1WL

[70] https://www.prnewswire.com/news-releases/john-hancock-and-human-api-join-forces-to-transform-the-life-insurance-purchase-process-300986166.html

[71] Everis report "Rethinking Healthcare for 2030" available at http://insurtechnttdata.everis.com/dist/resources/vlarrosa/insurtech/Insurtech_Insight_Health_Data_final_compressed.pdf

[72] https://www.clinicalomics.com/topics/oncology/multiple-myeloma/gns-healthcare/