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Abstract

Recent years have seen growing cases of data-driven tech mergers such as Google/Fitbit, in which a dominant digital platform acquires a relatively small firm possessing a large volume of consumer data. The digital platform can consolidate the consumer data with its existing data set from other services and use it for personalization in related markets. We develop a theoretical model to examine the impact of such mergers across the two markets that are related through a consumption synergy. The merger links the markets for data collection and data application, through which the digital platform can leverage its market power and hurt competitors in both markets. Personalization can lead to exploitation of some consumers in the market for data application. But insofar as competitors remain active, the merger increases total consumer surplus in both markets by intensifying competition. When the consumption synergy is large enough, the merger can result in monopolization of both markets, leading to further consumer harm when stand-alone competitors exit in the long run. Thus there is a trade-off where potential dynamic costs can outweigh static benefits. We also discuss policy implications by considering 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]

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

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[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 these cases 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).

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. On the one hand, 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. On the other hand, 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, albeit in varying degrees. Our specific focus in this paper is on the role of data in mergers 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 in the next section.

We start by sketching our model. Since Google/Fitbit serves as our motivating example, we will make reference to this case whenever relevant. There are two related markets, A for data

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[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.

application such as the digital health care market 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. Market A is a symmetric duopoly while we allow asymmetry in market B, partly motivated by the competitive landscape in the market for wearable devices where Apple is a market leader. Allowing asymmetric firms also enables us to identify interesting post-merger linkages between the two markets. 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. This model also applies to the case where firm C acquires firm B_1 and enters market A in partnership with firm A_1.

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 will be called firm C's target segment, and each consumer in the target segment, a targeted consumer. Personalization in market B is too costly so we ignore that possibility. For example, in the market for wearable devices, hardware reconfiguration that may be 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 patronizing firm C by buying its 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 powerful ecosystem, which it can leverage to enhance user experience in the digital health sector.

By personalization, we refer to firm C's ability to offer 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. Naturally, firm C will offer a personalized product at a personalized price, which we call collectively *product personalization*. When the firm offers a targeted consumer a standard product at a personalized price, we call it *personalized pricing*. Although personalization generates extra surplus to a consumer, how much of the extra surplus actually accrues to the consumer depends on the firm's ability to extract it through a personalized price, which in turn depends on competition. When the extracted surplus exceeds the cost of delivering a personalized product, firm C will choose personalization; otherwise, it will choose personalized pricing. For non-targeted consumers, firm C offers the standard product at a uniform price. In our baseline model, we assume that firm C can prevent its targeted consumers from having access to its standard product, for example, by search discrimination.

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 take away much of these benefits by using personalized prices except for those who are sufficiently far away from its location

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[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.

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 consumes 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 away from firm C's location, 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 the competitor's product.

On balance, total consumer surplus in market A may increase or decrease depending on the post-merger equilibrium. In what we call the equilibrium with accommodation, firm C's competitor remains active after the merger. This equilibrium arises when the consumption synergy is relatively small. In this case, the intensified competition for non-targeted consumers not only pushes down uniform prices but also limits the increase in personalized prices. As a result, total consumer surplus increases after the merger. But increased competition implies that firm C's stand-alone competitor is worse off after the merger, and may even choose to exit the market in the long run if the reduced profit does not cover its fixed cost. When the consumption synergy becomes sufficiently large, firm C can monopolize market A, reducing total consumer surplus. We call this the monopolization equilibrium in which firm C's competitor, albeit inactive, remains in the market, which makes the market contestable.

In market B, the market for data collection, competition intensifies unambiguously since both firms compete in uniform price and firm C has incentives to expand its market share above that in the Hotelling benchmark. When the consumption synergy is large enough, firm C can engage in 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 can eventually lead firm C to monopolize market B. By extension, this also leads to the monopolization of market A. 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 regardless of whether firm C monopolizes the market.

Our analysis also shows how the merger links firm C's competitors, firms A_2 and B_2, that are otherwise unrelated. First, the consumption synergy in market A is a source of value that consumer data has for firm C. Thus the consumption synergy makes firm C more aggressive in market B than when there is no consumption synergy. This implies negative externalities running from market A to firm B_2 through the consumption synergy. Second, firm B_2's competitive advantage in market B increases firm C's cost of expanding its customer based in market B, and hence its target segment in market A. This implies positive externalities created by firm B_2 for firm A_2.

A number of clear welfare implications of data-driven mergers emerge from our analysis.

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First, thanks to personalization and the consumption synergy, the merging parties are better off at the cost of their stand-alone competitors. Second, in market B, all consumers gain because of the intensified competition following the merger. Third, in market A, changes in consumer surplus depend on different equilibria: in the equilibrium with accommodation, consumer surplus increases after the merger; in the monopolization equilibrium, it decreases. Which type of equilibria is more likely depends on the size of consumption synergy. Fourth, the long-run effect is likely to be 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 can turn into the monopoly equilibrium, making consumers in both markets worse off. Thus there is a trade-off where potential dynamic costs can outweigh static benefits.

In view of the above welfare implications, we examine several policies often discussed and relevant to data-driven mergers. First, we analyze the effect of mandated data sharing between firm C and its competitor in market A. Intuitively, data sharing reduces the value of data to firm C as it allows the competitor to also use personalization. This softens competition and hurts consumers in market B, but benefits consumers in market A. It follows that firm C is worse off while its competitors in both markets are better off. In addition, data sharing makes monopolization less likely, hence mitigates the dynamic trade-off. Second, we consider the effect of prohibiting search discrimination in market A, which will allow targeted consumers access to firm C's standard product. Surprisingly, this can lead to a collusive outcome in which firm C can extract maximum surplus from targeted consumers. Without search discrimination, firm C chooses not to serve its non-targeted consumers, which allows its competitor to choose a high uniform price, which in turn allows firm C to increase its personalized prices. Prohibiting search discrimination also makes monopolization more likely. Next, we discuss the effect of banning below-cost pricing. This softens competition in market B and, as a result, in market A as well. Thus prices increase in both markets, benefiting firms at the cost of consumers. On the other hand, the ban prevents monopolization, hence also mitigates the dynamic trade-off. Finally, we consider the effect of blocking the merger. Once again, this clearly benefits stand-alone competitors. In market A, consumers benefit only if the merger were to lead to monopolization. In market B, consumers lose in the short run, but can benefit in the long run if the merger were to lead to monopolization. A general conclusion we can draw is that all of these policies except the prohibition of search discrimination 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 tech mergers. In the context of Google/Fitbit, personalizing health service by consolidating Fitbit's data with the data from Google's other services has a potential to generate benefits for consumers, barring privacy concerns. On the other hand, if Google's market power and data externalities eventually lead the market to tip in Google's favor, Google will be able to extract these potential benefits through personalization. Blocking the merger can prevent the consumer harm but also prevent the potential benefits from being realized. Thus competition authorities need to look for policies that can help realize potential benefits while minimizing consumer harm. Banning below-cost pricing and other predatory practices can protect small competitors and preserve the competitive landscape, thereby limiting Google's ability to extract consumer surplus. In addition, allowing consecutive mergers can also mitigate the trade-off. For instance, approving Apple's expansion into the digital health market following the Google/Fitbit merger will have pro-competitive effects while not sacrificing the potential benefits 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. On the one hand, blocking a merger can prevent long-term harm, while also preventing potential benefits from being realized. On the other hand, 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 personalization-based 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 data on consumers. We call this 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, which we call 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. First, the firm uses a richer mix of pricing policies, pure personalized pricing for some consumers, product personalization for other consumers, and uniform pricing for consumers its data scale does not cover. Second, the data scale and the data analytics have different effects on profits and consumer surplus. 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. Section 2 contains a literature review. Section 3 presents our model, while Section 4 provides the analysis of personalization in market A. Section 5 studies the cross-market effects from the merger. Section 6 discusses policy implications while Section 7 concludes the paper. Appendix provides selected proofs of the key results not provided in the main text. The online appendix contains additional 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 health industry.

2   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 Morten et al. ("Stigler Report", 2019). For reviews of the academic literature on the digital economy, see Goldfarb and Tucker (2019), or Calvano and Polo (2020).

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 (GAFAM: 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 (2020), Kamepalli et al. (2020), Katz (2020), and Motta and Peitz (2020) 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.[7] 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.[8]

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[7]For merger policy governing multi-sided platforms, see, for example, Jullien and Sand-Zantman (2020) and the references therein.

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

While not related to mergers, several studies analyze how data can be used for learning and affect market dynamics.[9] 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 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).[10] Zhang (2011) and Laussel and Resende (2020) consider product personalization in addition to personalized pricing, hence is closer to our study. But there are several key differences. First, they study a symmetric duopoly while our focus is on the asymmetric case where the merged firm can employ data-driven personalization while its stand-alone competitor cannot. This is due to our focus on data-driven mergers, from which asymmetry stems naturally. Second, we allow the merged firm to delink product personalization and personalized pricing, if it wishes to. To the extent that product personalization is costly and may not suit every customer the firm has information on, this flexibility seems plausible. Finally, we show how the merged firm's personalization strategy changes when cross-market effects are taken into account.

3   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

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

[10]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.

serve each market. In market A (B, resp.), firm A_1 (B_1, resp.) is located at 0 and firm A_2 (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 $v_A > 2$ to avoid trivial equilibria, which 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 where each firm charges a uniform price equal to 1 and earns a profit equal to $1/2$, with firm A_1's market share given by $[0, 1/2]$.

In market B, we allow asymmetry between firms, partly motivated by the competitive landscape in the market for wearable devices.[11] Specifically, we assume that a consumer located at x derives utility $v_B - x$ from firm B_1's product and $v_B + \gamma - (1-x)$ from firm B_2's product, where $v_B > 2$. Thus firm B_1 has competitive advantage if $\gamma < 0$ and B_2 has a competitive advantage if $\gamma > 0$. Before the merger, market B has an asymmetric Hotelling equilibrium with prices given by $\beta_1^0 = 1 - (\gamma/3)$ and $\beta_2^0 = 1 + (\gamma/3)$, hence firm B_1 serves $[0, x^0]$ where $x^0 = (3-\gamma)/6$. Then firms earn profits equal to $\Pi_{B_1}^0 = (\beta_1^0)^2/2$ and $\Pi_{B_2}^0 = (\beta_2^0)^2/2$. We focus our analysis on the case where $-3 < \gamma < 3$ so that market B is not monopolized before the merger. Allowing asymmetric firms enables us to identify interesting post-merger linkages between the two markets.

We are interested in 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.[12] Thus post-merger competition in market B continues to be in uniform price.

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[11] As discussed in the online appendix, Fitbit's global market share in wearable devices is less than 5%. Apple is a market leader with around 30% of market share, due possibly to stronger brand loyalty and the strength of its ecosystem.

[12] 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).

In market A, consumer data can be used for two types of personalization. Suppose firm C has acquired data and knows exact locations of all consumers in $[0, \delta_A]$. We call this segment 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. We call this *personalized pricing*. Moreover, firm C can utilize its data analytics and offer a personalized product that has a higher matching value for a targeted consumer than its standard product. We parameterize the higher matching value 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. We assume that offering the personalized product incurs per-unit cost c. Thus it is socially desirable to offer personalized products to consumers if $\phi_A x > c$. When firm C offers a personalized product to its targeted consumer, its price offer is clearly personalized as well. Thus we call this price-product personalization simply *product personalization*.[13]

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. In doing so, firm C has an option to choose between personalized pricing and product personalization, depending on the locations of its 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.[14] Such flexibility in pricing gives firm C a second-mover advantage in responding to the rival's pricing strategy.

We make two 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. This is clearly a strong assumption. But allowing imperfect correlation significantly complicates analysis without providing substantive additional insight. Second, we assume 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. 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

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[13]That the cost of personalization is constant at c is mainly to simplify analysis. In reality, the cost may vary across products and customers. For instance, suppose the cost of personalization is proportional to the degree of mismatch, say cx. Then the net benefit from personalization is $(\phi_A - c)x$. When $\phi_A > c$, firm C will choose product personalization for all targeted consumers; otherwise, it will choose personalized pricing. It is straightforward to check that our main results stay qualitatively the same in this case.

[14]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.

to how their interaction with Facebook can be used by advertisers and retailers. On the other hand, our motivating example of Google/Fibit will make consumer myopia less plausible. In this sense, our assumption of consumer myopia is mainly intended 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 market 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 commonly used in the analysis of competition in healthcare markets.[15] 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 such as above.

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 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.[16] It is becoming a new battlefield for personalization due to the unprecedented accumulation of health data.[17] Wearable devices are playing an important role in this. 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 such as blood pressure, glucose level, number of steps walked, calories consumed, etc. The data 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

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[15]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.

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

[17]In the online appendix, we provide a more detailed account of how the healthcare sector is transformed by big data and personalization.

as John Hancock. For example, John Hancock announced in 2018 that it would stop offering traditional life insurance, and only sell interactive life insurance that tracks fitness and health data through wearable devices and smartphones. In 2020, John Hancock further announced that it would streamline the life insurance buying experience through a strategic collaboration with Human API, a leading health data platform, offering a simple, digital way for consumers to share access to their electronic health records in real time.[18] 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.[19]

4 Equilibrium Analysis of Personalization

We start by analyzing the equilibrium in market A following the merger. 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 take δ_A as exogenous in this section, but will endogenize it in the next section. Recall that we consider two types of personalization: product personalization where the personalized product is offered at a personalized price; personalized pricing where the standard product is offered at a personalized price.

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 the cost of product personalization is c, it is socially desirable to offer personalized products to consumers if and only if $\phi_A x \geq c$. That is, product personalization has social value for the subset of targeted consumers in $[\tau, \delta_A]$ where $\tau \equiv c/\phi_A$ is the cost-benefit ratio of personalization. For the rest of targeted consumers, firm C can exercise personalized pricing since it has full information on their locations. Thus the choice between the two types of personalization is driven by the trade-off between the cost and benefit of product personalization. Throughout this section, we make the following assumptions.

Assumption 1: (i) $\delta_A \geq \tau \equiv c/\phi_A$; (ii) $\tau \leq 1/2$; (iii) $\phi_A \leq \min\{1, (2 + 4c)/3\}$.

Assumption 1-(i) allows us to study an interesting case where product personalization arises in equilibrium, without which firm C will use only personalized pricing for its targeted consumers. Assumption 1-(ii) says that the cost of product personalization is not large relative to its benefit so that product personalization is socially desirable for at least half of all consumers. Assumption 1-(iii) restricts the data analytics quality for a given cost of product personalization. It is a technical assumption that simplifies analysis but it also prevents firm C from monopolizing the market even if it had the full data scale, i.e., $\delta_A = 1$. For example, if $c = 0$ and $\phi_A = 1$, then

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[18]https://www.humanapi.co/john-hancock-press-release

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

$\delta_A = 1$ allows firm C to drive firm A_2 out of the market, but Assumption A-(iii) rules out this possibility by putting an upper bound of $2/3$ on ϕ_A when $c = 0$.

Personalization changes the pricing game in market A by expanding firm C's pricing arsenal. Denote firm C's personalized price for targeted consumer $x \in [0, \delta_A]$ by $p_A(x)$ when it offers the personalized product, and by $q_A(x)$ when it offers the standard product. In addition, firm C chooses a uniform price for non-targeted consumers, 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 engage in search discrimination to 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.[20] This allows firm C to delink its choice of personalized prices and its choice of uniform price.[21]

4.1 Characterization of equilibria

We now characterize the equilibria of the game. 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 and suppose firm C chooses product personalization. Targeted consumer x prefers the personalized offer from firm C 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 $p_A(x) = \min\{c, 1 - (2 - \phi_A)x + \alpha_2\}$. Since firm C can adjust its personalized price for each targeted consumer separately, it can reduce $p_A(x)$ down to marginal cost, i.e., $p_A(x) = c$. This defines the marginal consumer $\bar{x}$ as $p_A(\bar{x}) = c = 1 - (2 - \phi_A)\bar{x} + \alpha_2$, hence

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

Firm C can serve all targeted consumers $x \leq \bar{x}$ with product personalization. In doing so, it will choose personalized prices that make all targeted consumers indifferent between its personalized offer and its competitor's standard offer. Note that $\bar{x} \geq \hat{x}$ due to Assumption 1-(i), implying that personalization can serve as a more powerful weapon for firm C than uniform pricing in

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[20]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. In Section 6, we discuss the case where such search discrimination is prohibited.

[21]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.

defending its target segment.

Finally, suppose firm C chooses personalized pricing instead of product personalization. Then it can serve all consumers up to x such that $q_A(x)+x = \alpha_2+(1-x)$, leading to $q_A(x) = 1-2x+\alpha_2$. Once again, firm C can adjust its personalized price for each consumer, hence $q_A(x) = 0$ for the marginal consumer. This implies that firm C can serve all consumers $x \leq (1+\alpha_2)/2 \leq \bar{x}$ where the second inequality is due to Assumption 1-(i). This implies that if firm C can serve a subset of its targeted consumers with product personalization, it can always use personalized pricing in serving a subset of consumers closer to its location.

While personalization is a more powerful weapon than uniform pricing, product personalization comes at an additional cost c. Thus firm C's choice of pricing mix depends on the comparison between $p_A(x) - c$, $q_A(x)$ and α_1. Our first observation is 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 $x \leq \hat{x}$. If $x \in [0, \tau]$, then firm C can serve consumer x by choosing $q_A(x) = 1 - 2x + \alpha_2 \geq 1 - 2\hat{x} + \alpha_2 = \alpha_1$. If $x \in [\tau, \hat{x}]$, then firm C can serve consumer x by choosing $p_A(x) = 1 - (2 - \phi_A)x + \alpha_2$. Then $x \leq \hat{x}$ and $x \geq \tau = c/\phi_A$ imply

$$p_A(x) - c = 1 + \alpha_2 - 2x + \phi_A x - c \geq 1 + \alpha_2 - 2\hat{x} + \phi_A x - c = \alpha_1 + \phi_A x - c \geq \alpha_1.$$

Thus personalization allows firm C to serve its targeted consumers more profitably than uniform pricing.

Lemma 1 *It is never optimal for firm C to serve targeted consumers using uniform pricing. Firm C chooses personalized pricing to serve consumers in $[0, \tau]$ and product personalization to serve consumers in $[\tau, \delta_A]$.*

Lemma 1 establishes a clear result and simplifies analysis. When firm C can target some consumers using big data, it will serve them with personalized offers, starting with personalized pricing followed by product personalization. But the ability to use personalization is constrained by its data scale δ_A and data analytics quality ϕ_A. Even when firm C's data set covers the entire market ($\delta_A = 1$), whether or not firm C can monopolize the market depends on c and ϕ_A. Suppose $\delta_A = 1$. Since firm C can serve consumers only up to $\bar{x}$ using personalization, it must concede the remaining consumers in $[\bar{x}, 1]$ to 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 $\alpha_2 = (1 - \phi_A + c)/2$. This leads to $\bar{x} = \bar{\delta}$ where

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

Thus $[0, \bar{\delta}]$ is the maximum market segment that firm C can serve. Even when $\delta_A = 1$, firm C has to concede the segment $[\bar{\delta}, 1]$ to firm A_2. Note that $\bar{\delta} \geq 3/4$ due to Assumption 1-(ii), $\bar{\delta} \leq 7/8$ by Assumption 1-(iii), and $\bar{\delta}$ decreases in c and increases in ϕ_A. Suppose, for example, $c = \phi_A = 0$ so that $\bar{\delta} = 3/4$. In this case, firm A_2 can serve the segment $[3/4, 1]$, but

its market share shrinks as firm C's data analytics improves, although it cannot become smaller than $[7/8, 1]$.

Lemma 2 *Firm A_2 can always serve consumers in $[\bar{\delta}, 1]$ regardless of firm C's data scale or data analytics quality, where $\bar{\delta} \in [3/4, 7/8]$ is given in (3).*

Proof. When firm C uses personalization, the upper bound on the market segment it can serve was shown to be $\bar{\delta}$. The remaining case to consider is when firm C uses uniform pricing. The lowest uniform price it can charge is $\alpha_1 = 0$, in which case $\hat{x} = (1 + \alpha_2)/2$. Solving for firm A_2's optimal uniform price leads to $\alpha_2 = 1/2$, hence $\hat{x} = 3/4$. The lemma then follows since $\bar{\delta} \geq 3/4$ due to Assumption 1-(ii). ∎

Put differently, Lemma 2 shows how personalization allows firm C to expand its market reach. With uniform pricing, firm C can reach the maximum market size $[0, 3/4]$ by choosing $\alpha_1 = 0$. With product personalization, this can be expanded to $[0, \bar{\delta}]$ when the personalized price is set equal to the marginal cost of personalization.

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

4.1.1 Equilibrium when $\delta_A < 3/4$

First, in the segment $[\delta_A, 1]$, 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 $x \in [0, \tau]$, firm C chooses a personalized price $q_A(x)$ that makes consumer x indifferent between the two firms' standard products. Thus

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

Finally, for $x \in [\tau, \delta_A]$, firm C chooses product 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

$$p_A^*(x) = 1 - (2 - \phi_A)x + \alpha_2^* = 2 - \frac{2}{3}\delta_A - (2 - \phi_A)x. \tag{6}$$

These equilibrium prices are depicted in Figure 1.

— **Insert Figure 1 here.** —

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Then firm C's total profit is given by

$$
\begin{aligned}
\Pi_C^* &= \int_0^\tau q_A^*(x)\,dx + \int_\tau^{\delta_A} (p_A^*(x) - c)\,dx + \alpha_1^*(\hat{x} - \delta_A) \\
&= -\left(\frac{14 - 9\phi_A}{18}\right)\delta_A^2 + \left(\frac{2}{3} - c\right)\delta_A + \frac{1}{2} + \frac{c^2}{2\phi_A}.
\end{aligned}
$$

Meanwhile, firm A_2 serves consumers in $[\hat{x}, 1]$ with uniform price α_2^*, hence its profit is

$$
\Pi_{A_2}^* = \frac{1}{2}\left(1 - \frac{2}{3}\delta_A\right)^2.
$$

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. Thus by Lemma 1, firm C serves consumers in $[0, \tau]$ with personalized pricing, and those in $[\tau, \delta_A]$ with product personalization. In addition, firm C serves 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 $\hat{x}$.

4.1.2 Equilibrium when $3/4 \leq \delta_A < \bar{\delta}$

In this case, firm C cannot serve any of its non-targeted consumers. Competition in uniform price in the segment $[\delta, 1]$ would lead to prices given in (4). But $3/4 \leq \delta_A$ 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 $\delta_A \leq \hat{x}$. It is easy to see that, given $v_A > 2$, firm A_2 can maximize profit by choosing α_2 so that $\delta_A = \hat{x}$. This leads to the following equilibrium uniform prices:

$$
\alpha_1^{**} = 0, \ \alpha_2^{**} = 2\delta_A - 1. \tag{7}
$$

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

$$
\begin{aligned}
q_A^{**}(x) &= 2\delta_A - 2x, \text{ for } x \in [0, \tau], \tag{8} \\
p_A^{**}(x) &= 2\delta_A - (2 - \phi_A)x, \text{ for } x \in [\tau, \delta_A]. \tag{9}
\end{aligned}
$$

Given the above prices and market shares, firm C's profit is given by

$$
\Pi_C^{**} = \int_0^\tau q_A^{**}(x)\,dx + \int_\tau^{\delta_A} (p_A^{**}(x) - c)\,dx = \frac{(2 + \phi_A)}{2}\delta_A^2 - c\delta_A + \frac{c^2}{2\phi_A}.
$$

It is straightforward to check that $\Pi_C^* = \Pi_C^{**}$ when $\delta_A = 3/4$. Meanwhile, 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 $3/4 \leq \delta_A < \bar{\delta}$, firm C can serve only its targeted consumers, again with personalized pricing for those in $[0, \tau]$ and

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with product personalization for those in $[\tau, \delta_A]$. Firm A_2 serves all consumers not targeted by firm C. Thus the two firms' market shares are exogenously determined by δ_A.

4.1.3 Equilibrium when $\bar{\delta} \leq \delta_A$

In this case, firm C's target segment is so large that targeted consumers in $[\bar{\delta}, \delta_A]$ are served by firm A_2 in addition to all non-targeted consumers in $[\delta_A, 1]$. Following the discussion leading up to Lemma 2, we then have the following equilibrium uniform prices:

$$\alpha_1^{***} = 0, \ \alpha_2^{***} = \frac{1 - \phi_A + c}{2}. \tag{10}$$

Then firm C's personalized prices are[22]

$$q_A^{***}(x) = \frac{3 - \phi_A + c}{2} - 2x, \qquad \text{for } x \in [0, \tau], \tag{11}$$

$$p_A^{***}(x) = \begin{cases} \frac{3 - \phi_A + c}{2} - (2 - \phi_A)x, & \text{for } x \in [\tau, \bar{\delta}]. \\ \geq c, & \text{for } x \in [\bar{\delta}, \delta_A]. \end{cases} \tag{12}$$

Firm C's profit in this case is

$$\Pi_C^{***} = \int_0^\tau q_A^{***}(x)\, dx + \int_\tau^{\bar{\delta}} (p_A^{***}(x) - c)\, dx = \frac{(2 - \phi_A)}{2} \bar{\delta}^2 + \frac{c^2}{2\phi_A},$$

while firm A_2 makes profit equal to

$$\Pi_{A_2}^{***} = \frac{(1 - \phi_A + c)^2}{4(2 - \phi_A)}.$$

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 $\bar{\delta}$.

In the discussions so far, we have only characterized a candidate equilibrium in each case without checking its uniqueness. In the proof of the following proposition, we show that no other equilibria exist.

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

---

[22]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 $p_A^{***}(x) \geq c$, 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 $p_A^{***}(x) < c$.

- *When $\delta_A < 3/4$, there exists a unique equilibrium in which firm C chooses personalized pricing $q_A^*(x)$ for all consumers in $[0, \tau]$, product personalization with prices $p_A^*(x)$ for all consumers in $[\tau, \delta_A]$, and uniform price α_1^* for consumers in $[\delta_A, 1/2 + \delta_A/3]$, whereas firm A_2 serves the rest of consumers with uniform price α_2^*. These prices are given in (4), (5), and (6).*

- *When $3/4 \le \delta_A < \bar{\delta}$, there exists a unique equilibrium in which firm C chooses personalized pricing $q_A^{**}(x)$ for all consumers in $[0, \tau]$, product personalization with prices $p_A^{**}(x)$ for all consumers in $[\tau, \delta_A]$, and uniform price $\alpha_1^{**} = 0$, whereas firm A_2 serves consumers in $[\delta_A, 1]$ with uniform price α_2^{**}. These prices are given in (7), (8), and (9).*

- *When $\bar{\delta} \le \delta_A$, there exists a unique equilibrium in which firm C chooses personalized pricing $q_A^{***}(x)$ for all consumers in $[0, \tau]$, product personalization with prices $p_A^{***}(x)$ for all consumers in $[\tau, \bar{\delta}]$, and uniform price $\alpha_1^{***} = 0$, whereas firm A_2 serves consumers in $[\bar{\delta}, 1]$ with uniform price α_2^{***}. These prices are given in (10), (11), and (12).*

Proof. See Appendix.

4.2 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 in $[0, \tau]$ since they are offered personalized prices without the benefit of improved matching value. For targeted consumers in $[\tau, \delta_A]$, the benefit of improved matching value needs to be weighed against the cost of potentially higher personalized price. On the other hand, firm C's non-targeted consumers 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. On the other hand, firm C cannot monopolize the market since $\bar{\delta} \le 7/8$. Thus firm A_2 will continue to remain 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 A_2's profit decreases unambiguously. In all the three cases in Proposition 1, it is straightforward to verify that firm A_2's profit is less than $1/2$, its pre-merger profit. 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 $1/8$.

Second, firm C's profit increases when $\delta_A \leq \bar{\delta}$, but can decrease when $\delta_A > \bar{\delta}$ and ϕ_A becomes sufficiently large. This follows from comparing the second and third equilibria in Proposition 1. Having a larger data scale benefits firm C by allowing it to use personalization, but only up to $\delta_A = \bar{\delta}$. Beyond that, firm C cannot serve additional targeted consumers. But a higher value of ϕ_A intensifies competition and decreases firm A_2's uniform price, as can be seen from (10). This in turn reduces firm C's personalized prices, which are strategic complements to firm A_2's uniform price. This can make firm C's profit less than $1/2$, its pre-merger profit. To see this, notice that, when $\phi_A = 1$, firm C's profit is equal to $(4 - 4c + 5c^2)/8$, which is less than $1/2$ since $c \leq \phi_A/2 \leq 1/2$ where the first inequality is due to Assumption 1-(ii). Therefore, as ϕ_A increases to 1, firm C's profit monotonically decreases to less than $1/2$, implying that there is a threshold value of ϕ_A above which firm C's profit is less than $1/2$.

Third, personalization harms some consumers but benefits others. Before the merger, a targeted consumer with taste parameter x receives utility $v_A - x - 1$ given the Hotelling price equal to 1. After the merger, consumer x will be targeted with either personalised pricing or product personalization. But in either case, firm C adjusts its personalized offer so that consumer x will be indifferent between accepting firm C's personalized offer or choosing firm A_2's standard product. That is, consumer x will receive 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. Needless to say, all consumers outside firm C's target segment also benefit from the merger because competition in uniform price becomes more intense, leading to lower uniform prices than before the merger. Under our assumption that x is uniformly distributed, total consumer surplus increases after the merger.

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

- *reduces firm A_2's profit unambiguously;*

- *increases firm C's profit if $\delta_A < \bar{\delta}$, but reduces it if $\delta_A > \bar{\delta}$ and ϕ_A is sufficiently large;*

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- *harms some consumers but benefits others, but increases total consumer surplus.*

Proof. See Appendix.

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 and welfare. 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 is not monotonic. Firm C's profit Π_C^* increases in δ_A for $\delta_A < \delta^*$, after which it decreases where $\delta^* \equiv (6 - 9c)(14 - 9\phi_A) \leq 3/4$, the inequality being due to Assumption 1-(iii). 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 increases in δ_A up to $\delta_A = \min\{\delta^*, 3/4\}$, after which it is non-increasing in δ_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 after that. 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 $\delta_A \in [3/4, \bar{\bar{\delta}}]$, but is independent of δ_A after that. Consumer surplus is independent of ϕ_A when $\delta_A < \bar{\bar{\delta}}$, but increases in ϕ_A when $\delta_A \geq \bar{\bar{\delta}}$.*

Proof. See Appendix.

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 the firm but only up a certain point, because the firm's ability to serve additional targeted consumers is ultimately limited by its data analytics. As the firm benefits from a larger data scale, its competitor inevitably loses due to a decrease in its market share. On the other hand, an improvement in data analytics that benefits the firm has no effect on its competitor. This is because the benefit comes from the firm's ability to extract surplus from consumers that the firm already serves, rather than from poaching consumers from its competitor.

We close this section with a caveat. As our model is essentially static, Proposition 2 simply reiterates the well-known point that data can 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 $[\delta_A, 1]$. In the extreme case, firm C can expand its target segment to the entire market. This, coupled with improved data analytics that can relax the restriction $\bar{\bar{\delta}} \leq 7/8$, can result in the monopolization of market A by firm C. 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.

5 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 digital platform 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; in pure conglomerate mergers without any linkages, there is no sense in which firms can extend market power to other markets through a merger.

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. In this section, we endogenize firm C's target segment: consumer x's taste parameter is known to firm C if she chooses firm B_1 in market B, which, by our assumption of perfect correlation, is

also her taste parameter 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 ω by choosing firm C's personalized product in market A. This extra value can be interpreted as the 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. Throughout this section, we use the following assumptions.

Assumption 2: (i) $\omega \geq \gamma \geq 1$; (ii) $\phi_A = 1, \ c = 0$.

Assumption 2-(i) says firm B_2 has a competitive advantage in market B (i.e., $\gamma > 0$) but the consumption synergy in market A is larger. It allows us to explore the possibility the merged firm may price below-cost in market B when the consumption synergy is sufficiently large. The assumption $\gamma > 0$ may reflect the current market for wearable devices where Apple is a dominant player. Assumption 2-(ii) is intended primarily to simplify analysis since, with additional parameters ω and γ and the two linked markets, analysis becomes considerably more complicated. The implication of Assumption 2-(ii) is that firm C will now use product personalization and offer perfectly matched products to all of its targeted consumers. There will not be any substantive changes to the main insight from this section when we incorporate ϕ_A and c with $\phi_A \geq 2c$ as we did in the previous section. As before, we assume that firm C can prevent targeted consumers from purchasing its standard product. 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 profit after the merger is larger than that before the merger. Without the merger, two firms in each market play a simultaneous pricing game in uniform price. With the merger, we analyze market B first, which determines firm C's target segment, based on which we study market A. The timing of the pricing game in market A is the same as before. That is, uniform prices are simultaneously chosen first, after which firm C makes personalized offers. We solve the game backward.

5.1 Analysis of equilibria

Let us start with market A. Denote firm C's target segment by $[0, x^*]$ where x^* is the marginal consumer who purchased firm B_1's product in market B. By Assumption 2-(ii), firm C uses

product personalization for all consumers in $[0, x^*]$. In doing so, firm C chooses personalized prices to leave all targeted consumers indifferent between choosing either firm. Thus $v_A + \omega - p_A(x) = v_A - (1 - x) - \alpha_2$, hence $p_A(x) = 1 - x + \omega + \alpha_2$ for all $x \in [0, x^*]$.

We make several observations. First, since $p_A(1) = \omega + \alpha_2 > 0$, firm C can profitably serve all targeted consumers in market A, unlike in Section 4 where firm C's maximum market share was capped at $\bar{\delta} \leq 7/8$. 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 in market A, 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. Third, firm B_2's competitive advantage γ increases firm C's cost of expanding its target segment in market A, implying that γ also links the two markets by benefiting firm A_2. Therefore, the merger links not only firms A_1 and B_1 but also the two competitors, firms A_2 and B_2, that are otherwise unrelated.

From the discussions above, we expect two types of equilibria. If ω is significantly large relative to γ, 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.

5.1.1 Equilibrium with accommodation

When the consumption synergy ω is not large enough, monopolizing market B can be costly to firm C as it would require aggressive competition against the rival that has competitive advantage (recall, $\gamma > 0$). In this case, firm C will accommodate its competitor in both markets. We derive such an equilibrium in this section. As we show below, the equilibrium with accommodation is possible only when $x^* \leq \hat{x}$ where we recall that $[0, x^*]$ is firm C's target segment in market A endogenously determined in market B, and $\hat{x} = (1 + \alpha_2 - \alpha_1)/2$ is the marginal consumer in market A when competition is in uniform price.

In market A, this case corresponds to the case with $\delta_A < 3/4$ in Section 4.1.1. The only differences are $c = 0$, $\phi_A = 1$, and the presence of ω. Thus substituting δ_A by x^*, we obtain

$$\alpha_1^* = 1 - \frac{4x^*}{3}, \ \alpha_2^* = 1 - \frac{2x^*}{3}, \ \hat{x} = \frac{1}{2} + \frac{x^*}{3}.$$

For this equilibrium to exist, we need $\alpha_1^* \geq 0$, hence $x^* \leq 3/4$. This also implies $\hat{x} = 1/2 + x^*/3 \in [x^*, 3/4]$. Given α_2^*, firm C's personalized prices are

$$p_A^*(x) = 2 + \omega - x - \frac{2x^*}{3}.$$

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In market B, firm C chooses β_1 to maximize total profit from both markets

$$\Pi_C = \beta_1 x^* + \int_0^{x^*} p_A^*(x)dx + \left(1 - \frac{4x^*}{3}\right)\left(\frac{1}{2} - \frac{2x^*}{3}\right) = -\frac{5}{18}(x^*)^2 + \left(\frac{2}{3} + \omega + \beta_1\right)x^* + \frac{1}{2},$$

where $x^* = (1 - \beta_1 + \beta_2 - \gamma)/2$. This leads to the best response function defined by $\beta_1 = (23x^* - 9\omega - 6)/9$. Firm B_2's profit is $\Pi_{B_2} = \beta_2(1 - x^*)$, hence its best response is given by $\beta_2 = (1 + \gamma + \beta_1)/2$. Solving them for the equilibrium uniform prices in market B, we obtain

$$\beta_1^* = \frac{45 - 23\gamma - 36\omega}{59}, \ \beta_2^* = \frac{52 + 18\gamma - 18\omega}{59}, \ x^* = \frac{33 + 9\omega - 9\gamma}{59}. \tag{13}$$

Since this equilibrium is possible when $x^* \leq 3/4$, we must have $\omega \leq 5/4 + \gamma$. Substituting x^* into the equilibrium prices in market A given above, we obtain

$$\alpha_1^* = \frac{15 + 12\gamma - 12\omega}{59}, \ \alpha_2^* = \frac{37 + 6\gamma - 6\omega}{59}, \ p_A^*(x) = \frac{96 + 6\gamma + 53\omega}{59} - x. \tag{14}$$

The equilibrium prices in both markets are depicted in Figure 2.

— **Insert Figure 2 here.** —

We now show that the merger is an equilibrium outcome by showing that firm C's total equilibrium profit is larger than the sum of the two firms' pre-merger equilibrium profits. Before the merger, firm A_1 earns profit equal to $1/2$ and firm B_1's profit is $(1 - \gamma/3)^2/2$. So the total pre-merger profit is less than 1. By substituting the best response function β_1 into Π_C, firm C's total equilibrium profit can be expressed in terms of x^* as

$$\Pi_C^* = \frac{1}{2} + \frac{41}{18}(x^*)^2.$$

Since $x^* > 1/2$ because $\omega \geq \gamma$ by Assumption 2-(i), we have $\Pi_C^* > 1$, implying that the merger is an equilibrium outcome. In addition, Π_C^* increases in ω but decreases in γ, as does x^*. Thus the merger is more likely when the consumption synergy is stronger, but less likely when there is a stronger competitor in the market where consumer data is harvested.

In contrast, the competitors' profits are

$$\Pi_{B_2}^* = \beta_2^*(1 - x^*) = 2\left(\frac{26 + 9\gamma - 9\omega}{59}\right)^2, \ \Pi_{A_2}^* = \alpha_2^*(1 - \hat{x}) = \frac{1}{2}\left(\frac{37 + 6\gamma - 6\omega}{59}\right)^2.$$

Both profits increase in γ but decrease in ω. Thus firm B_2's competitive advantage not only benefits itself but also creates positive externalities for firm A_2. Likewise, the consumption synergy in market A hurts both firms A_2 and B_2. But both firms are worse off after the merger. Consider firm B_2 first. Before the merger, firm B_2 serves more than half of the market, charging price $\beta_2^0 = 1 + (\gamma/3) > 1$. But after the merger, it charges price $\beta_2^* < 1$ to serve less than half of the market since $1 - x^* < 1/2$. Similarly, firm A_2's pre-merger profit is $1/2$, being from serving

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half of the market at price equal to 1. After the merger, it serves less than half of the market, charging price less than $1/2$.

To summarize, the equilibrium with accommodation is possible when $\omega \leq 5/4 + \gamma$. In this equilibrium, firms A_1 and B_1 choose to merge, following which firm C's market share increases to $[0, x^*]$ in market B where $33/59 < x^* \leq 3/4$. In market A, firm C's market share increases further to $[0, \hat{x}]$ where $x^* \leq \hat{x}$. Firm C serves all consumers in $[0, x^*]$ using personalized offers, serves additional consumers in $[x^*, \hat{x}]$ with uniform price, while firm A_2 serves the rest with uniform price.

There are several notable cross-market effects arising in this equilibrium, which we discuss here. First, $\beta_1^* < 0$, hence firm C engages in below-cost pricing in market B. But this allows firm C to increase the size of target segment in market A above $1/2$, its pre-merger market share. Second, there is cross subsidization in that firm C's loss in market B due to below-cost pricing is more than offset by the profit gain in market A. Thus below-cost pricing in the market for data collection is driven by the firm's incentives to engage in consumer exploitation through personalization in the market for data application. Clearly, such incentives become stronger as the consumption synergy becomes stronger, hence β_1^* decreases in ω. Third, firm B_2 suffers negative externalities from market A due to the consumption synergy. As ω increases, firm C becomes more aggressive in market B, which intensifies competition and harms firm B_2. Finally, firm A_2 benefits from positive externalities from firm B_2. Firm B_2's competitive advantage is a countervailing force that constrains firm C's expansion in market B, hence in market A by extension. As γ increases, x^* decreases and, as a result, both uniform prices increase in market A. We summarize below the discussions so far. The proof follows the same step used in the proof of Proposition 1, so is omitted.

Proposition 4 *Suppose $\omega \leq \gamma + 5/4$. Then there is a unique equilibrium in which firms A_1 and B_1 choose to merge and create firm C.*

- *Subsequent equilibrium prices are as given in (13) and (14).*

- *Firm C engages in below-cost pricing in market B to increase market share to $[0, x^*]$, and increases its market share in market A to $[0, \hat{x}]$ where x^* is given in (13) and $x^* \leq \hat{x} \leq 3/4$.*

- *Firm B_2's equilibrium price decreases in ω, hence the consumption synergy in market A creates negative externalities and hurts firm B_2.*

- *Firm A_2's equilibrium price increases in γ, hence firm B_2's competitive advantage creates positive externalities and benefits firm A_2.*

The equilibrium with accommodation can be sustained when the consumption synergy is not too large, which limits firm C's target segment in market A. As we have discussed previously, however, data externalities can allow firm C to expand its target segment and monopolize market A, although market B remains as a duopoly. On the other hand, firm C will monopolize both markets when the consumption synergy becomes sufficiently large, as we discuss below.

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5.1.2 Monopolization

When the consumption synergy ω is considerably large relative to γ, firm C can be tempted to monopolize both markets. A necessary condition for this is $x^* \geq \hat{x}$, as shown in Proposition 4. In this case, firm C's target segment in market A includes the marginal consumer $\hat{x}$. Then, as in Proposition 1, one may ask if an equilibrium may exist in which firm C serves all of its targeted consumers only and concedes the rest to firm A_2. We show below that such an equilibrium is not possible, which leaves $x^* = 1$ as the only possibility.

Suppose there is an equilibrium with $\hat{x} \leq x^* < 1$. Then following the argument in Section 4.1.2, firm A_2 chooses uniform price $\alpha_2 = 2x^* - 1$ and serves all consumers in $[x^*, 1]$. Suppose now firm C deviates to increase its target segment to $[0, x']$ with $x' > x^*$. This allows firm C to use personalization for additional consumers in $[x^*, x']$. The cost of expanding its market share can be intensified competition in uniform price, leading to a lower uniform price by firm A_2, which in turn compels firm C to cut its personalized prices. However, as shown above, firm A_2's uniform price is $\alpha_2 = 2x^* - 1$ when $\hat{x} \leq x^* < 1$, which increases in x^*. Thus firm C does not face any trade-off in expanding its target segment, implying that its deviation to x' is profitable. This implies that there cannot be an equilibrium with $\hat{x} \leq x^* < 1$. Then the only possibility is when $x^* = 1$, i.e., monopolization.[23]

Proposition 5 *Suppose $\omega > \gamma + 5/4$. Then there is a unique equilibrium in which firms A_1 and B_1 choose to merge and create firm C.*

- *Firm C monopolizes both markets with prices $p_A^{**}(x) = 2 + \omega - x$ for all $x \in [0, 1]$ in market A and $\beta_1^{**} = -1 - \gamma$ in market B.*

- *Firm C's equilibrium profit is $\Pi_C^{**} = (1 + 2\omega - 2\gamma)/2 > 1$.*

Proof. See Appendix.

Once again, firm C engages in below-cost pricing in market B to squeeze its competitor. The equilibrium in Proposition 5 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. For example, in market A, firm C is not able to extract full consumer surplus even though it can in principle exercise perfect price discrimination. Of course, 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.

The above situation is likely to prevail only in the short run, however. If competitors exit the market in the long run, then the monopolization equilibrium can turn into the monopoly

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[23]When $x^* = 1$, firm A_2 chooses 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 $\alpha_2(\varepsilon) = 2x^*(\varepsilon) - 1$.

equilibrium, which will be much more profitable for firm C, and hence to the detriment of consumers. 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 $\beta^m = v_B/2 > 1$.

5.2 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 equilibrium with accommodation. Consider market A. Before the merger, price is equal to 1 and firms share the market equally. After the merger, prices are given in (14) and the market is divided at $\hat{x} = 1/2 + x^*/3$. 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.[24] Given the uniform distribution, one can show that total consumer surplus in market A increases after the merger. On the other hand, all consumers in market B are unambiguously better off. Before the merger, prices are $\beta_1^0 = 1 - \gamma/3$, $\beta_2^0 = 1 + \gamma/3$, and the market is divided at $x^0 = (3 - \gamma)/6$. After the merger, prices and the marginal consumer are given in (13). Since $x^* > x^0$, $\beta_1^* < 0 < \beta_1^0$, and $\beta_2^* < \beta_2^0$, all consumers in $[0, x^0] \cup [x^*, 1]$ are better off since 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 $v_B - x - \beta_1^* - \left(v_B + \gamma - (1 - x) - \beta_2^0 \right) = 1 - 2x - \gamma - \beta_1^* + \beta_2^0 > 0$. 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 because $(v_A + \omega - p_A^{**}(x)) - (v_A - x - 1) = 2x - 1 \leq 0$. Thus all consumers who purchased from firm A_1 before the merger are worse off. Similarly, consumer $x \in [1/2, 1]$ is better off after the merger if $(v_A + \omega - p_A^{**}(x)) - (v_A - (1 - x) - 1) = 1 - 2x \geq 0$, implying that all consumers who purchased from firm A_2 before the merger are also worse off. It follows that total consumer surplus in market A decreases unambiguously after the merger. In market B, it is obvious that the merger benefits all consumers thanks to below-cost pricing, although one needs to exercise caution in interpreting this result. The

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[24]The threshold value is given by $v_A - x - 1 = v_A + \omega - p_A^*(x)$, hence $x = (37 + 6\gamma - 6\omega)/118$.

comparison of consumer surplus in market B is in relation to the monopolization equilibrium, rather than the monopoly equilibrium. If the merger leads to the latter in the long run, then the merger hurts all consumers in both markets. In the monopoly equilibrium, consumer surplus is zero for all consumers in market A and, in market B, it is lower than the pre-merger consumer surplus since $v_B > 2$ implies $\beta^m = v_B/2 > 1 - \gamma/3 = \beta_1^0$, i.e., the monopoly price is higher than the pre-merger price.

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. Consumers as a whole gain in the market for data collection because competition intensifies in that market. On the other hand, consumers in the market for data application are better off if the consumption synergy is not large enough so that the merged firm does not monopolize the market. Otherwise, they are worse off despite data-enabled personalization made possible by the merger. It is because monopolization allows the merged firm to extract from all consumers the additional surplus generated from the consumption synergy and the improved matching value created by personalization.

Proposition 6 *The merger with cross-markets effects has the following welfare implications.*

- *Firm C's total profit is larger than the sum of the two firms' pre-merger profits.*

- *Both firms A_2 and B_2 are worse off than before the merger.*

- *In market A, total consumer surplus is larger in the equilibrium with accommodation but smaller in the monopolization equilibrium than before the merger.*

- *In market B, total consumer surplus is larger in both equilibria.*

- *In the long run when firms A_2 and B_2 exit following monopolization, consumers are worse off in both markets than before the merger.*

Proof. See Appendix.

6 Policy Implications

Our analysis in Section 5 has established that the data-driven merger can be pro-competitive in the market for data collection. In the market for data application, total consumer surplus can also increase after the merger if the consumption synergy is not large enough. As we have stressed, however, these are short-term benefits that could be outweighed by long-term costs if the merger eventually leads to market tipping. 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 discuss several possible remedies that are often discussed in relation to tech mergers.[25] First, we analyze the effect of mandated data sharing between the merged firm and its competitor. Second, we have assumed so far that the merged firm can prevent its targeted consumers from having access to its standard product offered at a uniform price. We ask what happens if the firm cannot employ such a discriminatory practice. Third, we examine the effect of banning below-cost pricing. Finally, we briefly discuss the effect of blocking the merger altogether. Throughout this section, we continue to maintain Assumption 2 and use notation $p_C(x)$ to denote firm C's personalized price for consumer x to distinguish it from $p_A(x)$ used in the previous section. We also denote the marginal consumer in market B by $\tilde{x}$ to facilitate comparison with x^* in the previous section.

6.1 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. Needless to say, firm A_2 benefits from such one-way data sharing. We assume firm A_2's personalization technology is identical to firm C's. But only firm C can leverage the consumption synergy since firm A_2 continues to be a stand-alone competitor. 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 and benefits firm B_2. An immediate consequence is that consumers in market B 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 note first that, even with data sharing, firm C can serve all targeted consumers thanks to the consumption synergy. This is because, for any personalized price $p_{A_2}(x)$ chosen by firm A_2, firm C can choose personalized price $p_C(x) \geq 0$ such that $v_A + \omega - p_C(x) \geq v_A - p_{A_2}(x)$. Bertrand competition for consumer x will lead to $p_{A_2}(x) = 0$, hence firm C will choose $p_C(x) = \omega$ to serve consumer x. Clearly $p_C(x) = \omega$ is lower than all personalized prices without data sharing, the latter given by $p_A(x) = \omega + \alpha_2 + 1 - x$. Thus firm C can continue to serve all its targeted consumers despite data sharing, but at lower personalized prices than without data sharing.

Based on the above observation, we can identify 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 $\omega \leq \gamma + 3/2$, there is an equilibrium in 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, called the equilibrium

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

with accommodation I, has the same structure as the equilibrium with accommodation in the previous section, 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 $\omega \in [\gamma + 3/2, \gamma + 3]$, then there is an equilibrium where firm C serves only targeted consumers while firm A_2 serves the rest, to be called the equilibrium with accommodation II. Finally, if $\omega > \gamma + 3$, then firm C monopolizes both markets.

Table 1: Equilibria with or without data sharing

ω	$[1, \gamma + \frac{5}{4}]$	$[\gamma + \frac{5}{4}, \gamma + \frac{3}{2}]$	$[\gamma + \frac{3}{2}, \gamma + 3]$	$\gamma + 3 \leq \omega$
No data sharing	Accommodation	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, where the first row indicates the range 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.

A general observation we can make is that 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. Finally, data sharing can be pro-competitive by intensifying competition where data is used and by making monopolization harder to achieve. The following proposition summarizes key implications of data sharing.

Proposition 7 *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 smaller in all equilibria than without data sharing.*

- *Monopolization is less likely with data sharing in the sense that the monopolization equilibrium arises for $\omega \geq \gamma + 3$ whereas, without data sharing, the monopolization equilibrium arises for $\omega \geq \gamma + 5/4$.*

Proof. See Online Appendix.

6.2 Prohibition of search discrimination in market for data application

Suppose firm C is prohibited from engaging in search discrimination that prevents its targeted consumers from having access to its standard product offered at a uniform price.[26] This implies that firm C's targeted consumer x can choose firm C's standard product in addition to its personalized product and firm A_2's product. Thus the problem consumer x faces now is $\max\{v_A - (p_C(x) - \omega), v_A - (\alpha_1 + x), v_A - (\alpha_2 + 1 - x)\}$ where the terms inside the rounded brackets represent the 'effective price' consumer x pays for each choice.

The extra choice given to targeted consumers implies that personalization is less effective in extracting consumer surplus, if firm C serves non-targeted consumers. In this case, firm C's personalized prices are constrained by its own uniform price. That is, given α_1, its personalized price $p_C(x)$ needs to satisfy $p_C(x) - \omega \leq \alpha_1 + x$; otherwise, targeted consumers will choose the standard product. On the other hand, if firm C chooses not to serve any of its non-targeted consumers, then its choice of personalized prices is no longer constrained by its own uniform price, but by firm A_2's uniform price as before. This presents an opportunity for the two firms to achieve a collusive outcome.

To see how a collusive outcome is possible in market A, let $[0, \tilde{x}]$ be firm C's target segment. Consider the following outcome. Firm C chooses sufficiently high α_1 that is not accepted by any non-targeted consumers. For example, $\alpha_1 > v_A$ is sufficient for this. In response, firm A_2 chooses the maximum uniform price to serve all non-targeted consumers, i.e., $\alpha_2 = v_A - (1 - \tilde{x})$. Given α_2, firm C can extract full surplus from each one of its targeted consumers by choosing personalized price $p_C(x) = v_A + \omega$, which is accepted by consumer x as she would be worse off by choosing either α_1 or α_2. We call this a collusive outcome since it is supported by firm C's choice of a collusive uniform price, which allows firm A_2 to extract the maximum surplus from all non-targeted consumers and firm C to extract full surplus from its targeted consumers.[27]

The possibility of the collusive outcome makes firm C more aggressive in market B than when search discrimination is allowed. This hurts firm B_2 but benefits consumers in market B. In addition, firm C's personalized price in the collusive outcome increases in ω and v_A. This implies that firm C is likely to monopolize both markets when ω or v_A is large enough. In this case, firm C can exercise perfect price discrimination in market A, which is in contrast to the monopolization equilibrium when search discrimination is allowed.[28] Thus firm C's monopo-

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[26]This corresponds to the case in Chen et al. (2020) where consumers are active in identity management, except one key difference that we consider product personalization while Chen et al. (2020) consider only personalized pricing for the standard product. Product personalization generates an extra value $\omega + x$ for consumer x but the standard product does not. Thus in Chen et al. (2020), the firm cannot use a mix of personalized prices and uniform price (on the equilibrium path), but it is possible in our case.

[27]Note that firm C's off-the-equilibrium price here is restricted to $\alpha_1 > v_A$. This is different from our discussion in Section 5.1.2 where firm C's off-the-equilibrium price is $\alpha_1 = 0$.

[28]In the monopolization without search discrimination, the off-the-equilibrium prices that satisfy trembling-hand perfection are such that $\alpha_1 > v_A$ and $\alpha_2 = v_A - (1 - \tilde{x}(\varepsilon))$ where $\tilde{x}(\varepsilon) < 1$ follows firm C's tremble in market B.

lization of market B, hence market A, is also more likely than when search discrimination is allowed in the sense that monopolization obtains for a larger set of values for (ω, v_A).

To summarize, prohibiting search discrimination can be used as a collusive device, which benefits firm C, and firm A_2 as well insofar as it remains active in the market. But it reduces total consumer surplus in market A. In market B, total consumer surplus (weakly) increases thanks to intensified competition, which in turn hurts firm B_2. Finally, prohibiting search discrimination does not mitigate the dynamic trade-off; on the contrary, it worsens it by rendering monopolization more likely than when search discrimination is allowed.

Proposition 8 *Suppose firm C is not allowed to prevent its targeted consumers from having access to its standard product offered at a uniform price.*

- *When $v_A < 3$ and $\omega < 3 + \gamma - v_A$, the collusive equilibrium exists. In market A, firm C serves $[0, \tilde{x}]$ with $p_C(x) = v_A + \omega$, and firm A_2 serves the rest with $\alpha_2 = v_A - (1 - \tilde{x})$ where $\tilde{x} = (3 - \gamma + v_A + \omega)/6$. In market B, prices are $\beta_1 = (3 - \gamma - 2v_A - 2\omega)/3$ and $\beta_2 = (3 + \gamma - v_A - \omega)/3$.*

- *When $v_A < 3$ and $\omega \geq 3 + \gamma - v_A$, or when $v_A \geq 3$, the monopolization equilibrium exists. Firm C charges $p_C(x) = v_A + \omega$ in market A, and prices in market B are given by $\beta_1 = -1 - \gamma$ and $\beta_2 = 0$.*

- *Firm C is better off but firm B_2 is worse off, while firm A_2 is better off as long as it remains active in the market.*

- *Total consumer surplus is smaller in market A but larger in market B.*

- *Monopolization is more likely in the sense that monopolization is possible for a larger set of values for (ω, v_A) than when search discrimination is allowed.*

Proof. See Online Appendix.

Table 2 shows various types of equilibria with or without search discrimination for different ranges of (ω, v_A). In the table, the first row indicates the range of ω and we note $\omega \geq \gamma \geq 1$ by Assumption 2 and $\gamma + 5/4 > 3 + \gamma - v_A$ since $v_A > 2$.

Table 2: Equilibria with or without search discrimination

(ω, v_A)	$[1, 3 + \gamma - v_A]$ $v_A < 3$	$[3 + \gamma - v_A, \gamma + \frac{5}{4}]$ $v_A < 3$	$[3 + \gamma - v_A, \gamma + \frac{5}{4}]$ $v_A \geq 3$	$\gamma + 5/4 \leq \omega$ $v_A \geq 3$
Discrimination	Accommodation	Accommodation	Accommodation	Monopolization
No discrimination	Colluision	Monopolization	Monopolization	Monopolization

6.3 Restriction on below-cost pricing

We have seen in Section 5 that firm C will engage in below-cost pricing in market B with a view to harvesting a large set of consumer data that can be used in market A. What happens if the competition authority bans below-cost pricing? We discuss its implications below.

Given the restriction $\beta_1 \geq 0$, the equilibrium with accommodation remains the only possibility. In this equilibrium, firm C chooses $\beta_1 = 0$ since its total profit increases in its market share in market B, denoted by $\tilde{x}$. Then, from firm B_2's best response, $\beta_2 = (1 + \gamma + \beta_1)/2$, we obtain firm B_2's equilibrium price as $\beta_2 = (1 + \gamma)/2$. Given $\beta_1 = 0$ and $\beta_2 = (1 + \gamma)/2$, we can solve for firm C's equilibrium market share as $\tilde{x} = (3 - \gamma)/4$. Comparing $\tilde{x}$ with x^* in (13), we have $x^* > \tilde{x}$. Thus firm C's market share decreases when below-cost pricing is not allowed. Meanwhile, the equilibrium in market A is precisely the same as in the equilibrium with accommodation in Section 5, with the only difference that x^* is replaced by $\tilde{x}$, hence $\alpha_1 = 1 - (4\tilde{x}^2)/3$, $\alpha_2 = 1 - (2\tilde{x}^2)/3$, and $p_C(x) = \omega + \alpha_2 + 1 - x$. Consequently, all prices in market A increase when $\tilde{x}$ decreases due to the ban on below-cost pricing. Thus banning below-cost pricing reduces consumer surplus in both markets. On the other hand, the ban prevents firm C from monopolizing the market, which can benefit consumers in the long run. This suggests a trade-off between short-terms losses from the ban and the long-term gains from preventing monopolization.

Proposition 9 *Suppose firm C is not allowed to engage in below-cost pricing.*

- *Both firms A_2 and B_2 benefit at the cost of firm C.*

- *In both markets, all prices increase, hence all consumers are worse off as a result of the ban.*

- *The ban prevents monopolization so consumers can benefit in the long run compared to when below-cost pricing is allowed.*

6.4 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 digital industries, which may leave blocking the merger as the only alternative. We discuss briefly what happens if the competition authority blocks the merger altogether. The effects of blocking the merger on profits and consumer surplus depend on the counterfactual equilibrium that would prevail if the merger were allowed. Based on the analysis in Section 5 and Proposition 6, we can summarize the effects as follows.

Proposition 10 *Suppose the merger is blocked.*

- *The sum of profits for firms A_1 and B_1 is smaller than that if the merger were allowed.*

- *Both firms A_2 and B_2 earn larger profits than if the merger were allowed.*

- *In market A, total consumer surplus is smaller if $\omega \leq \gamma + 5/4$, and larger if $\omega > \gamma + 5/4$ than if the merger were allowed.*

- *In market B, total consumer surplus is smaller in the short run than if the merger were allowed, but larger in the long run if $\omega > \gamma + 5/4$ and firm B_2 exits the market following the merger.*

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 Google's proposed 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 benefits all consumers in the market for wearable devices. Third, in the digital health market, the merger increases total consumer surplus when stand-alone competitors continue to remain active, but decreases it when the market is tipped in Google's favor. Fourth, market tipping is more likely when the consumption synergy is sufficiently large, which can harm consumers in both markets in the long run. Fifth, the presence of a strong competitor such as Apple in the market for wearable devices generates positive externalities for stand-alone competitors in the digital health market, making market tipping less likely.

We have also examined the effects of blocking the merger as well as several remedies such as data sharing, prohibition of search discrimination, 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. While not modelled in this paper, allowing consecutive mergers can also mitigate the dynamic trade-off. For example, if the Google/Fitbit merger is approved, then allowing Apple's expansion into the digital health market can have pro-competitive effects.[29]

Our use of the stylized Hotelling model is mainly for simplicity of analysis. But we think the economic insight and qualitative results should continue to be valid in a generalized setting with discrete choices. But the comparison of consumer surplus depends on our assumption of uniform

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[29]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.

distribution, and may not generalize to different distributions. Thus empirical studies are needed for quantitative analysis of consumer welfare in the assessment of the merger. Likewise, empirical studies on the size of consumption synergy can help competition authorities in assessing when the merger is more or less likely to lead to the significant lessening of competition. Finally, we have assumed away issues such as adverse selection, moral hazard, and privacy 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. 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 the equilibrium 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, Lemma 1 shows that 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 $\delta_A < \bar{\delta}$. In this case, 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. Then it follows that the only possible deviation is in uniform price, but this 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 c, and its uniform price is zero, 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

(i) Comparison of firm A_2's profits

When $\delta_A \leq 3/4$, $\Pi_{A_2}^* = \frac{1}{2}\left(1 - \frac{2}{3}\delta_A\right)^2 < \frac{1}{2}$, 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 $\Pi_{A_2}^{**}\left(\frac{3}{4}\right) = \frac{1}{8}$. Finally, when $\delta_A > \bar{\delta}$, it is straightforward to check $\Pi_{A_2}^{***} = \frac{(1-\phi_A+c)^2}{4(2-\phi_A)} < \frac{1}{2}$. Thus firm A_2 is worse off after the merger.

(ii) Comparison of the merged firm's profits

Recall that firm A_1's pre-merger profit is $1/2$. First, when $\delta_A < 3/4$, firm C's profit is

$$\Pi_C^* = -\left(\frac{14 - 9\phi_A}{18}\right)\delta_A^2 + \left(\frac{2}{3} - c\right)\delta_A + \frac{1}{2} + \frac{c^2}{2\phi_A} > \frac{1}{2}.$$

When $3/4 \leq \delta_A < \bar{\delta}$, firm C's profit is

$$\Pi_C^{**} = \frac{(2 + \phi_A)}{2}\delta_A^2 - c\delta_A + \frac{c^2}{2\phi_A}.$$

It is easy to see that Π_C^{**} increases in δ_A for $\delta_A > 3/4$. Thus we have $\Pi_C^{**}(\delta_A) > \Pi_C^{**}(3/4) = 1/2 + (16c^2 - 24c\phi_A + 9\phi_A^2 + 2\phi_A)/(32\phi_A)$. To show $\Pi_C^{**}(3/4) > 1/2$, it suffices to show $\Phi(\phi_A) \equiv 16c^2 - 24c\phi_A + 9\phi_A^2 + 2\phi_A > 0$. Given Assumption 1-(i), $\phi_A > 2c$, we have $\Phi'(\phi_A) > 0$. Thus $\Phi(\phi_A) > \Phi(2c) = 4c + 4c^2 > 0$.

Finally, when $\delta_A \geq \bar{\delta}$, firm C's profit is

$$\Pi_C^{***} = \frac{(3 - c - \phi_A)^2}{8(2 - \phi_A)} + \frac{c^2}{2\phi_A}.$$

Differentiating Π_C^{***} with respect to ϕ_A, we have

$$\frac{\partial \Pi_C^{***}}{\partial \phi_A} = -\frac{(1 + c - \phi_A)(3 - c - \phi_A)}{8(2 - \phi_A)^2} - \frac{c^2}{2\phi_A^2} < 0.$$

Thus, Π_C^{***} decreases monotonically in ϕ_A. Moreover, when $\phi_A = 1$, we have

$$\Pi_C^{***} = \frac{(2 - c)^2}{8} + \frac{c^2}{2} = \frac{5}{8}c^2 - \frac{1}{2}c + \frac{1}{2} < \frac{1}{2}$$

since $c \leq \phi_A/2 \leq 1/2$ by Assumption 1-(ii). On the other hand, $\Pi_C^{***} = \frac{9}{16} > 1/2$ when $\phi_A = c = 0$. Thus, for a fixed value of c, $\Pi_C^{***} > 1/2$ when ϕ_A is small enough, but $\Pi_C^{***} < 1/2$ when ϕ_A becomes sufficiently large. Thus there is a threshold value of ϕ_A above which $\Pi_C^{***} < 1/2$.

(iii) Comparison of consumer surplus

Before the merger, the total consumer surplus is

$$S_0 \equiv \int_0^{1/2} (v_A - x - 1)\,dx + \int_{1/2}^1 (v_A - (1 - x) - 1)\,dx = v_A - \frac{5}{4}.$$

After the merger, targeted consumers receive the same surplus as when they purchase firm A_2's standard product, hence $v_A - (1 - x) - \alpha_2$.

First, when $\delta_A < 3/4$, we have $\alpha_2^* = 1 - \frac{2}{3}\delta_A$, hence the total consumer surplus after the merger is given by

$$S_1 \equiv \int_0^{\delta_A} (v_A - (1 - x) - \alpha_2^*)\,dx + \int_{\delta_A}^{\hat{x}} (v_A - x - \alpha_1^*)\,dx + \int_{\hat{x}}^1 (v_A - (1 - x) - \alpha_2^*)\,dx$$

$$= v_A - \frac{5}{4} + \frac{4}{9}\delta_A^2 > S_0.$$

Next, when $3/4 \leq \delta_A < \bar{\delta}$, we have $\alpha_2^{**} = 2\delta_A - 1$, and the post-merger consumer surplus after the merger becomes

$$S_1 = \int_0^{\delta_A} (v_A - (1 - x) - \alpha_2^{**})\,dx + \int_{\hat{x}}^1 (v_A - (1 - x) - \alpha_2^{**})\,dx$$

$$= v_A - \frac{5}{4} + \left(\frac{7}{4} - 2\delta_A \right) \geq S_0,$$

where the last inequality follows from Assumption 1-(iii) since $\phi_A \leq (2 + 4c)/3$ implies $\bar{\delta} \leq 7/8$.

Finally, when $\delta_A > \bar{\delta}$, we have $\alpha_2^{***} = (1 - \phi_A + c)/2$, and the total consumer surplus is

$$S_1 = \int_0^1 (v_A - (1 - x) - \alpha_2^{***})\,dx = v_A - \frac{1}{2} - \frac{1 - \phi_A + c}{2} > v_A - \frac{5}{4}.$$

Thus the merger increases total consumer surplus in all cases. ∎

Proof of Proposition 3

We will make use of the expressions derived in the proof of Proposition 2. Let us start with firm A_2's profit. 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.

Consider next firm C's profit. When $\delta_A < 3/4$, Π_C^* is concave in δ_A and reaches maximum when $\delta_A = \delta^* = (6 - 9c)/(14 - 9\phi_A)$ where $\delta^* \leq 3/4$ by Assumption 1-(iii). Differentiating Π_C^* with respect to ϕ_A, we have $\partial \Pi_C^* / \partial \phi_A = (\delta_A^2 - \tau^2)/2 \geq 0$ where the inequality is by Assumption 1-(i). 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 $\partial \Pi_C^{***}/\partial \phi_A \leq 0$.

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 $3/4 \leq \delta_A < \bar{\delta}$, $S_1 = v_A - 2\delta_A + 1/2$, which is decreasing in δ_A but independent of ϕ_A. When $\delta_A > \bar{\delta}$, $S_1 =$

$1/2 - (1 - \phi_A + c)/2$, which is increasing in ϕ_A but independent of δ_A. ∎

Proof of Proposition 5

Consider market A first. Given $\hat{x} \leq x^*$, firm C cannot serve any consumers in $[x^*, 1]$. Thus it chooses uniform price $\alpha_1 = 0$, implying $\hat{x} = (1 + \alpha_2)/2$. Firm A_2 chooses α_2 to maximize profit $\alpha_2(1 - \hat{x})$ subject to $\hat{x} \leq x^*$. This leads to $\alpha_2^{**} = 2x^* - 1$ with firm A_2 serving all in $[x^*, 1]$, hence $p_A(x)^{**} = 1 + \omega + \alpha_2^{**} - x = \omega + 2x^* - x$.

Consider now market B. Firm C's total profit is given by

$$\Pi_C = \beta_1 x^* + \int_0^{x^*} p_A^{**}(x)\, dx = (\beta_1 + \omega)\, x^* + \frac{3}{2}(x^*)^2.$$

Firm C maximizes Π_C subject to $x^* - 1 \leq 0$. Given β_2, this optimization program is equivalent to the program that firm C chooses x^* to maximize

$$\Pi_C = (1 - \gamma + \beta_2 - 2x^* + \omega)\, x^* + \frac{3}{2}(x^*)^2,$$

subject to $x^* \leq 1$, where we substituted $\beta_1 = 1 - \gamma + \beta_2 - 2x^*$.

Differentiating Π_C with respect to x^*, we obtain

$$\frac{\partial \Pi_C}{\partial x^*} = \omega - \gamma + \beta_2 + 1 - x^*.$$

Since $\omega \geq \gamma$ and $\beta_2 \geq 0$, the above derivative is positive. Thus, the constraint $x^* = 1$ must be binding. This leads to

$$\beta_1^{**} = -1 - \gamma, \quad \beta_2^{**} = 0, \quad x^* = 1.$$

Then we have $p_A^{**}(x) = 2 + \omega - x$, and the resulting profit is

$$\Pi_C^{**} = (-1 - \gamma) + \int_0^1 p_A^{**}(x)dx = \frac{1 + 2\omega - 2\gamma}{2}.$$

Given $\omega > 5/4 + \gamma$, we have $\Pi_C^{**} > 1$, hence the merger is profitable.

We now check possible deviations. Given $\beta_1^{**} = -1 - \gamma$, $\beta_2^{**} = 0$, and $x^* = 1$, there is no profitable deviation for firm B_2. Thus the only meaningful deviation is for firm C to increase its price. First, suppose firm C deviates to $\beta_1^d > \beta_1^{**}$, which leads to $\hat{x} \leq \tilde{x}^d < 1$. But, as we have already shown above, β_1^{**} is the best response to β_2^{**} when $\hat{x} \leq \tilde{x}^d$. So such a deviation cannot be profitable.

It remains to check if there is a profitable deviation β_1^d that leads to $\tilde{x}^d < \hat{x}$. Following the deviation, competition in market A leads to $\alpha_1 = 1 - (4\tilde{x}^d)/3$, $\alpha_2 = 1 - (2\tilde{x}^d)/3$, and $\hat{x} = 1/2 + \tilde{x}^d/3$. Then $\tilde{x}^d < \hat{x}$ is equivalent to $\tilde{x}^d < 3/4$. Given firm C's personalized prices

$p_A^d(x) = 2 + \omega - x - (2\tilde{x}^d)/3$, firm C chooses β_1^d to maximize its total profit

$$\Pi_C^d = \frac{1}{2} - \frac{5}{18}(\tilde{x}^d)^2 + \left(\frac{2}{3} + \omega + \beta_1^d\right)\tilde{x}^d,$$

subject to the constraint $\tilde{x}^d < 3/4$. Given $\beta_2^{**} = 0$, the optimal deviation price can be found as $\beta_1^d = (11 - 23\gamma - 18\omega)/41$ when $\omega < \gamma + 7/4$, which implies $\tilde{x}^d = (15 - 9\gamma + 9\omega)/41 < 3/4$. Substituting β_1^d back to the deviation profit, we obtain $\Pi_C^d = (3\omega - 3\gamma + 5)/82$. Then we have

$$\Pi_C^d - \Pi_C^{**} = \frac{9(\omega - \gamma)^2 - 52(\omega - \gamma) + 25}{82} < 0$$

for $\gamma + 5/4 < \omega < \gamma + 7/4$. Thus there is no profitable deviation. When $\omega \geq \gamma + 7/4$, the optimal deviation price is $\beta_1^d = -\gamma - 1/2$, which implies $\tilde{x}^d = 3/4$. Then the deviation profit is $\Pi_C^d = (24\omega - 24\gamma + 15)/32$, hence

$$\Pi_C^d - \Pi_C^{**} = -\frac{8\omega - 8\gamma + 1}{32} < 0.$$

Thus there is no profitable deviation either when $\omega \geq \gamma + 7/4$. ∎

Proof of Proposition 6

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.

First, consider the pre-merger equilibrium. In market A, the prices are $\alpha_1 = \alpha_2 = 1$ and the marginal consumer is at $1/2$. The resulting consumer surplus is

$$CS_A = \int_0^{1/2}(v_A - x - 1)dx + \int_{1/2}^1(v_A - (1-x) - 1)dx = v_A - \frac{5}{4}.$$

In market B, the prices are $\beta_1 = 1 - \gamma/3$ and $\beta_2 = 1 + \gamma/3$ and the marginal consumer is at $1/2 - \gamma/6$. The resulting consumer surplus is

$$CS_B = \int_0^{1/2 - \gamma/6}(v_B - x - \beta_1)dx + \int_{1/2-\gamma/6}^1(v_B + \gamma - (1-x) - \beta_2)\,dx$$

$$= v_B + \frac{\gamma}{2} + \frac{\gamma^2}{36} - \frac{5}{4}.$$

Second, consider the equilibrium with accommodation after the merger. In market A, given x^*, the prices are $p_A^*(x) = 2 + \omega - x - 2x^*/3$, $\alpha_1 = 1 - 4x^*/3$, and $\alpha_2 = 1 - 2x^*/3$, with the marginal consumer $\hat{x} = 1/2 + x^*/3$. In market B, the prices are $\beta_1 = (45 - 23\gamma - 36\omega)/59$ and

$\beta_2 = (52 + 18\gamma - 18\omega)/59$ and the marginal consumer $x^* = (33 + 9\omega - 9\gamma)/59$. Thus we have

$$
\begin{aligned}
CS_A^{MA} &= \int_0^{x^*} (v_A + \omega - p_A^*(x))dx + \int_{x^*}^{1/2+x^*/3} (v_A - x - \alpha_1)dx + \int_{1/2+x^*/3}^1 (v_A - (1-x) - \alpha_2)dx \\
&= v_A - \frac{5}{4} + \frac{4(x^*)^2}{9},
\end{aligned}
$$

$$
\begin{aligned}
CS_B^{MA} &= \int_0^{x^*} (v_B - x - \beta_1)dx + \int_{x^*}^1 (v_B + \gamma - (1-x) - \beta_2)dx \\
&= v_B - \frac{5}{4} - \frac{5\gamma^2}{36} + \frac{(21 + 54\omega + 5\gamma)(1083 + 54\omega + 241\gamma)}{125316} + \frac{\gamma(26 - 9\omega + 9\gamma)}{59}
\end{aligned}
$$

where the superscript 'MA' denotes 'merger accommodation'.

Third, consider the monopolization equilibrium after the merger. In market A, the prices are $p_A^*(x) = 2 + \omega - x$ for all $x \in [0, 1]$. In market B, the prices are $\beta_1 = -1 - \gamma$ and $\beta_2 = 0$. Thus we have

$$
CS_A^{MM} = \int_0^1 (v_A + \omega - p_A^*(x))dx = v_A - \frac{3}{2},
$$

$$
CS_B^{MM} = \int_0^1 (v_B - x - \beta_1)dx = v_B - \frac{5}{4} - \frac{5\gamma^2}{36} + \frac{(3 + \gamma)(21 + 5\gamma)}{36},
$$

where the superscript 'MM' denotes 'merger monopolization'.

From the above, it follows $CS_A^{MM} \leq CS_A \leq CS_A^{MA}$ and $CS_B \leq CS_B^{MA}$, CS_B^{MM}. ∎

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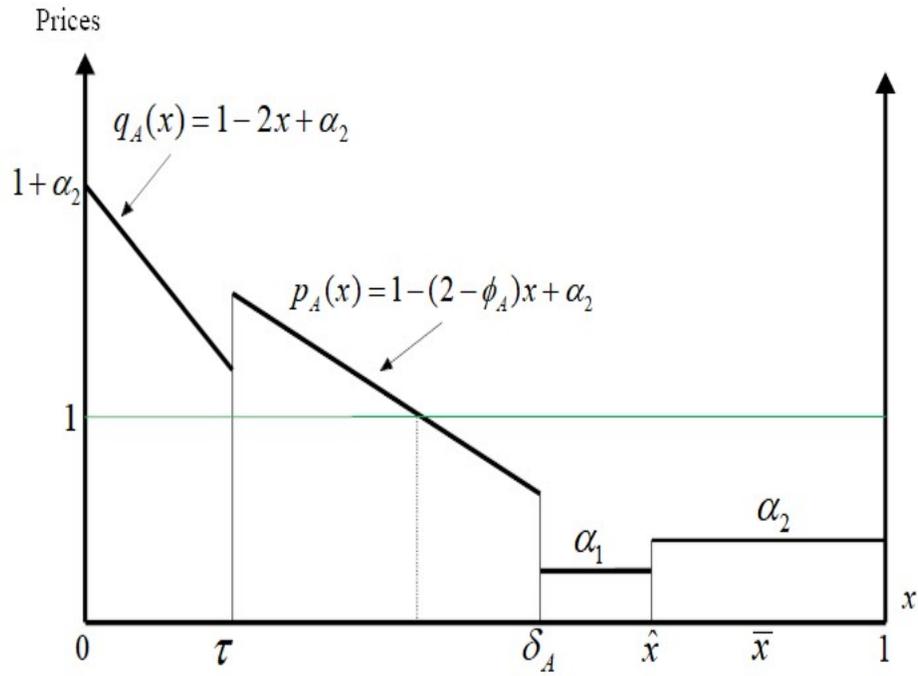Zhang, J. (2011). The perils of behavior-based personalization, *Marketing Science*, 30(1): 170-186.

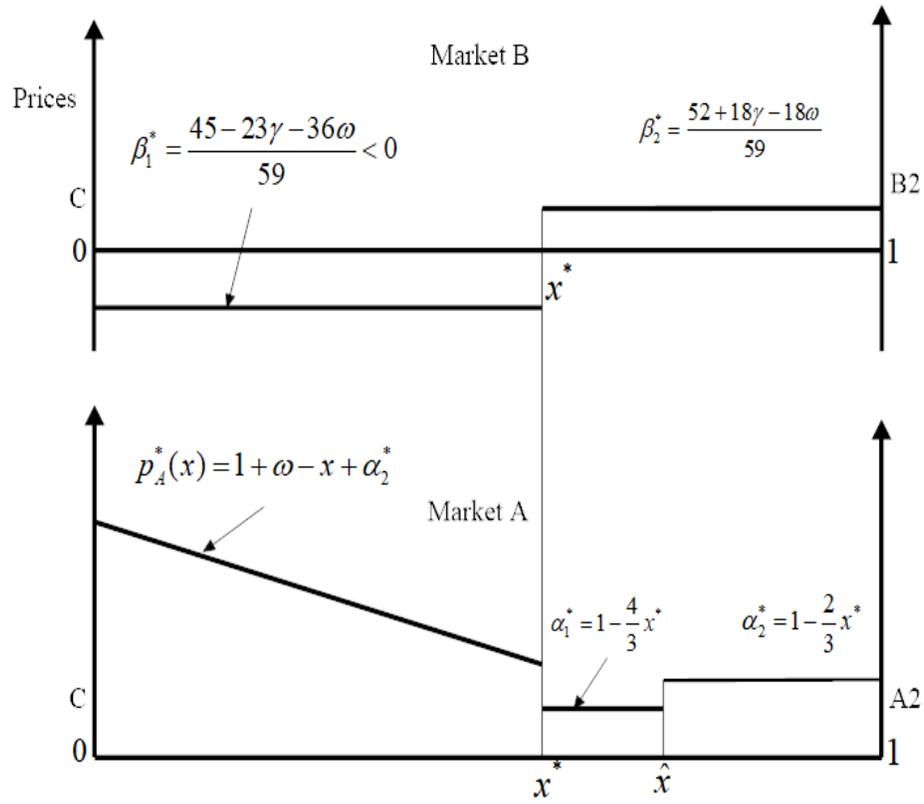**Figure 1: Equilibrium Prices under Personalization**

Market B

Prices

$\beta_1^* = \dfrac{45 - 23\gamma - 36\omega}{59} < 0$

$\beta_2^* = \dfrac{52 + 18\gamma - 18\omega}{59}$

C

B2

0

1

x^*

$p_A^*(x) = 1 + \omega - x + \alpha_2^*$

Market A

$\alpha_1^* = 1 - \dfrac{4}{3}x^*$

$\alpha_2^* = 1 - \dfrac{2}{3}x^*$

C

A2

0

1

x^* $\hat{x}$

Figure 2: Prices in the Equilibrium with Accommodation

Online Appendix for Data-Driven Mergers and Personalization

1. Proof of Proposition 7

Let $[0, \tilde{x}]$ denote firm C's target segment, and $\hat{x}$ 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 $p_C(x) = \omega < p_A(x) = 2 + \omega - x - (2x^*)/3$, 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.

(i) Equilibrium when $\tilde{x} < \hat{x} < 1$

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 $\alpha_1^\star = 1 - (4\tilde{x})/3$, $\alpha_2^\star = 1 - (2\tilde{x})/3$, and $\hat{x} = 1/2 + \tilde{x}/3$. As before, we need $\alpha_1^\star \geq 0$, hence $\tilde{x} \leq 3/4$.

Firm C's optimization problem in market B is to choose β_1 to maximize its total profit

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

Firm B_2 chooses β_2 to maximize its $\Pi_{B_2} = \beta_2(1 - \tilde{x})$. Solving the two firms' best response problems simultaneously, we obtain the equilibrium uniform prices and the marginal consumer in market B as

$$
\beta_1^\star = \frac{27 - 18\omega - \gamma}{19}, \ \ \beta_2^\star = \frac{23 - 9\omega + 9\gamma}{19}, \ \ \tilde{x} = \frac{15 + 9\omega - 9\gamma}{38}.
$$

Substituting $\tilde{x}$ into $\alpha_1^\star$, $\alpha_2^\star$, and $\hat{x}$, we obtain

$$
\alpha_1^\star = \frac{9 - 6\omega + 6\gamma}{19}, \ \ \alpha_2^\star = \frac{14 - 3\omega + 3\gamma}{19}, \ \ \hat{x} = \frac{72 + 9\omega - 9\gamma}{114}.
$$

The condition $\tilde{x} \leq 3/4$ is equivalent to $\omega \leq \gamma + 3/2$. This equilibrium, to be called the equilibrium with accommodation I, corresponds to the equilibrium with accommodation in the absence of data sharing. Recall that the equilibrium with accommodation is possible when $\omega \leq \gamma + 5/4$. Thus the set of ω that admits the equilibrium with accommodation I is larger. Put differently, the value of ω that induces the monopolization equilibrium in the absence of data sharing can lead to the equilibrium with accommodation I given data sharing. This implies that data sharing makes monopolization more difficult.

We compare the above with case without data sharing. The above equilibrium is possible when $\omega \leq \gamma + 3/2$. Since the same range of ω admits both types of equilibria without data sharing, we make comparison in two separate cases.

Comparing the above with the equilibrium with accommodation, it is easy to verify $\beta_1^\star > \beta_1^*$, $\beta_2^\star > \beta_2^*$, $\alpha_1^\star > \alpha_1^*$, $\alpha_2^\star > \alpha_2^*$, and $\tilde{x} < x^*$. Thus data sharing softens competition in uniform price in both markets, hurting all consumers in market B and all non-targeted consumers in market A. On the other hand, it benefits firm C's competitors in both markets due to the softened competition and smaller market share firm C can obtain. Finally, competition for targeted consumers intensifies given data sharing. Put together, we conclude that data sharing unambiguously hurts firm C.

(ii) Equilibrium when $\hat{x} \leq \tilde{x} \leq 1$

Consider market A first. 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 $\alpha_2 = 2\tilde{x} - 1$. Then in market B, firm C chooses β_1 to maximize

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

subject to $\tilde{x} - 1 \leq 0$, while firm B_2 chooses β_2 to maximize $\Pi_{B_2} = \beta_2(1 - \tilde{x})$. This leads to the following two cases depending on whether the constraint $\tilde{x} - 1 \leq 0$ is binding.

Case 1: $\gamma + \frac{3}{2} \leq \omega < \gamma + 3$

In this case, the equilibrium prices and the marginal consumer in market B are given by

$$\beta_1^{\star\star} = \frac{3 - 2\omega - \gamma}{3}, \quad \beta_2^{\star\star} = \frac{3 - \omega + \gamma}{3}, \quad \tilde{x} = \frac{\omega - \gamma + 3}{6}.$$

Since $\tilde{x} = (\omega - \gamma + 3)/6 < 1$, monopolization does not arise in this equilibrium, to be called the equilibrium with accommodation II. Then $\alpha_2^{\star\star} = 2\tilde{x} - 1 = (\omega - \gamma)/3 < 1$. For the same range of ω, no data sharing leads to the monopolization equilibrium. Thus it follows that all consumers in market B are worse off when data sharing is in place. In market A, consumer x pays $p_A(x) = 2 + \omega - x$ without data sharing. Then it is easy to see that all consumers pay less in market A after data sharing. Needless to say, data sharing benefits both stand-alone competitors at the cost of firm C.

Case 2: $\omega \geq \gamma + 3$

In this case, the equilibrium uniform prices in market B are

$$\beta_1^{\star\star\star} = -1 - \gamma, \quad \beta_2^{\star\star\star} = 0.$$

Thus this equilibrium also features monopolization as in the case without data sharing. The only difference is that consumers in market A now pay personalized prices $p_C(x) = \omega$, instead of $p_A(x) = 2 + \omega - x$. Thus consumers in market A are better off given data sharing.

In the main text, we have already established that data sharing hurts firm C, benefits both competitors, increases total consumer surplus in market A if $\omega \geq \gamma + 5/4$, decreases total

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consumer surplus in market B in all equilibria, and leads to the monopolization equilibrium for larger values of ω than without data sharing. Thus it only remains to show that total consumer surplus in market A with data sharing is larger than that without data sharing when $\omega \leq \gamma + 5/4$.

When there is no data sharing, total consumer surplus in market A in the equilibrium with accommodation was already calculated in the proof of Proposition 6 as

$$
\begin{aligned}
CS_A^{MA} &= \int_0^{x^*} (v_A + \omega - p_A^*(x))dx + \int_{x^*}^{1/2+x^*/3} (v_A - x - \alpha_1)dx + \int_{1/2+x^*/3}^1 (v_A - (1-x) - \alpha_2)dx \\
&= v_A - \frac{5}{4} + \frac{4(x^*)^2}{9},
\end{aligned}
$$

where $x^* = (33 + 9\omega - 9\gamma)/59$. With data sharing, total consumer surplus in market A in the equilibrium with accommodation I can be calculated as

$$
\begin{aligned}
CS_A^{MDI} &\equiv \int_0^{\tilde{x}} (v_A + \omega - p_C(x))dx + \int_{\tilde{x}}^{\hat{x}} (v_A - x - \alpha_1^\star)dx + \int_{\hat{x}}^1 (v_A - (1-x) - \alpha_2^\star)dx \\
&= v_A - \frac{13}{18}(\tilde{x})^2 + 2\tilde{x} - \frac{5}{4},
\end{aligned}
$$

where $\tilde{x} = (15 + 9\omega - 9\gamma)/38$. Comparing the two, we have

$$
CS_A^{MDI} - CS_A^{MA} = \frac{1}{2 \times 38^2}(5 + 3\omega - 3\gamma)(391 - 39\omega + 39\gamma) - \frac{4}{9}\left(\frac{33 + 9\omega - 9\gamma}{59}\right)^2.
$$

Using $\omega \leq \gamma + 5/4$, we can verify $CS_A^{MDI} > CS_A^{MA}$. Thus total consumer surplus is larger in all equilibria with data sharing. ∎

2. Proof of Proposition 8

1. Analysis of market A

We start with market A. With prohibition on search discrimination, firm C's personalized prices are constrained by its own uniform price if it serves any non-targeted consumer; otherwise, it is constrained by firm A_2's uniform price, as before. Denote the personalized price for targeted consumer x in the first case by $p_C(x)$, and that in the second case by $p_A(x)$. Then we have

$$
\begin{aligned}
p_A(x) &= \min\{\omega + \alpha_2 + 1 - x, v_A + \omega\}, \\
p_C(x) &= \min\{\omega + \alpha_1 + x, v_A + \omega\}.
\end{aligned}
$$

Let $[0, \tilde{x}]$ be firm C's target segment in market A and $\hat{x}$ be the marginal consumer when competition is in uniform price, hence $\hat{x} = (1 - \alpha_1 + \alpha_2)/2$. Note that firm C can serves all its targeted consumers thanks to Assumption 2-(ii). We divide analysis into two cases based on the relative locations of $\hat{x}$ and $\tilde{x}$.

(i) $\tilde{x} \geq \hat{x}$

In this case, firm C can serve all consumers in $[0, \tilde{x}]$ with personalized prices while firm A_2 serves the rest. Unlike the case with search discrimination, firm C's uniform price in $[\tilde{x}, 1]$ cannot be $\alpha_1 = 0$ since, then, all targeted consumers will also choose firm C's standard product. Thus, when firm C does not serve any non-targeted consumers, it sets α_1 sufficiently high ($\alpha_1 > v_A$, to be exact) so that it is not accepted by any consumers, both targeted and non-targeted. Then firm A_2's profit is $\Pi_{A_2} = \alpha_2(1 - \tilde{x})$. Firm A_2 chooses its uniform price to extract maximum surplus from the segment $[\tilde{x}, 1]$, leading to $\alpha_2^* = v_A - (1 - \tilde{x})$ and $\hat{x} = (v_A + \tilde{x} - \alpha_1)/2$. Given $\alpha_2^* = v_A - (1 - \tilde{x})$, firm C's personalized prices are given by $p_A(x) = v_A + \omega$. Thus firm C can extract full consumer surplus from each of its targeted consumers. Thus profits are $\pi_C^* = (v_A + \omega)\tilde{x}$ and $\Pi_{A_2}^* = (v_A - (1 - \tilde{x}))(1 - \tilde{x})$. Here we use lower-case π for firm C's profit in market A, to distinguish it from firm C total profit Π_C.

For the above to be an equilibrium outcome, we need to check conditions that guarantee no profitable deviations exist. Clearly, firm A_2 does not have incentives to deviate from the above. Then the only meaningful deviation is for firm C to cut its uniform price to α_1^d that leads to $\hat{x}^d > \tilde{x}$, charge $p_C(x)^d = \omega + \alpha_1^d + x$ for all consumers in $[0, \tilde{x}]$, and charge α_1^d for consumers in $[\tilde{x}, \hat{x}^d]$. Firm C's profit from this deviation is

$$\pi_C^d = \int_0^{\tilde{x}} p_C(x)^d dx + \alpha_1^d(\hat{x}^d - \tilde{x}) = \frac{1}{2}\tilde{x}^2 + \omega\tilde{x} + \alpha_1^d \left(\frac{v_A + \tilde{x} - \alpha_1^d}{2} \right).$$

One can show that the deviation profit is lower than the equilibrium profit, i.e., $\pi_C^d < \pi_C^*$, if and only if

$$\tilde{x} \geq \begin{cases} \frac{1}{5}v_A, & \text{if } v_A < \frac{10}{3}, \\ v_A - 1 - \sqrt{v_A^2 - 4v_A + 5}, & \text{if } v_A \geq \frac{10}{3}. \end{cases} \tag{8.1}$$

We omit the derivation of (8.1) since it is long and tedious, but it is available upon request.

In sum, given (8.1), there can be a *collusive outcome* in market A in which firm C extracts full surplus from each of its targeted consumers by charging $p_A(x) = v_A + \omega$, and firm A_2 serves $[\tilde{x}, 1]$ with uniform price $\alpha_2^* = v_A - (1 - \tilde{x})$ which leaves consumer $\tilde{x}$ zero surplus. This outcome is supported by firm C's choice of a high enough uniform price ($\alpha_1 > v_A$) that is not accepted on the equilibrium path.

(ii) $\tilde{x} < \hat{x}$

In this case, firm C can serve some non-targeted consumers in $[\tilde{x}, \hat{x}]$ through Hotelling competition, hence its personalized prices are constrained by its own uniform price. That is, firm C charges $p_C(x)$ for consumers in $[0, \tilde{x}]$ and α_1 for consumers in $[\tilde{x}, 1]$. This leads to firm C's profit

$$\pi_C = \int_0^{\tilde{x}} p_C(x) dx + \alpha_1(\hat{x} - \tilde{x}) = \frac{1}{2}\tilde{x}^2 + \omega\tilde{x} + \alpha_1 \left(\frac{1 - \alpha_1 + \alpha_2}{2} \right).$$

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Then firm C's best response is $\alpha_1 = (1 + \alpha_2)/2$. Firm A_2's profit is $\Pi_{A_2} = \alpha_2(1 - \hat{x}) = \alpha_2(1 + \alpha_1 - \alpha_2)/2$, hence its best response is $\alpha_2 = (1 + \alpha_1)/2$. This gives us equilibrium prices, $\alpha_1^{**} = \alpha_2^{**} = 1$, $p_C(x) = \omega + 1 + x$, hence $\hat{x}^{**} = 1/2$. Then profits are $\pi_C^{**} = \tilde{x}^2/2 + \omega\tilde{x} + 1/2$ and $\Pi_{A_2}^{**} = 1/2$. Since this equilibrium is possible when $\tilde{x} < \hat{x}$, we need $\tilde{x} < 1/2$.

Next, we derive conditions that ensure there are no profitable deviations. Once again, firm A_2 has no reason to deviate. Nor can firm C profitably decrease its uniform price. The only possible deviation is for firm C to increase its uniform price and serve only targeted consumers with personalized prices $p_A(x) = \omega + 2 - x > p_C(x) = \omega + 1 + x$ for all $x \le \tilde{x} < 1/2$. Firm C's profit from the deviation is

$$\pi_C^d = \int_0^{\tilde{x}} (2 + \omega - x)dx = (2 + \omega)\tilde{x} - \frac{1}{2}\tilde{x}^2.$$

Note that $\pi_C^d - \pi_C^{**} = -\tilde{x}^2 + 2\tilde{x} - 1/2$. Thus the deviation is not profitable if and only if

$$\tilde{x} < \frac{2 - \sqrt{2}}{2}. \tag{8.2}$$

In sum, given (8.2), there is a *partial Hotelling outcome* in market A in which firm C serves all of its targeted consumers charging $p_C(x) = \omega + 1 + x$, additional consumers in $[\tilde{x}, 1/2]$ charging uniform price $\alpha_1^{**} = 1$, and firm A_2 serves consumers in $[1/2, 1]$ with uniform price $\alpha_2^{**} = 1$.

Before moving onto the analysis of market B, we note that we have not fully solved the game in market A. We have only characterized possible equilibrium outcomes under conditions (8.1) and (8.2). We are agnostic about other possible outcomes when these conditions are not met.

2. Analysis of market B

In market B, $\tilde{x}$ is given by $\tilde{x} = (1 - \beta_1 + \beta_2 - \gamma)/2$. When market A has the collusive outcome, firm C's total profit is $\Pi_C = (\omega + v_A + \beta_1)\tilde{x}$. Substituting β_1 from $\tilde{x}$, we have $\Pi_C = (\omega + v_A + 1 - \gamma + \beta_2 - 2\tilde{x})\tilde{x}$. Then an interior optimal value of $\tilde{x}$ is $\tilde{x} = (\omega + v_A + 1 - \gamma + \beta_2)/4$. Since $\beta_2 \ge 0$ and $\omega \ge \gamma$, it follows that $\tilde{x} \ge 1$ if $v_A \ge 3$. That is, $v_A \ge 3$ is a sufficient condition for monopolization by firm C. Based on this and our analysis in market A, we now consider the following three cases.

(i) $v_A < 3$

Then from (8.1), firm C's profit when market A has a collusive outcome is

$$\Pi_C = \beta_1\tilde{x} + (v_A + \omega)\tilde{x} = (\beta_1 + v_A + \omega)\left(\frac{1 - \gamma + \beta_2 - \beta_1}{2}\right).$$

Firm C maximizes the above profit subject to $v_A/5 \le \tilde{x} \le 1$. Firm B_2's profit is $\Pi_{B_2} =$

$\beta_2(1 - \tilde{x}) = \beta_2(1 + \gamma - \beta_2 + \beta_1)/2$. When $\omega < 3 + \gamma - v_A$, the equilibrium prices in market B are

$$\beta_1^* = \frac{3 - \gamma - 2v_A - 2\omega}{3}, \ \beta_2^* = \frac{3 + \gamma - v_A - \omega}{3}. \tag{8.3}$$

This leads to the marginal consumer $\tilde{x}^* = (3 - \gamma + v_A + \omega)/6$, which satisfies $v_A/5 \leq \tilde{x} \leq 1$ given $\omega < 3 + \gamma - v_A$. We call this the *collusive equilibrium*, as it leads to the collusive outcome in market A.

When $\omega \geq 3 + \gamma - v_A$, the equilibrium prices in market B are

$$\beta_1^* = -1 - \gamma, \ \beta_2^* = 0. \tag{8.4}$$

Then the marginal consumer is $\tilde{x}^* = 1$. We call this the *monopolization equilibrium*, as it leads to the monopolization of market A. Note that this equilibrium is different from the monopolization equilibrium in Section 5, where firm C cannot extract full consumer surplus because off-the-equilibrium uniform prices in market A that satisfy trembling-hand perfection are $\alpha_1 = 0, \alpha_2 = 2\tilde{x} - 1$ for $\tilde{x} < 1$. In the current monopolization equilibrium, off-the-equilibrium uniform prices in market A are given by $\alpha_1 > v_A$ and $\alpha_2 = v_A - (1 - \tilde{x})$ for $\tilde{x} < 1$. This allows firm C to extract full consumer surplus in market A.

(ii) $v_A \geq 3$

As we have seen above, this case admits only the monopolization equilibrium.

(iii) Partial Hotelling outcome in market A when $\tilde{x} < \hat{x}$

We now show that there cannot be an equilibrium in which market A has a partial Hotelling outcome. In this case, firm C chooses β_1 to maximize its total profit

$$\begin{aligned}
\Pi_C &= \beta_1 \tilde{x} + \frac{1}{2}\tilde{x}^2 + \omega \tilde{x} + \frac{1}{2} \\
&= -\frac{3}{8}\beta_1^2 + \frac{1}{4}(1 - \gamma + \beta_2 - 2\omega)\beta_1 + \frac{1}{8}(1 - \gamma + \beta_2)^2 + \omega\left(\frac{1 - \gamma + \beta_2}{2}\right) + \frac{1}{2},
\end{aligned}$$

subject to $\tilde{x} < (2 - \sqrt{2})/2$. As before, firm B_2's profit is $\Pi_{B_2} = \beta_2(1 - \tilde{x})$, leading to the best response $\beta_2 = (1 + \gamma + \beta_1)/2$. Then the equilibrium prices in market B are

$$\beta_1^{**} = 2\sqrt{2} - 1 - \gamma, \ \beta_2^{**} = \sqrt{2}, \tag{8.5}$$

and the marginal consumer is $\tilde{x}^{**} = \frac{2 - \sqrt{2}}{2} < \hat{x}^{**} = \frac{1}{2}$. Firm C's profit in this case is

$$\begin{aligned}
\Pi_C &= (2\sqrt{2} - 1 - \gamma)\frac{2 - \sqrt{2}}{2} + \frac{1}{2}\left(\frac{2 - \sqrt{2}}{2}\right)^2 + \omega\left(\frac{2 - \sqrt{2}}{2}\right) + \frac{1}{2} \\
&= 2\sqrt{2} - \frac{7}{4} + \frac{2 - \sqrt{2}}{2}(\omega - \gamma).
\end{aligned}$$

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But given $\beta_2^{**} = \sqrt{2}$, firm C has incentives to deviate to a lower price that leads to the case where $\tilde{x}^d > \hat{x}^d$ so that the collusive outcome obtains in market A. This deviation gives firm C much higher profit in market A than the partial Hotelling outcome, which more than offsets the loss from the deviation in market B. That is, firm C has a profitable deviation, and hence the partial Hotelling outcome in market A cannot be sustained in equilibrium. The detailed analysis is quite long, hence omitted, but is available upon request.

Putting together the results we have obtained so far, we have

Lemma A. (i) When $v_A < 3$ and $\omega < 3 + \gamma - v_A$, there exists a collusive equilibrium in which equilibrium prices in market B are $\beta_1^* = (3 - \gamma - 2v_A - 2\omega)/3 < 0$ and $\beta_2^* = (3 + \gamma - v_A - \omega)/3 > 0$ with the marginal consumer given by $\tilde{x}^* = (3 - \gamma + v_A + \omega)/6 \in (v_A/5, 1)$. In market A, firm C extracts full surplus from each of its targeted consumers by charging $p_A(x) = v_A + \omega$, and firm A_2 serves $[\tilde{x}^*, 1]$ with uniform price $\alpha_2^* = v_A - (1 - \tilde{x})$ which leaves consumer $\tilde{x}$ zero surplus. This outcome is supported by firm C's choice of a high enough uniform price ($\alpha_1 > v_A$) that is not accepted on the equilibrium path. Firms' total profits are

$$\Pi_C^* = (\beta_1^* + v_A + \omega)\tilde{x}^* = \frac{(3 - \gamma + v_A + \omega)^2}{18},$$

$$\Pi_{B_2}^* = \beta_2^*(1 - \tilde{x}^*) = \frac{(3 + \gamma - v_A - \omega)^2}{18},$$

$$\Pi_{A_2}^* = \alpha_2^*(1 - \tilde{x}^*) = (v_A - (1 - \tilde{x}^*))(1 - \tilde{x}^*) = \frac{(7v_A - 3 - \gamma + \omega)(3 - \gamma + v_A + \omega)}{36}.$$

(ii) When $v_A \geq 3$, or $v_A < 3$ and $\omega \geq 3 + \gamma - v_A$, there exists the monopolization equilibrium arises in which prices in market B are given by $\beta_1^* = -1 - \gamma$ and $\beta_2^* = 0$. In market A, firm C charges $p_A(x) = v_A + \omega$ to extract full surplus from all consumers. Thus firm C's total profit is

$$\Pi_C^* = v_A + \omega - 1 - \gamma.$$

3. Welfare implications

Using Lemma A, Propositions 4 and 5, we can derive the following welfare implications of the prohibition on search discrimination. Note that, when search discrimination is allowed, there are two possible equilibria: the equilibrium with accommodation when $\omega \leq \gamma + 5/4$ and the monopolization equilibrium when $\omega > \gamma + 5/4$. Note also that firm C's market share in the collusive equilibrium is larger than that in the equilibrium with accommodation: $\tilde{x}^* = (3 - \gamma + v_A + \omega)/6 > 5/6 > x^* = (33 + 9\omega - 9\gamma)/59$.

First, firm C benefits from the prohibition on search discrimination. Clearly, its profit is larger in the collusive equilibrium than in the equilibrium with accommodation. Also its profit is larger in the monopolization equilibrium when search discrimination is prohibited. Note that monopolization is supported by a wider range of γ when search discrimination is prohibited: with search discrimination, monopolization arises when $\omega > \gamma + 5/4$; without search discrimination, monopolization arises for any value of ω when $v_A \geq 3$ and, when $v_A < 3$, it arises

for $\omega \in [3 + \gamma - v_A, 5/4 + \gamma]$. It follows that firm C is better off when search discrimination is not allowed.

Second, firm B_2 is worse off unambiguously. Comparing the equilibrium with accommodation and the collusive equilibrium, firm B_2's market share is smaller in the latter. Moreover, prices in (8.3) are lower than those in the equilibrium with accommodation. In addition, as argued previously, monopolization is supported by a wider range of γ when search discrimination is prohibited.

Third, firm A_2's profit is higher in the collusive equilibrium than in the equilibrium with accommodation thanks to the higher uniform price α_2^* despite the smaller market share, $\tilde{x}^*$. On the other hand, monopolization can kick in for lower values of ω when search discrimination is not allowed. Thus firm A_2 is better off only if it remains active in the market.

Fourth, total consumer surplus in market A is unambiguously smaller than when search discrimination is allowed. This follows since, when search discrimination is not allowed, targeted consumers have zero surplus in both equilibria while non-targeted consumers end up paying higher uniform prices in the collusive equilibrium than in the equilibrium with accommodation that would arise with search discrimination.

Finally, total consumer surplus in market B depends on different pairs of equilibria with or without search discrimination. We consider three cases. (i) If $v_A \geq 3$, then we have the monopolization equilibrium without search discrimination. When search discrimination is allowed, we have the equilibrium with accommodation if $\omega \leq \gamma + 5/4$. In this case, direct comparison shows that total consumer surplus is larger when search discrimination is prohibited. When search discrimination is allowed, we have the monopolization equilibrium if $\omega > \gamma + 5/4$, in which case the total consumer surplus is the same. (ii) If $2 < v_A < 3$, there are three cases to consider. When $\omega < 3 + \gamma - v_A$, we have the collusive equilibrium without search discrimination and the equilibrium with accommodation with search discrimination. Note that prices in (8.3) are lower than those in the equilibrium with accommodation. So even though some consumers shift from firm B_2 to firm C without search discrimination, the price effect dominates. As a result, total consumer surplus is larger when search discrimination is prohibited. The same is true when $3 + \gamma - v_A \leq \omega < \gamma + 5/4$. When $\omega > \gamma + 5/4$, the monopolization equilibrium arises in both cases, hence total consumer surplus is the same. ∎

3. 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.[30] Since its founding

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

in 2009, GV has invested in nearly 60 life sciences companies.[31] 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 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.[32]

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.[33] 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.[34]

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.[35] 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.[36] 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.[37] 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

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

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

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

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

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

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

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

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.[38]

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).[39] 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%).[40] 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.[41] 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.[42]

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.[43] 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.[44]

An ostensible reason for Google's bid for Fitbit is Google's intention to gain a toehold in the

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[38]https://www.wsj.com/articles/paging-dr-google-how-the-tech-giant-is-laying-claim-to-health-data-11578719700

[39]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.

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

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

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

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

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

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 was "about devices, not data", and that Fitbit data would not be used for Google ads.[45] 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.[46]

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".[47] 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.[48] 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.

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

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

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

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

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.[49] Brooks Tingle, president 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.[50]

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.[51] "We're hoping to be more personalized in the way we offer health solutions," said Vivian Lee, Verily's President of Health Platforms.[52] 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.

4. Big Data and Personalization in Health Care

The global digital health market is estimated to reach $505 billion by 2025, up from $86 billion in 2018.[53]. This is a new battlefield for big-data applications. 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.[54] 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

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

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

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

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

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

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

European Insurance and Occupational Pensions Authority (EIOPA), many insurance companies have developed their own big data analytics (BDA) strategies or have included many BDA 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.[55]

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.[56]

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.[57] 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.[58]

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

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

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

[57]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.

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

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 other wearable devices to begin tracking.[59] 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.[60] 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.[61]

Similar strategies are adopted by Oscar Health, an insurance technology startup. In August 2014, the company announced that it would begin offering members a free Misfit fitness wearable plus Amazon gift-card rewards 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 work 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%.[62]

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.[63] The use of big data is becoming more prevalent in personalized health care at all stages of prevention, diagnosis, and treatment.

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

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

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

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

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