Generic Competition Paradox and the Role of Information Asymmetry in Pharmaceutical Markets

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Contrary to traditional economic theory predicting lower prices with increased competition, we observe a paradoxical increase in some brand-name drug prices following the entry of generic alternatives (i.e., the *Generic Competition Paradox (GCP)*). This paradox has led to increased healthcare spending and attracted significant academic interest. However, much of the current research, focusing on consumer heterogeneity and pseudo-generic drugs and attributing the GCP primarily to these factors, overlooks the extensive market and consumer knowledge possessed by brand-name firms and the resulting *information asymmetry* between brand-name and generic firms. Thus, it fails to fully explain the GCP and to provide a comprehensive understanding of pharmaceutical markets. To bridge this gap, by considering the brand-name firm's private information about consumers, we develop a game-theoretic model to analyse interactions between a brand-name firm and a generic firm over two periods (signaling and full-information). We find that the brand-name firm can use *limit pricing* in the signaling period to deter generic entry by charging below its monopoly price, then increase its price and allow generic entry in the full-information period, leading to the GCP. Consequently, under information asymmetry, limit pricing may arise from the brand-name firm's *anticompetitive* practices, and offers an *alternative* explanation for the GCP. While limit pricing and the GCP often result in higher drug prices, reduced consumer choice, and increased healthcare spending, we find that they can sometimes *benefit* consumers and society. This finding challenges the widely accepted belief that information asymmetry and the GCP are always detrimental, highlighting their complex role in pharmaceutical markets.

Key words: Generic competition paradox; limit pricing; information asymmetry; brand-name drug; pharmaceutical industry

1. Introduction

Patents grant brand-name firms a period of exclusivity, during which they can charge higher prices to recoup their research and development costs. Once this exclusivity period ends, generic firms can enter the market and offer more affordable generic drugs, which are equivalent to brand-name drugs in terms of active ingredients, dosage, and intended use (Grabowski and Vernon 1996, Frank and Salkever 1997). According to the traditional economic theory, increased competition from generic drugs should drive down prices for brand-name drugs. However, in certain instances, the prices of brand-name drugs have been observed to increase after generic alternatives become available (Grabowski and Vernon 1992, Frank and Salkever 1997, Regan 2008). For example, the price of the brand-name drugs Cleocin and NSAID increased by approximately 16% after the entry of their generic counterparts (Ching 2004). This counterintuitive phenomenon is commonly referred to as the ‘Generic Competition Paradox’ (GCP) in the pharmaceutical industry (Scherer 1993).

The GCP has significant implications for healthcare systems and consumers. Brand-name drugs account for 88% of $456 billion total expenditure on prescription drugs in the US in 2018 (Mulcahy et al. 2021, Mulcahy 2021). Hence, unexpected increases in brand-name drug prices result in a substantial rise in overall healthcare spending. By increasing the brand-name drug prices, the GCP softens competition in the market and can also increase generic drug prices (i.e., the umbrella effect), leading to a further rise in spending on prescription drugs (Arcidiacono et al. 2013). For instance, between February 2000 and February 2002 in the US, the GCP led to a $400 million increase in total spending on just 14 brand-name drugs (Regan 2008). The increase in prescription drug expenditure can strain healthcare budgets, leading to financial challenges for individuals and the institutions responsible for providing healthcare services (The Physicians Foundation 2016, Maloney 2021, Bartz 2022). As a result, understanding the causes of the GCP and managing its effects become very crucial for policymakers and healthcare stakeholders aiming to balance innovation, affordability, and accessibility in pharmaceutical markets.

Due to its significance, the GCP has attracted considerable academic interest. Several scholars (e.g., Frank and Salkever 1992, Ferrara and Missios 2012, Kong 2009) determined consumer heterogeneity (e.g., in loyalty, insurance coverage, product substitutability, etc.) as the main driver behind the GCP. Additionally, some researchers (e.g., Ferrándiz 1999, Hollis 2005) identified the introduction of pseudo-generic (or authorized-generic) drugs, developed and marketed by brand-name firms themselves, as another factor. However, pseudo-generic drugs constitute only less than 10% of the generic drugs in the US (Fowler et al. 2023),[1] and the empirical evidence indicates that more than 50% of the increase in brand-name drug prices due to the GCP cannot be attributed to consumer heterogeneity (Regan 2008). Consequently, current research does not provide a comprehensive explanation for the GCP observed in pharmaceutical markets.

Further, brand-name firms often possess more extensive knowledge about the market and consumers compared to generic firms (Branstetter et al. 2016, Ellison and Ellison 2011). This is because brand-name firms have a longer presence in the market due to the patent protection and have the financial resources to conduct comprehensive market studies (Ellison and Ellison 2011, Feldman 2020), whereas generic firms enter the market much later and operate on narrower profit margins, limiting their market research capabilities (Sood et al. 2020, Feldman 2020). This disparity in resources and market knowledge between brand-name and generic firms highlights the *information asymmetry*

[1] Also, see the Food and Drug Administration’s (FDA’s) Office of Generic Drugs Annual Reports at `https://www.fda.gov/drugs/generic-drugs/annual-reports`

prevalent in the pharmaceutical industry. Surprisingly, despite its prevalence, there is no research that considers this information asymmetry between brand-name and generic firms and examines its impact on the GCP, consumers and society.

These observations highlight the limitations of existing research and indicate that, to provide a more comprehensive understanding of pharmaceutical markets, it is essential to consider information asymmetry between brand-name and generic firms. It is still not clear how the information asymmetry affects the competition between brand-name and generic firms and whether it benefits or harms consumers and society. Further, it is unclear to what extent brand-name firms become anticompetitive and exploit information asymmetry to discourage generic entry, and whether this anticompetitive behavior plays any role in the GCP observed in practice. This paper examines these open research questions.

In this paper, we develop a game-theoretic model with asymmetric information to examine the interactions between a brand-name firm (i.e., an incumbent, it/its) and a generic firm (i.e., a potential entrant, he/his) in a market over two periods (signaling and full-information). The generic firm has successfully developed his generic drug and considers entering the market to sell it (Morton 1999). Consumers have either 'high' or 'low' sensitivity/elasticity to the price of the brand-name drug relative to that of the generic drug (relative price sensitivity, hereafter). The generic firm is new in the market and does not know the consumers' relative price sensitivity, while the brand-name firm is well-informed about the market and possesses private information regarding consumers' relative price sensitivity. Depending on the consumers' relative price sensitivity, the brand-name firm is either high or low type, and the extent of disparity between the two types of the brand-name firm determines the level of information asymmetry. At the beginning of the signaling (first) period, the brand-name firm sets the price for its drug, and upon observing the brand-name firm's price, the generic firm updates his belief about the brand-name firm's type and decides whether to enter the market in the signaling period. If the generic firm decides to enter, he invests in building his capacity, incurring a fixed cost, and he immediately learns about the brand-name firm's type and competes with it by choosing his price. However, if the generic firm decides not to enter, he stays out of the market until the full-information period and the brand-name firm becomes a monopoly during the signaling period. At the beginning of the full-information (second) period, all information is revealed to the public (e.g., through government and/or industry insider reports, state Medicaid actions, and case documents, see Feldman 2020), allowing the generic firm to learn about the brand-name firm's type. Then, the game between brand-name and generic firms in the full-information period proceeds under complete information.

By characterizing the equilibrium of the signaling game between brand-name and generic firms, we find that there are cases where, during the signaling period, the low-type brand-name firm charges a price lower than its monopoly price to mimic the high-type brand-name firm and deter generic entry (i.e., engages in 'limit pricing'). Once all information is revealed in the full-information period, the low-type brand-name firm increases its price and allows generic entry, resulting in the GCP. Consequently, in the presence of information asymmetry, the brand-name firm can engage in *anti-competitive practices* and use *limit pricing* to delay the generic entry, validating the conjecture in Ellison and Ellison (2011). In certain cases, this strategic use of limit pricing, stemming from the brand-name firm's anticompetitive behavior, leads to an increase in the brand-name drug's price, and offers an alternative explanation for the GCP observed in practice. These findings shed light on why there is delay in generic entry and 10% of brand-name drugs face no generic competition, even after their patents expire (Ellison and Ellison 2011, Kanavos 2014, Department of Health and Human Services 2017).

Interestingly, when we analyse welfare implications of the information asymmetry, we find that the low-type brand-name firm's *anticompetitive behavior* and *limit pricing strategy* can actually *benefit* consumers and the society in certain cases. The strategic use of limit pricing by the brand-name firm creates market conditions that delay generic competition under information asymmetry, ultimately leading to prolonged high drug prices, reduced consumer choice, and increased total spending on prescription drugs. Indeed, due to all these negative effects, we demonstrate that, in certain cases, the information asymmetry and resulting limit pricing strategy of the low-type brand-name firm lead to lower consumer surplus and reduced social welfare. However, when the degree of information asymmetry is moderate, meaning that high- and low-type brand-name firms are similar but not too similar, the low-type brand-name firm's limit pricing strategy allows more consumers to afford the brand-name drug they highly value and leads to higher consumer surplus and social welfare. This result holds true, even in certain cases when the GCP occurs. Contrary to expectations among field experts and policymakers (Lexchin 2004, Feldman 2020), this suggests that information asymmetry and the GCP, when it occurs, are not necessarily detrimental to consumers and society.

Finally, we extend our model by considering cases with a continuum of types for the brand-name firm, dual sources of information asymmetry, multiple generic firms and sequential generic entry. In each of these extensions, we confirm the robustness of our main results and, respectively, obtain the following new findings:

- When the brand-name firm has a continuum of types, rather than revealing their types to deter generic entry, some intermediate types charge prices below their monopoly levels and mimic another type to prevent generic entry during the signaling period. They raise their prices to monopoly levels in the full-information period. This implies that brand-name firms don't always use limit pricing due to anticompetitive motives, and their prices can increase, even without generic entry or the presence of GCP.

- Having more sources of information asymmetry creates additional types for the brand-name firm to mimic, making it easier to deter generic entry. Consequently, the brand-name firm increasingly resorts to limit pricing and the GCP occurs in more cases.
- As the number of generic firms considering market entry increases, the low-type brand-name firm increasingly uses limit pricing to deter generic entry, while there are fewer cases where the GCP occurs and/or consumers benefit from information asymmetry.
- In the presence of sequential generic entry, the low-type brand-name firm and a generic firm engage in tacit collusion to collectively deter further generic entry. This collusion gives rise to the GCP, which becomes increasingly more difficult to observe with each additional generic entry.

All aforementioned results offer useful insights on pharmaceutical markets and have important policy implications. We discuss these in detail in Section 7.

The remainder of this paper is organized as follows. We review the related literature in the next section. We set up our model in Section 3 and present the results based on our equilibrium analysis in Section 4. Next, in Section 5, we study the welfare implications of the information asymmetry. In Section 6, we extend our analysis to check the robustness of our main results. Finally, Section 7 concludes the paper. Proofs of the results in Section 4 and Section 5 are presented in Online Appendix B, while proofs of the results in Section 6 are available in Online Appendix G.

2. Related Literature

Our paper contributes to literature streams on the *Generic Competition Paradox (GCP)* and *limit pricing*. Next, we review relevant research in these literature streams and describe our contributions.

Research on the GCP: Substantial empirical research provides evidence for the GCP, wherein brand-name drug prices increase in response to the generic entry (e.g., see Grabowski and Vernon 1992, Frank and Salkever 1997, Regan 2008, Ching 2004). Theoretical research mainly attributes this paradox to consumers' heterogeneity (Frank and Salkever 1992, Perloff et al. 1995, Kong 2009, Ferrara and Missios 2012). By considering heterogeneous consumer loyalties to the brand-name drug, Frank and Salkever (1992) show that, once a generic drug becomes available in the market, price-insensitive, highly loyal consumers continue to purchase the brand-name drug, while price-sensitive, less loyal consumers switch to the cheaper generic drug. The demand by highly loyal price-insensitive consumers allows the brand-name firm to raise its price after generic entry, leading to the GCP. Perloff et al. (1995) use the spatial-differentiation model to study the competition between brand-name and generic drugs, and they find that, pre-generic entry, the brand-name firm charges a low price to cater to consumers with characteristics far away from its product; however, after the generic entry, it increases its price when these consumers prefer the new generic drug. Kong (2009) considers heterogeneity in consumers' insurance coverage and, through numerical examples, shows that, post-generic entry, consumers with high insurance coverage prefer the brand-name drug, while those with limited coverage opt for the more affordable generic alternative. The brand-name firm responds to this shift in its consumer base by increasing the price. Ferrara and Missios (2012) build upon Kong (2009) by exploring cases involving multiple generic firms and consumers with a continuous spectrum of insurance coverage.

There is also theoretical research that identifies the introduction of pseudo- or authorized-generic drugs as another driver behind the GCP (Ferrándiz 1999, Kamien and Zang 1999, Hollis 2005, Kong 2009). For example, using a model and numerical examples, Ferrándiz (1999) and Kong (2009) show that introducing their own pseudo-generic drugs makes it less costly for the brand-name firms to price discriminate highly loyal or less price-sensitive consumers. Consequently, when coupled with consumer heterogeneity, the entry of pseudo-generic drugs increases prices for the brand-name drugs and leads to the GCP.

The main distinction between our paper and the literature stream on the GCP is our focus on the role of information asymmetry in pharmaceutical markets. We contribute to this literature stream by identifying the brand-name firm's (anticompetitive) limit pricing strategy under information asymmetry as another rationale behind the GCP. Furthermore, in contrast to aforementioned papers, our paper examines welfare implications of information asymmetry and the GCP and demonstrates that they do not necessarily harm consumers or society.

Research on limit pricing: In his seminal paper, Bain (1949) introduces the concept of limit pricing (i.e., pricing below the monopoly price) and suggests that incumbent firms in monopolistic or oligopolistic markets may strategically set prices just low enough to deter potential entrants. Building on Bain (1949), Milgrom and Roberts (1982) explore the role of information asymmetry, specifically the limited information available to potential entrants about an incumbent firm's production cost, and demonstrate how such information asymmetry can lead to the implementation of limit pricing strategies. Bagwell and Ramey (1988) extend the model in Milgrom and Roberts (1982) and find that the limit pricing can occur in equilibrium even when the incumbent firm signals its production cost through the price and also the advertising spending. Bagwell (2007) expands on Bagwell and Ramey (1988) by considering the incumbent firm's private information regarding its production cost and level of patience, and potential entrant's private information regarding his fixed entry cost. He shows that the incumbent firm uses limit pricing to deter entry only when it is privately informed about both its production cost and level of patience.

The primary distinction between our paper and the literature stream on limit pricing lies in our examination of the incumbent brand-name firm's asymmetric information about the market, particularly regarding consumers' relative price sensitivity, and our focus on its pivotal role in leading to the GCP. This approach enables us to better capture the dynamics between brand-name and generic firms and to provide a more nuanced understanding of the pharmaceutical markets. Moreover, in contrast to this literature stream, we examine welfare implications of information asymmetry and the GCP.

Our contributions to the literature stream on limit pricing include three key findings. First, possessing private information regarding consumers' relative price sensitivity, the incumbent brand-name firm can have an anticompetitive stance and use limit pricing strategy to delay the generic entry. Second, this anticompetitive use of limit pricing strategy can lead to an increase in brand-name firm's price after generic entry, and provides an alternative explanation for the GCP observed in practice. Lastly, consumers and society can actually benefit from the information asymmetry and GCP, which are prevalent in the pharmaceutical industry.

3. Model and Preliminaries

We consider a brand-name firm (i.e., an incumbent, it/its) and a generic firm (i.e., a potential entrant, he/his) that interact over two periods (signaling and full-information). The signaling (first) period starts at time 0 and ends at time $T < \infty$ while the full-information (second) period starts at time T and goes to ∞. We assume continuous-time discounting and let $\rho \in (0,1)$ denote the discount rate. (Our results hold true, even when we assume discrete-time discounting.) We use subscript $j = B$ for the brand-name firm or drug and subscript $j = G$ for the generic firm or drug throughout the paper.

Before the signaling period, due to the right for data exclusivity under its patent, the brand-name firm sells its drug in a market as a monopoly and the generic firm cannot enter (Branstetter et al. 2016, FDA 2020). At the beginning of the signaling period, the brand-name firm's right for data exclusivity expires and the generic firm considers entering the market. To enter the market and compete with the brand-name firm, the generic firm must build his capacity at cost $K > 0$ (Morton 1999, Gallant et al. 2018, Gupta et al. 2021). We let $k = \rho K$ denote the discounted fixed capacity cost per unit time. Also, since production costs of generic drugs are much lower (Goldman et al. 2011, Liu et al. 2009), we normalize the generic firm's unit production cost to zero without loss of generality, and let $c > 0$ be the brand-name firm's unit production cost. Next, we present the notations of our base model in Table 1 and discuss its various aspects.

3.1. Market and Information Asymmetry

We normalize consumers' price sensitivity (elasticity) to the generic drug to 1 and define $b > 0$ as consumers' price sensitivity to brand-name drug relative to the generic drug (consumers' relative price sensitivity, hereafter). In line with empirical research indicating that consumers are less price-sensitive to brand-name drugs compared to generic drugs (Ching 2010a,b, Herr and Suppliet 2017), we let $b < 1$. The consumers' relative price sensitivity can be either high, b^H, or low, b^L, where $1 > b^H > b^L > 0$. The relative price sensitivity b is b^H with probability λ_b and b^L with probability $1 - \lambda_b$. The probability λ_b is common knowledge.

Table 1 Notations in the Base Model (Sections 3, 4 and 5)

		Indices
i	:	Brand-name firm's type (i.e., $i = H$ for high-type and $i = L$ for low-type brand-name firm)
j	:	Firm/drug type (i.e., $j = B$ for brand-name firm/drug and $j = G$ for generic firm/drug)
		Endogenous variables
p_j	:	Price of drug j
q_j	:	Consumers' demand (per unit time) for drug j
		Definitions
c	:	The unit production cost of the brand-name drug
K	:	The generic firm's fixed capacity cost
ρ	:	The instantaneous interest rate
k	:	The discounted fixed capacity cost per unit time, i.e., $k \equiv \rho K$
λ_b	:	The probability that the brand-name firm is $H-$type
γ	:	The substitution factor of the brand-name and generic drugs
α_j	:	Consumers' valuation for drug j
b^i	:	Consumers' relative price sensitivity to the drug of $i-$type brand-name firm
p_B^{Mi}	:	The optimal monopoly price of $i-$type brand-name firm
p_j^{Di}	:	The optimal duopoly price for drug j when the brand-name firm is $i-$type
q_B^{Mi}	:	The monopoly demand (per unit time) for the drug of $i-$type brand-name firm
q_j^{Di}	:	The duopoly demand (per unit time) for drug j when the brand-name firm is $i-$type
$\mathcal{U}^i(\cdot)$	:	Consumers' (net) utility function when the brand-name firm is $i-$type
$\Pi_j^i(\cdot)$	:	Profit function of firm j when the brand-name firm is $i-$type
Π_B^{Mi}	:	The optimal monopoly profit (per unit time) of the $i-$type brand-name firm
Π_j^{Di}	:	The optimal duopoly profit (per unit time) of firm j when the brand-name firm is $i-$type

Before the signaling period, due to its patent protection, the brand-name firm has long enjoyed a monopoly in the market, which allowed it to learn more about the market and consumers (Ellison and Ellison 2011, Feldman 2020). Therefore, at the beginning of the signaling period, the brand-name firm has private information and knows consumers' relative price sensitivity b while the generic firm does not know it. (When the information asymmetry is on the brand-name firm's production cost c instead of consumers' relative price sensitivity b, we obtain similar results, see Online Appendix C.) Depending on consumers' relative price sensitivity, the brand-name firm's price and profit differ. Hence, throughout the paper, we shall refer to the brand-name firm as high-type ($H-$type) and low-type ($L-$type) when consumers' relative price sensitivity is b^H and b^L, respectively. We shall use superscript $i = H$ for $H-$type brand-name firm and $i = L$ for the $L-$type brand-name firm.

The larger the gap between b^H and b^L (i.e., $(b^H - b^L)$), the greater the difference between the two types of brand-name firms, and the more severe the information asymmetry between brand-name and generic firms becomes. Hence, the gap $(b^H - b^L)$ measures the *degree* or *level of information asymmetry* between the brand-name and generic firms.

At the beginning of the full-information period, all information about consumers and the market is revealed to public (e.g., through government agency and industry insider reports, state Medicaid actions and case documents, see Feldman 2020), and consumers' relative price sensitivity becomes common knowledge.

3.2. Consumer Utility and Demand

We consider a representative consumer and use $\mathcal{U}^i(\cdot)$ to denote his/her (net) utility per unit time (e.g., a day) when the brand-name firm's type is $i \in \{H, L\}$. Similar to Dixit (1979), Singh and Vives (1984), Regan (2008), and Ferrara and Missios (2012), we let $\mathcal{U}^i(\cdot)$ have a quasi-linear quadratic form, i.e.,

$$\mathcal{U}^i(q_B, q_G) = \alpha_G q_G - \frac{1}{2} q_G^2 + \frac{\alpha_B}{b^i} q_B - \frac{1}{2b^i} q_B^2 - \gamma q_B q_G - \sum_{j \in \{B,G\}} p_j q_j, \tag{1}$$

for $i \in \{H, L\}$, where q_j and p_j are, respectively, the demand[2] and price of drug $j \in \{B, G\}$; α_j is the consumer's valuation[3] (or maximum willingness to pay) for drug $j \in \{B, G\}$ (Kong 2009, Häckner 2000); and $\gamma \in (0, 1)$ is the degree of product differentiation between drugs (i.e., they are perfect substitutes if $\gamma = 1$ and are independent if $\gamma = 0$, see Ferrara and Missios (2012)). It is empirically shown that people value a brand-name drug more than its generic counterparts;[4] therefore, we let $\alpha_B > \alpha_G$ (Payette and Grant-Kels 2012, Bronnenberg et al. 2015, Hermosilla and Ching 2024). In addition, akin to the literature (Vives 1984, Choné and Linnemer 2020), $0 < \gamma < 1$ ensures that brand-name and generic drugs are substitutes, and each drug's own price affects its demand more compared to the price of the other drug.

[2] Since the mid-1970s, the new substitution laws allow pharmacists to substitute the FDA-approved generic drug for the brand-name drug within the same therapeutic class (Grabowski and Vernon 1992). Therefore, consumers have the flexibility to choose between brand-name and generic prescription drugs.

[3] The consumer valuation α_j can also be interpreted as the marginal utility or the base market demand for drug $j \in \{B, G\}$ (Häckner 2000). More generally, α_j is a measure for the advantage in demand enjoyed by one of the firms (Dixit 1979). In that regard, α_j in our model is similar to the quality in a vertical product differentiation model (e.g., see Häckner 2000).

[4] Between 30% to 60% people believe that the quality and therapeutic efficacy of the brand-name drug outperform that of the generic drug (Payette and Grant-Kels 2012). This valuation pattern is largely attributed to "nonactive ingredients, reliability, safety, packaging, or psychic utility" (Bronnenberg et al. 2015). In clinical practice, it is highly likely that a change of tablet appearance (Faasse et al. 2013, Kesselheim et al. 2013, 2014) or different inactive ingredients can cause more side effects, and a slight variation of the chemical formula may lead to patients' different reaction (Choudhry 2021). Furthermore, although the active ingredients of the two drugs are equivalent, the effect of nocebo (e.g., see Colloca 2017) and bad medical news about patients' own health condition (e.g., see Hermosilla and Ching 2024) can make consumers value the brand-name drug more.

By maximizing the consumer's net utility per unit time in (1) (net utility, hereafter) with respect to q_B and q_G, we obtain the demand for the brand-name and generic drugs in market $i \in \{H, L\}$ (conditional on both being positive, see Lemma 1), respectively, as follows:

$$q_B^i(p_B, p_G) = \frac{(\alpha_B - b^i p_B) - b^i \gamma(\alpha_G - p_G)}{1 - b^i \gamma^2}, \tag{2}$$

$$q_G^i(p_B, p_G) = \frac{(\alpha_G - p_G) - \gamma(\alpha_B - b^i p_B)}{1 - b^i \gamma^2}. \tag{3}$$

3.3. Firms' Prices and Profits

Let us derive brand-name and/or generic firm's price and profit in monopoly and duopoly settings.

3.3.1. Monopoly setting: When the brand-name drug is the only drug in the market so that the brand-name firm faces no competition (i.e., the monopoly setting) and the brand-name firm's type is $i \in \{H, L\}$, the representative consumer's net utility in (1) reduces to $\mathcal{U}^i(q_B) = \alpha_B q_B / b^i - q_B^2 / 2b^i - p_B q_B$. By maximizing the net utility, the demand for the brand-name drug in market $i \in \{H, L\}$ is $q_B^i = \alpha_B - b^i p_B$. Then, the monopoly profit of the brand-name firm in market $i \in \{H, L\}$ is given by $\Pi_B^{Mi}(p_B) = (p_B - c)(\alpha_B - b^i p_B)$. Using the first order conditions, $i-$type brand-name firm's optimal monopoly price and profit in market $i \in \{H, L\}$ are, respectively, given by:

$$p_B^{Mi} = \frac{c}{2} + \frac{\alpha_B}{2b^i} \text{ and } \Pi_B^{Mi} = \frac{(\alpha_B - b^i c)^2}{4b^i}. \tag{4}$$

3.3.2. Duopoly setting: When both brand-name and generic drugs exist in the market so that the brand-name and generic firms compete (i.e., duopoly setting), we assume that the brand-name firm is the Stackelberg leader, i.e., the brand-name firm determines the price p_B first and then, observing p_B, the generic firm chooses his price p_G (Frank and Salkever 1997, Kong 2009, Ferrara and Missios 2012). By (2) and (3), $i-$type brand-name firm's and generic firm's profits per unit time (profits, hereafter) in the duopoly setting are given, respectively, by:

$$\Pi_B^{Di}(p_B) = (p_B - c)\frac{(\alpha_B - b^i p_B)(2 - b^i \gamma^2) - b^i \gamma \alpha_G}{2(1 - b^i \gamma^2)}, \tag{5}$$

$$\Pi_G^{Di}(p_G) = p_G \frac{(\alpha_G - p_G) - \gamma(\alpha_B - b^i p_B)}{1 - b^i \gamma^2}. \tag{6}$$

By using backward induction, Lemma 1 characterizes the optimal duopoly prices of brand-name and generic drugs under competition when the brand-name firm is type $i \in \{H, L\}$. Lemma 1 indicates that, in market $i \in \{H, L\}$ both brand-name and generic drugs exist in the market and there is competition between brand-name and generic firms when the gap between consumer valuations for brand-name and generic drugs (i.e., $(\alpha_B - \alpha_G)$) is neither too high nor too low. All consumers prefer the brand-name drug and the brand-name firm becomes a monopoly in cases where $(\alpha_B - \alpha_G)$ is high enough, while all consumers prefer the generic drug, and the generic firm becomes a monopoly in cases where $(\alpha_B - \alpha_G)$ is low enough.

Lemma 1. *In the duopoly setting, when the brand-name firm is type $i \in \{H, L\}$, there is competition and optimal prices of brand-name and generic drugs are, respectively, given by:*

$$p_B^{Di} = \frac{c}{2} + \frac{\alpha_B}{2b^i} - \frac{\alpha_G \gamma}{4 - 2b^i\gamma^2} \text{ and } p_G^{Di} = \frac{(4 - 3b^i\gamma^2)\alpha_G}{8 - 4b^i\gamma^2} - \frac{(\alpha_B - b^i c)\gamma}{4}, \tag{7}$$

if, and only if,

$$\max\left\{\alpha_G, \frac{b^i\gamma\alpha_G}{2 - b^i\gamma^2} + b^i c\right\} < \alpha_B < \frac{\alpha_G(4 - 3b^i\gamma^2)}{\gamma(2 - b^i\gamma^2)} + b^i c. \tag{8}$$

By substituting the prices in Lemma 1 into (5) and (6), the optimal duopoly profits of the brand-name and generic firms when the brand-name firm is $i-$type are, respectively, given by:

$$\Pi_B^{Di} \equiv \Pi_B^{Di}(p_B^{Di}) = \frac{\left[2\alpha_B - b^i\gamma(\alpha_G + \alpha_B\gamma) - b^i c(2 - b^i\gamma^2)\right]^2}{8b^i(2 - b^i\gamma^2)(1 - b^i\gamma^2)}, \tag{9}$$

$$\Pi_G^{Di} \equiv \Pi_G^{Di}(p_G^{Di}) = \frac{\left[(\alpha_B - b^i c)(2 - b^i\gamma^2)\gamma - \alpha_G(4 - 3b^i\gamma^2)\right]^2}{16(2 - b^i\gamma^2)^2(1 - b^i\gamma^2)}. \tag{10}$$

3.4. Sequence of Events

The sequence of events is as follows.

Signaling period: First, at the beginning of the signaling period, knowing the consumers' relative price sensitivity, the brand-name firm determines its price p_B. Second, observing the brand-name firm's price p_B, the generic firm updates his belief about the brand-name firm's type and decides whether to enter the market or not. We let $\hat{\lambda}_b(p_B)$ be the generic firm's updated or posterior belief about the brand-name firm's type. Note that the generic firm enters the market at the beginning of the signaling period if, and only if, his discounted (expected) profit at time 0 (i.e., $\int_0^\infty e^{-\rho t}\big[\hat{\lambda}_b(p_B)\Pi_G^{DH} + (1 - \hat{\lambda}_b(p_B))\Pi_G^{DL}\big]\mathrm{d}t$) is greater than the fixed capacity cost K (i.e., $\hat{\lambda}_b(p_B)\Pi_G^{DH} + (1 - \hat{\lambda}_b(p_B))\Pi_G^{DL} > k$). If the generic firm does not enter the market, the brand-name firm continues to be a monopoly in the signaling period; however, if the generic firm enters the market by incurring the fixed capacity costs K, he learns the brand-name firm's type and chooses his price p_G (Milgrom and Roberts 1982, Bagwell 2007).[5] Third, the representative consumer decides the type and amount of the drugs to purchase, depending on which drugs are available in the market in the signaling period.

Full-information period: Fourth, at the beginning of the full-information period, all information about consumers and the market is revealed to public. Fifth, knowing its type, the brand-name firm chooses its price p_B in the full-information period. Sixth, knowing the brand-name firm's type and observing brand-name firm's price, the generic firm chooses his price p_G if he is already in the

[5] Before entering the market, the generic firm cannot observe the brand-name firm's true price in the monopoly period and hence he cannot infer the market or brand-name firm's type (Hiltzik 2017, Dafny et al. 2023). However, when it is actually in the market, the generic firm can quickly learn consumers' relative price sensitivity and the brand-name firm's type through pricing and/or other resources.

market, and, if he has not entered the market yet, he decides whether to enter the market in the full-information period or not. Note that, if he is not already in the market, observing the brand-name firm's type $i \in \{H, L\}$, the generic firm enters the market at the beginning of full-information period if, and only if, his discounted (expected) profit at time T (i.e., $\int_T^\infty e^{-\rho t}\Pi_G^{Di}\mathrm{d}t$) is greater than the fixed capacity cost K (i.e., $\Pi_G^{Di} > \rho e^{\rho T} K$). If the generic firm decides not to enter the market in the full-information period, the brand-name firm continues to be a monopoly in the full-information period, and if the generic firm enters the market by incurring the fixed capacity cost K, he chooses his price p_G and engages in a competition with the brand-name firm. Finally, the representative consumer decides the type and amount of the drugs to purchase in the full-information period, depending on drugs available in the market.

3.5. A Necessary Condition

In line with the main focus of the paper, we restrict our analysis throughout the paper to cases where the GCP can occur and assume that the generic firm's prior belief λ_b and the discounted fixed capacity cost k satisfy:

$$\lambda_b \Pi_G^{DH} + (1-\lambda_b)\Pi_G^{DL} < k < \Pi_G^{DL}. \tag{11}$$

The above condition is necessary for the existence of the GCP, see Lemma A.2 in Online Appendix A.2. Condition (11) ensures that: (i) the generic firm enters the market if he knows the brand-name firm is $L-$type, and (ii) the generic firm expects to make negative discounted profits (i.e., $\left[(1-\lambda_b)\Pi_G^{DL} + \lambda_b \Pi_G^{DH}\right]/\rho < K$) so that he stays out of the market if the brand-name firm's price in the signaling period is uninformative and the generic firm cannot distinguish between the two types.

In addition, condition (11) requires that, in the duopoly setting, the generic firm makes higher profit when competing with $L-$type brand-name firm as opposed to $H-$type brand-name firm, i.e., $\Pi_G^{DL} > \Pi_G^{DH}$. We derive a sufficient condition on α_B and α_G and show that there are cases where $\Pi_G^{DL} > \Pi_G^{DH}$ for all $0 < b^L < b^H < 1$, see Lemma A.3 in Online Appendix A.3.

4. Equilibrium Analysis

We use backward induction to characterize the perfect Bayesian equilibrium (PBE) of the sequential game between the brand-name and generic firms in pure strategies. The brand-name and generic firms' equilibrium strategies in the full-information period are straightforward. If the generic firm entered the market in the signaling period, the brand-name and generic firms will continue competing in the full-information period by, respectively, charging their duopoly prices p_B^{Di} and p_G^{Di} as given by (7). However, if the generic firm did not enter the market in the signaling period, it follows from (11) that, in the full-information period, the generic firm will stay out of the market and the brand-name firm will continue being a monopoly by charging the price p_B^{MH} when the brand-name firm is $H-$type, whereas he will enter the market, and brand-name and generic firms will compete by, respectively, charging their duopoly prices p_B^{DL} and P_G^{DL} when the brand-name firm is $L-$type.

In the remainder of this section, we focus on the brand-name and generic firms' equilibrium strategies in the signaling period. In the signaling period, only two types of equilibrium can emerge: the *separating* and *pooling* equilibrium. In the *separating* equilibrium, $H-$ and $L-$type brand-name firms choose different prices; as a result, the generic firm can infer the brand-name firm's type by observing its price. In the *pooling equilibrium*, $H-$ and $L-$type brand-name firms pool together and choose the same price, and thus, the generic firm cannot infer the brand-name firm's type by observing its price. By condition (11), the generic firm enters the market only when he knows the brand-name firm is $L-$type. Thus, the generic firm enters the market and charges its duopoly price p_G^{DL} only in a separating equilibrium when the brand-name firm is $L-$type, and he stays out in all other equilibria.

Below, we first characterize the separating and pooling equilibrium in Section 4.1 and Section 4.2, respectively, and then, we establish the stable equilibrium in Section 4.3 and determine the conditions under which the GCP occurs in Section 4.4. In preparation, we define $\Pi_B(i, p_B, i')$ as the brand-name firm's profit in the case where the generic firm believes that the brand-name firm is type $i' \in \{H, L\}$ when the actual type of the brand-name firm is $i \in \{H, L\}$. Since the generic firm enters the market only when he believes that the brand-name firm is $L-$type (by (11)), we have

$$\Pi_B(i, p_B, L) = (p_B - c)\frac{(\alpha_B - b^i p_B) - b^i\gamma(\alpha_G - p_G)}{1 - b^i\gamma^2},$$
$$\Pi_B(i, p_B, H) = (p_B - c)(\alpha_B - b^i p_B)$$

for $i \in \{L, H\}$.

4.1. The Separating Equilibrium

In a separating equilibrium, the $H-$ and $L-$type brand-name firms, respectively, charge prices $\hat{p}_B^H$ and $\hat{p}_B^L$ in the signaling period based on their true type $i = L, H$, so that $\hat{p}_B^H \neq \hat{p}_B^L$. Thus, the generic firm can infer its type after observing the brand-name drug's price $\hat{p}_B^i$. By Lemma A.4(i) in Online Appendix A.4, in a separating equilibrium, it is always optimal for the $L-$type brand-name firm to charge the duopoly price (i.e., $\hat{p}_B^L = p_B^{DL}$), and $H-$type brand-name firm's price $\hat{p}_B^H$ must satisfy:

$$\Pi_B(L, p_B^{DL}, L) \geq \Pi_B(L, \hat{p}_B^H, H), \tag{12}$$

$$\Pi_B(H, \hat{p}_B^H, H) \geq \max_{p_B \neq \hat{p}_B^H} \Pi_B(H, p_B, L). \tag{13}$$

Condition (12) ensures that, in a separating equilibrium, $L-$type brand-name firm has no incentive to mimic the H type and charge its price $\hat{p}_B^H$. Condition (13) guarantees that, in a separating equilibrium, the $H-$type brand-name firm has no incentive to deviate to any other off-equilibrium-path prices under the generic firm's belief that the brand-name firm is of $L-$type when a signal other than $\hat{p}_B^H$ is sent (i.e., the $H-$type brand-name firm truthfully signals its type). Among all separating equilibria satisfying conditions (12) and (13), it is sufficient to consider the least-cost separating equilibrium (which maximizes the $H-$type brand-name firm's profit), as it Pareto dominates all other separating equilibria. Next, using conditions (12) and (13), Lemma 2 characterizes the least-cost separating equilibrium. In preparation, we define the threshold $b^{H(1)}(b^L)$ as follows:

$$b^{H(1)}(b^L) = \frac{2\alpha_B b^L}{2\alpha_B - \sqrt{\frac{4\alpha_G^2 b^L}{2-b^L\gamma^2} - \frac{2b^L\left((\alpha_B - b^L c)\gamma - \alpha_G\right)^2}{1-b^L\gamma^2}}}, \tag{14}$$

and for $b^H \in (0,1)$, the threshold $b^{L(1)} \in (0, b^H)$ is uniquely determined by $b^{H(1)}(b^{L(1)}) = 1$. Clearly, $b^{H(1)}(b^L) > b^L$ for all $b^L \in (0,1)$.

LEMMA 2 **(The Separating Equilibrium)**. *There exists a unique least-cost separating equilibrium, in which the price of $H-$ and $L-$type brand-name firm in the signaling period is given, respectively, by*

$$\hat{p}_B^H = \begin{cases} p_B^{MH}, & \textit{if } b^L \in (0, b^{L(1)}) \textit{ and } b^H \in (b^{H(1)}(b^L), 1), \\ \frac{\alpha_B}{2b^{H(1)}(b^L)} + \frac{c}{2} < p_B^{MH}, & \textit{otherwise,} \end{cases}$$

and $\hat{p}_B^L = p_B^{DL}$.

Lemma 2 shows that, in the least-cost separating equilibrium in the signaling period, the $H-$type brand-name firm charges its monopoly price if the two types of the brand-name firm are sufficiently different (i.e., the gap between b^L and b^H is large) and charges less than its monopoly price otherwise. When two types of the brand-name firm are different enough, L type's duopoly price p_B^{DL} is significantly higher than the H type's monopoly price p_B^{MH}. Thus, it is very costly for the L type to mimic H type so that H type charges its monopoly price. When two brand-name firm types are not very different (i.e., the gap between b^H and b^L is small enough), however, the L type can prevent the generic entry in the signaling period by charging the monopoly price p_B^{MH} and mimicking the H type. Therefore, in such cases in a separating equilibrium, the $H-$type brand-name firm charges a price lower than its monopoly price p_B^{MH} in the signaling period and thereby makes it very costly for the L type to mimic itself.

4.2. The Pooling Equilibrium

In a pooling equilibrium, the $L-$type brand-name firm mimics the H type, and thus the generic firm does not obtain new information from observing the brand-name firm's price. Let $\hat{p}_B$ be the price charged by the brand-name firm in the signaling period in a pooling equilibrium. With a slight abuse of notation, we shall use $\Pi_B(i, \hat{p}_B, \{H, L\})$ to denote $i-$type brand-name firm's profit when both types of brand-name firm pool so that the generic firm does not know the brand-name firm's exact type. When the generic firm does not know the exact type of the brand-name firm, he will not enter the market and $i-$type brand-name firm will be a monopoly and its profit is equal to $\Pi_B(i,\hat{p}_B,\{H,L\}) = \Pi_B^{Mi}(\hat{p}_B) = (\hat{p}_B - c)(\alpha_B - b^i\hat{p}_B)$. Then by Lemma A.4(ii) in Online Appendix A.4, the signaling-period price $\hat{p}_B$ in a pooling equilibrium must satisfy:

$$\Pi_B(L,\hat{p}_B,\{H,L\}) \geq \max_{p_B \neq \hat{p}_B} \Pi_B(L,p_B,L), \tag{15}$$

$$\Pi_B(H,\hat{p}_B,\{H,L\}) \geq \max_{p_B \neq \hat{p}_B} \Pi_B(H,p_B,L). \tag{16}$$

Condition (15) ensures that, in a pooling equilibrium, mimicking the H type to deter entry must make the $L-$type brand-name firm better off as opposed to revealing its type. In addition, condition (16) guarantees that H type's profit in a pooling equilibrium is greater than the best it can earn by charging any other price under the most unfavorable belief of the generic firm, i.e., when the brand-name firm is believed to be $L-$type. If condition (16) is violated, the $H-$type brand-name firm will be better off by deviating to a different price, and hence, charging the pooling price $\hat{p}_B$ will not be rational for H type.

Using conditions (15) and (16), Lemma 3 characterizes the pooling equilibria. In preparation, we define the threshold $b^{L(2)}(b^H) \in (0,b^H)$ as folllows:

$$b^{L(2)}(b^H) = \frac{2\alpha_B b^H}{2\alpha_B + \sqrt{\frac{4\alpha_G^2 b^H}{2-b^H\gamma^2} - \frac{2b^H\left((\alpha_B - b^H c)\gamma - \alpha_G\right)^2}{1-b^H\gamma^2}}}, \tag{17}$$

and $b^{L(3)}$ uniquely satisfies $b^{H(1)}(b^{L(3)}) = b^{L(2)}(1)$. For $b^L \in (0,b^{L(3)})$, the threshold $b^{\tilde{H}(1)}(b^L)$ is the unique b^H that satisfies $b^{L(2)}(b^H) = b^{H(1)}(b^L)$.

Lemma 3 **(Pooling Equilibria)**. *A pooling equilibrium does not exist if, and only if,* $b^L \in (0,b^{L(3)})$ *and* $b^H \in (b^{\tilde{H}(1)}(b^L),1)$*; otherwise, there exist multiple pooling equilibria, in which the price of* $H-$ *and* $L-$*type brand-name firm in the signaling period is given by* $\hat{p}_B \in [\frac{\alpha_B}{2b^{H(1)}(b^L)} + \frac{c}{2}, \frac{\alpha_B}{2b^{L(2)}(b^H)} + \frac{c}{2}]$.

Lemma 3 asserts that there is no pooling equilibrium when the two types of brand-name firm are sufficiently different. In such cases, mimicking $H-$type brand-name firm to deter the generic entry by charging the same price is very costly for the L type (i.e., condition (15) is violated). Thus, $L-$type brand-name firm allows entry instead of charging the same price.

Lemma 3 also shows that, when the two types of brand-name firm are sufficiently similar, there is at least one pooling equilibrium. By setting its price at pooling price $\hat{p}_B$, the $H-$type brand-name firm deters the generic entry, thereby maintaining its monopoly status during the signaling period. However, if the H type deviates from this pooling price, the generic firm, under its off-equilibrium belief, believes that the brand-name firm is of the $L-$type and decides to enter the market. As a result, such a deviation and the choice to charge a different price makes the $H-$type brand-name firm worse off. Similarly, by setting its price to the pooling price and mimicking the H type, the $L-$type brand-name firm, while charging a price that can be lower than its monopoly price, also deters generic entry, thereby maintaining its monopoly status during the signaling period. Given that the two types of the brand-name firm are not very different, the gap between L type's price in the pooling equilibrium and its monopoly price is relatively small. Consequently, pooling with the H type and charging the same price improves $L-$type brand-name firm's overall profits.

4.3. The Equilibrium Selection

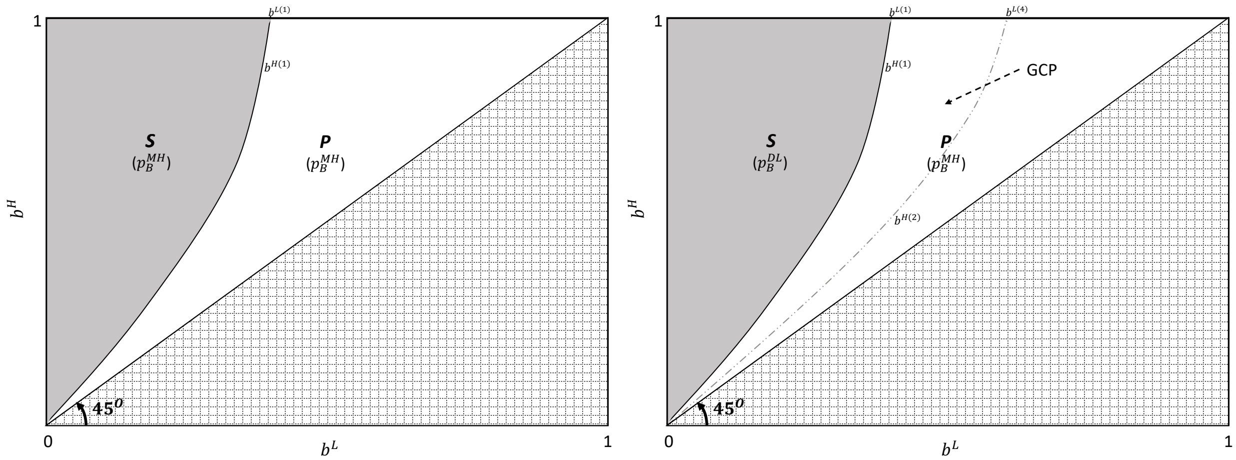
When characterizing the separating and pooling equilibria above, we placed no restrictions on the generic firm's off-equilibrium beliefs. Moreover, by Lemmas 2 and 3, there can be multiple equilibria in some cases. To put structure on off-equilibrium beliefs and eliminate equilibria that are Pareto dominated, we, respectively, use the Intuitive Criterion (e.g., see Cho and Kreps 1987) and Pareto dominance (e.g., see Harsanyi and Selten 1988, Bolton and Dewatripont 2004), and characterize the (self-enforcing) *stable* equilibrium in Proposition 1. Figure 1 illustrates Proposition 1.

PROPOSITION 1 **(The Stable Equilibrium).** *(i) For $b^L \in (0, b^{L(1)})$ and $b^H \in (b^{H(1)}(b^L), 1)$, the stable equilibrium is a separating equilibrium, in which the price of $H-$ and $L-$type brand-name firm in the signaling period is, respectively, given by $\hat{p}_B^H = p_B^{MH}$ and $\hat{p}_B^L = p_B^{DL}$.*

(ii) For $b^L \in (0,1)$ and $b^H \in (b^L, \min\{b^{H(1)}(b^L), 1\})$, the stable equilibrium is a pooling equilibrium, in which the price of $H-$ and $L-$type brand-name firm in the signaling period is given by $\hat{p}_B = p_B^{MH}$.

Proposition 1(i) shows that, when two types of the brand-name firm are sufficiently different (i.e., Region S in Figure 1), the stable equilibrium is separating, and $H-$ and $L-$type brand-name firms choose different prices in the signaling period and reveal their types (i.e., H type charges its monopoly price p_B^{MH} (see Region S in Figure 1(a)) while L type charges its duopoly price p_B^{DL} (see Region S in Figure 1(b))). This is because, in such cases, the price to mimic $H-$type brand-name firm (i.e., p_B^{MH}) is significantly lower than the lowest price that the $L-$type brand-name firm can charge to prevent entry without being worse off (i.e., $\frac{\alpha_B}{2b^{H(1)}(b^L)} + \frac{c}{2}$ by Lemma 3). In other words, mimicking the $H-$type brand-name firm to prevent generic entry in the signaling period is very costly for the $L-$type brand-name firm when two types of the brand-name firm are different enough.

Proposition 1(ii) shows that, when the two types of the brand-name firm are sufficiently similar (i.e., Region P in Figure 1), the stable equilibrium is pooling, and $H-$ and $L-$type brand-name firms charge price p_B^{MH} (see Region P in Figures 1(a) and 1(b)) and do not reveal their types in the signaling period. The intuition is as follows. In the separating equilibrium when the two types of the brand-name firm are similar enough, the $H-$type brand-name firm charges a price (i.e., $\frac{\alpha_B}{2b^{H(1)}} + \frac{c}{2}$) lower than its monopoly price p_B^{MH} in order to separate itself and prevent competition, while the $L-$type brand-name firm charges its duopoly price p_B^{DL} and faces competition from the generic



(a) $H-$type brand-name firm (b) $L-$type brand-name firm

Figure 1 Signaling-period prices of H− and L−type brand-name firms in the stable equilibrium

Note. In the figure, the region (with pattern) below 45° line is irrelevant because $b^H > b^L$, and the stable equilibrium is separating in grey region (Region S) and pooling in white region (Region P). The dependence of thresholds in b^H on b^L in the figure are dropped for notational convenience, e.g., $b^{H(1)} \equiv b^{H(1)}(b^L)$.

firm (see Lemma 2). In contrast, in the pooling equilibrium that survives the Intuitive Criterion, the $H-$type brand-name firm charges its monopoly price p_B^{MH} while the $L-$type brand-name firm charges p_B^{MH} and sets the price below its monopoly price p_B^{ML} to deter generic entry, but still high enough to make higher profits than in a competitive market with the generic firm (i.e., *limit pricing*). Consequently, both $H-$ and $L-$type brand-name firms are better off from pooling and charging the same price p_B^{MH} in equilibrium when H and L types of the brand-name firm are sufficiently similar. This implies that the limit pricing can emerge in equilibrium as a result of the $L-$type brand-name firm's anticompetitive behavior.

4.4. The Generic Competition Paradox in Equilibrium

By Proposition 1, there is no generic entry when the brand-name firm is $H-$type; moreover, the $L-$type brand-name firm reduces its price after generic entry and charges the duopoly price p_B^{DL} in the signaling and full-information periods when two types of the brand-name firm are sufficiently different. This indicates that the GCP, if any, occurs in equilibrium only when the brand-name firm is $L-$type, and the two types of the brand-name firm are sufficiently similar (i.e., $b^L \in (0,1)$ and $b^H \in (b^L, \min\{b^{H(1)}(b^L), 1\})$ as in Region P in Figure 1(b)).

Theorem 1 below characterizes exact conditions under which the GCP occurs. In preparation, we define the thresholds $b^{H(2)}(b^L) \in (b^L, b^{H(1)}(b^L))$ and $b^{L(4)} \in (0,1)$, respectively, as follows:

$$b^{H(2)}(b^L) = \frac{b^L \alpha_B (2 - b^L \gamma^2)}{\alpha_B (2 - b^L \gamma^2) - b^L \gamma \alpha_G}, \tag{18}$$

$$b^{L(4)} = \frac{\gamma\alpha_G + \alpha_B(2+\gamma^2) - \sqrt{(\gamma\alpha_G + \alpha_B(2+\gamma^2))^2 - 8\gamma^2\alpha_B^2}}{2\gamma^2\alpha_B}, \tag{19}$$

where $b^{H(2)}(b^L) < 1$ if, and only if, $b^L \in (0, b^{L(4)})$

THEOREM 1. *In the stable equilibrium, the GCP occurs if, and only if, the brand-name firm is $L-$type, and $b^L \in (0, b^{L(4)})$ and $b^H \in (b^{H(2)}(b^L), \min\{b^{H(1)}(b^L), 1\})$.*

Theorem 1 reveals that the GCP will arise in stable equilibrium when the brand-name firm is the $L-$type and is sufficiently similar, but not too similar, to H type (i.e., part of Region P above the dashed line in Figure 1(b)). By Proposition 1(ii), when the two types of the brand-name firm are sufficiently similar (i.e., $b^L \in (0,1)$ and $b^H \in (b^L, \min\{b^{H(1)}(b^L), 1\})$), the $L-$type brand-name firm, in the signaling period, limits its price and charges p_B^{MH} ($< p_B^{ML}$) to mimic H type and prevent the generic entry while, in the full-information period, the $L-$type brand-firm charges the duopoly price p_B^{DL} as the generic firm learns its actual type and enters the market. In such cases, $L-$type brand-name firm's price increases after generic entry and the GCP occurs (i.e., $p_B^{DL} > p_B^{MH}$ (by (4) and (7)) if the $L-$type brand-name firm is *not* too similar to $H-$type brand-name firm (i.e., $b^L < b^{L(4)}$ and $b^H > b^{H(2)}(b^L)$); and the GCP does not occur, otherwise. By this result, we show that the GCP can occur due to the limit pricing strategy of the brand-name firm in the presence of information asymmetry. In doing so, we address the debate among industry experts (e.g., see Ellison and Ellison 2011) and formally identify the information asymmetry and resulting (anticompetitive) limit pricing strategy as another rationale behind the GCP.

5. Welfare Implications

We now examine the impact of information asymmetry on consumer surplus (i.e., the total discounted net utility of the representative consumer) and social welfare (i.e., sum of consumer surplus and the total discounted profits of brand-name and generic firms) by comparing scenarios with and without information asymmetry. The information asymmetry does not exist and thus has no impact on consumers and welfare in the full-information period. Moreover, it has no impact on consumers and firms in the signaling period when either the stable equilibrium is separating or the brand-name firm is $H-$type. This is because in the former, the brand-name firm's type is entirely revealed to the generic firm in the signaling period (see Proposition 1(i)), and in the latter, the $H-$type brand-name firm is the only firm in the market (i.e., no generic entry) with or without information asymmetry (see Proposition 1(ii)). Therefore, to determine the impact of the information asymmetry, it is enough to compare consumer surplus and social welfare in the signaling period, with and without asymmetric information, only when the stable equilibrium is pooling (i.e., $b^L \in (0,1)$ and $b^H \in (b^L, \min b^{H(1)}(b^L), 1))$, and the brand-name firm is of type L (i.e., Regions P_1, P_2, and P_3 in Figure 2). In such cases, under information asymmetry, the generic firm's entry is delayed until the full-information period and the fixed capacity cost K is incurred at time T, rather than time 0. We take this into account when we determine the impact of information asymmetry on the social welfare (see the proof of Proposition 2).

We characterize the impact of information asymmetry on consumer surplus and social welfare in Proposition 2 and illustrate it in Figure 2. In preparation, we define $b^{H(3)}(b^L)$ and $b^{H(4)}(b^L)$, respectively, as follows:

$$b^{H(3)}(b^L) = \frac{2\alpha_B b^L}{4\alpha_B - 2b^L c - \sqrt{3(\tilde{\alpha}_B^L)^2 + \frac{4b^L\alpha_G^2}{(2-b^L\gamma^2)^2} + \frac{4b^L\alpha_G(\alpha_G+\gamma\tilde{\alpha}_B^L)}{2-b^L\gamma^2} + \frac{(\tilde{\alpha}_B^L)^2+b^L\alpha_G^2-2b^L\gamma\tilde{\alpha}_B^L\alpha_G}{1-b^L\gamma^2}}}, \tag{20}$$

$$b^{H(4)}(b^L) = \frac{2\alpha_B b^L}{2b^L c + \sqrt{32kb^L + 11(\tilde{\alpha}_B^L)^2 + \frac{4\alpha_G^2 b^L}{(2-b^L\gamma^2)^2} + \frac{4\alpha_G b^L(\gamma\tilde{\alpha}_B^L-3\alpha_G)}{2-b^L\gamma^2} + \frac{7((\tilde{\alpha}_B^L)^2+b^L\alpha_G^2-2b^L\gamma\tilde{\alpha}_B^L\alpha_G)}{b^L\gamma^2-1}}}, \tag{21}$$

where $\tilde{\alpha}_B^L := \alpha_B - b^L c$ is the absolute advantage of consumer valuation for the brand-name drug. In addition, we let $b^{L(5)}$ and $b^{L(6)}$ be unique b^L values that, respectively, satisfy $b^{H(3)}(b^L) = 1$ and $b^{H(4)}(b^L) = 1$. By comparing these thresholds, it is easy to show that $b^{H(1)}(b^L) > b^{H(3)}(b^L) > b^{H(2)}(b^L) > b^{H(4)}(b^L) > b^L$, and $0 < b^{L(1)} < b^{L(5)} < b^{L(4)} < b^{L(6)} < 1$.

Proposition 2. *Suppose that $b^L \in (0,1)$ and $b^H \in (b^L, \min\{b^{H(1)}(b^L), 1\})$ (i.e., the stable equilibrium is pooling) and the brand-name firm is $L-$type.*

(i) The consumer surplus in the signaling period with information asymmetry increases relative to that without information asymmetry if, and only if, $b^L \in (0, b^{L(5)})$ and $b^H \in (b^{H(3)}(b^L), \min\{b^{H(1)}(b^L), 1\})$.

(ii) The social welfare in the signaling period with information asymmetry increases relative to that without information asymmetry if, and only if, $b^L \in (0, b^{L(6)})$ and $b^H \in (b^{H(4)}(b^L), \min\{b^{H(1)}(b^L), 1\})$.

Proposition 2(i) shows that, in cases where the stable equilibrium is pooling (i.e., Regions P_1, P_2 and P_3 in Figure 2), the information asymmetry leads to a higher consumer surplus only if $H-$ and $L-$type brand-name firms are sufficiently different (i.e., Region P_1 in Figure 2). In contrast to conventional wisdom, this implies that the brand-name firm's information asymmetry can benefit consumers. Recall from Proposition 1 that, in Regions P_1, P_2 and P_3 in Figure 2, the $L-$type brand-name firm limits its price and charges H type's monopoly price p_B^{MH} in the signaling period to delay generic entry. As a result, the information asymmetry creates two countervailing effects on consumers. It leads to limit pricing and reduces the brand-name drug's price for consumers, and it delays generic entry and prevents consumer from buying an alternative and cheaper (generic) drug. The former effect dominates the latter and the consumer surplus increases when $H-$ and $L-$type brand-name firms are different enough (i.e., Region P_1 in Figure 2) while the latter effect dominates the former, and the consumer surplus decreases when H and L types of the brand-name firm are similar enough (i.e., Regions P_2 and P_3 in Figure 2).

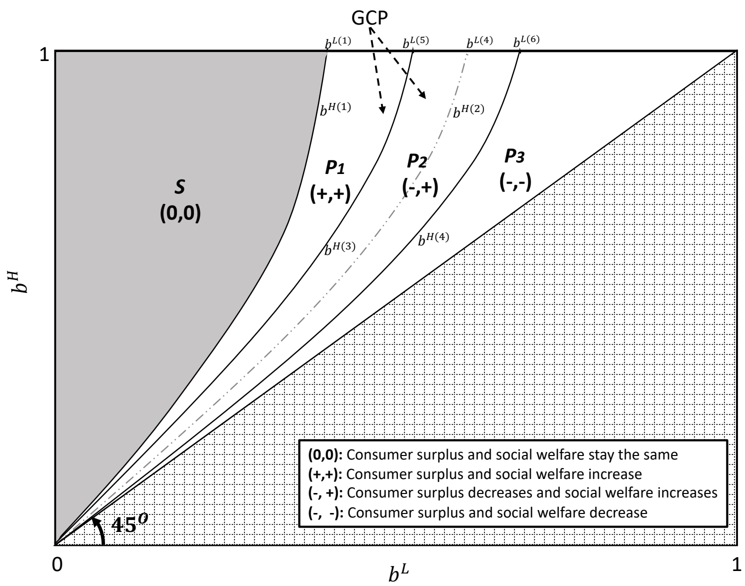


Figure 2 Welfare implications of the information asymmetry in the stable equilibrium when the brand-name firm is L−type

Note. In the figure, the region (with the pattern) below 45° line is irrelevant because $b^H > b^L$, and the stable equilibrium is separating in grey region (Region S) and pooling in white region (Regions P_1, P_2 and P_3). The dependence of thresholds in b^H on b^L in the figure are dropped for notational convenience, e.g., $b^{H(1)} \equiv b^{H(1)}(b^L)$.

Similarly, Proposition 2(ii) shows that, in cases where the stable equilibrium is pooling (i.e., Regions P_1, P_2 and P_3 in Figure 2), the information asymmetry improves the social welfare only when the two types of the brand-name firm are sufficiently different (i.e., Regions P_1 and P_2 in Figure 2). This suggests that brand-name firm's information asymmetry is not necessarily bad for the entire society. As is the case with the consumer surplus, the information asymmetry results in limit pricing and creates two countervailing effects on total firm profits in the signaling period. While it allows the L-type brand-name firm to maintain its monopoly and earn higher profits, it prevents the generic firm from entering and thus results in no profits for him. The former effect dominates the latter and the firms' total profit in the signaling period increases when the two types of the brand-name firm are sufficiently similar. The latter effect dominates the former, and the firms' total profit in the signaling period decreases when two types of the brand-name firm are sufficiently different. Further, when two types of the brand-name firm are sufficiently different (i.e., Region P_1 in Figure 2), the consumer-surplus-increasing effect of the information asymmetry dominates the total-firm-profits-decreasing effect of the information asymmetry so that the social welfare increases. When H and L types of the brand-name firm are neither very similar nor very different (i.e., Region P_2 in Figure 2), the total-firm-profits-increasing effect of information asymmetry is so high that the social welfare increases, even though the information asymmetry decreases consumer surplus.[6] Lastly, the social welfare decreases under the information asymmetry when the two types of the brand-name firm are similar enough (i.e., Region P_3 in Figure 2) because the information asymmetry decreases consumer surplus more than it increases total firm profits.

There is a common belief among experts that the GCP, if it occurs, is bad for consumers and the society because it leads to a higher price for the brand-name drug (Lexchin 2004). Contrary to this belief, Figure 2 shows that, in cases where the GCP occurs (i.e., Region P_1 and part of Region P_2 above the dashed curve), the social welfare always increases, while the consumer surplus increases in some cases (i.e., Region P_1). Therefore, the GCP can actually benefit consumers and the society when it occurs because of information asymmetry.

6. Extensions

We extend our model to scenarios with: (i) a continuum of types; (ii) dual sources of information asymmetry; (iii) multiple generic firms; and (iv) sequential generic entry. This allows us to check the robustness of our main results and obtain novel insights.

6.1. A Continuum of Types

We now consider a continuum of types for the brand-name firm and assume that consumers' relative price sensitivity b can take any value between 0 and 1. At the beginning of the signaling period, the generic firm does not know b and believes that it is uniformly distributed within the interval $(0,1]$. We use superscript "b" to denote the brand-name firm type.

Monopoly and duopoly settings: Prices and profits of the $b-$type brand-name firm and the generic firm in the monopoly and duopoly settings are, respectively, the same as those in Sections 3.3.1 and 3.3.2 when b^i is set to b. That is, $p_B^{Mb} = p_B^{Mi}$ and $\Pi_B^{Mb} = \Pi_B^{Mi}$ as given by (4), and $p_j^{Db} = p_j^{Di}$ and $\Pi_j^{Db} = \Pi_j^{Di}$ for $j \in \{B, G\}$ as given by (7), (9) and (10) when $b^i = b$. Also, condition (8) for $b^i = b$ is still sufficient to ensure the competition between firms in the duopoly setting.

A necessary condition: To focus on cases where the GCP can occur, we assume that the discounted fixed capacity cost k satisfies:

$$\frac{\int_{b^{L(1)}}^{1} \Pi_G^{Db} \mathrm{d}b}{1 - b^{L(1)}} < k < \Pi_G^{D0}. \tag{22}$$

Note that the brand-name firm of type $b = b^{L(1)}$ is indifferent between allowing entry by revealing its type and preventing it by mimicking type $b = 1$, while those with type $b > b^{L(1)}$ are better off mimicking type $b = 1$ to prevent entry. Thus, condition (22) ensures that the generic firm refrains

[6] In practice, a five-month generic entry delay could be worth as much as hundreds of millions of dollars in additional monopoly revenues (Feldman and Frondorf 2017).

from entering if he only knows that the brand-name firm is type $b \in [b^{L(1)}, 1]$ without knowing its actual type, but it enters when he knows that the brand-name firm is type $b = 0$. Also, condition (22) requires Π_G^{Db} to be decreasing in $b \in (0, 1]$, which is always true under the sufficient condition of Lemma A.3 in Online Appendix A.3.

6.1.1. A partial-pooling equilibrium. In the full-information period, all information is revealed and the generic firm knows the brand-name firm's type. Let us define $b = b^{(1)}$ as the type of the brand-name firm at which the generic firm, upon observing the brand-name firm's type, is indifferent between entering the market and staying out, i.e., $\Pi_G^{Db} = k$ when $b = b^{(1)}$.[7] Thus, in the full-information period, if the brand-name firm is of type $b \le b^{(1)}$, the generic firm enters the market, and brand-name and generic firms charge their duopoly prices p_B^{Db} and p_G^{Db}, respectively; however, if the brand-name firm is of type $b > b^{(1)}$, the generic firm stays out and brand-name firm charges its monopoly price p_B^{Mb}.

In the signaling period, the only possible type of equilibrium is a *partial-pooling equilibrium*, where some types of the brand-name firm pool together by choosing the same price while other types separate themselves by choosing different prices. Proposition 3 characterizes a partial-pooling equilibrium which survives the Intuitive Criterion and thus can happen in practice.[8] In preparation, we let $b^{(2)} \in (0, b^{(1)})$ be the unique value that satisfies:

$$\frac{\int_{b^{(2)}}^{b^{H(1)}(b^{(2)})} \Pi_G^{Db} \mathrm{d}b}{b^{H(1)}(b^{(2)}) - b^{(2)}} = k.$$

By definition, the threshold $b^{H(1)}(b)$ represents the highest type that $b-$type brand-name firm can mimic to deter generic entry without being worse off (i.e., $\Pi_G^{Db} \le k$ for $b \ge b^{H(1)}(b)$). Consequently, $b = b^{(2)}$ is the lowest type that can mimic another type to deter generic entry. Also, $b^{(1)} < b^{H(1)}(b^{(2)})$ by definition.

PROPOSITION 3. *There exists a partial-pooling equilibrium, in which, in the signaling period:*

(i) For $b \in (0, b^{(2)})$, the generic firm enters the market and prices of $b-$type brand-name and generic firms are, respectively, given by p_B^{Db} and p_G^{Db}.

(ii) For $b \in [b^{(2)}, b^{H(1)}(b^{(2)})]$, the generic firm stays out of the market and the price of $b-$type brand-name firm is given by $p_B^{Mb^{H(1)}(b^{(2)})}$.

(iii) For $b \in (b^{H(1)}(b^{(2)}), 1]$, the generic firm stays out of the market and the price of $b-$type brand-name firm is given by p_B^{Mb}.

[7] Such a threshold type $b^{(1)} \in (0, 1)$ always exists and is unique by (22) and Π_G^{Db} being decreasing in b.

[8] The partial-pooling equilibrium also survives the refinement criterion developed by Harrington (1987) that the reasonable beliefs should be monotonic in the signal.

Proposition 3(i) and (iii) state that brand-name firms of low and high types (i.e., $b \in (0, b^{(2)})$ or $b \in (b^{H(1)}(b^{(2)}), 1])$ differentiate themselves by setting distinct prices, thereby revealing their types. Brand-name firms of high type (i.e., $b \in (b^{H(1)}(b^{(2)}), 1])$ cannot be mimicked by other types since it is too costly, and moreover, the generic entry is not profitable in their presence. Therefore, they charge their monopoly prices p_B^{Mb} and reveal their types. In addition, brand-name firms of low type (i.e., $b \in (0, b^{(2)})$) must charge significantly lower prices to mimic a higher type and deter generic entry. Instead, they allow entry and compete with the generic firm by charging the price p_B^{Db}.

Proposition 3(ii) shows that brand-name firms of intermediate type (i.e., $b \in [b^{(2)}, b^{H(1)}(b^{(2)})]$) pool together by charging the same price. Brand-name firms of type $b \in [b^{(2)}, b^{(1)})$ face competition and obtain significantly lower profits if they reveal their types. To deter entry and avoid competition, they mimic type $b = b^{H(1)}(b^{(2)})$ and charge $p_B^{Mb^{H(1)}(b^{(2)})}$, a price lower than their own monopoly price p_B^{Mb}. As a result, brand-name firms of type $b \in [b^{(2)}, b^{(1)})$ engage in anticompetitive practices and use limit pricing to deter generic entry. Brand-name firms of type $b \in [b^{(1)}, b^{H(1)}(b^{(2)}))$ can deter generic entry by revealing their types. However, to reveal their types, they need to charge significantly low prices. Instead, they prevent the generic entry in a less costly way, i.e., they mimic type $b = b^{H(1)}(b^{(2)})$ and reduce their price to $p_B^{Mb^{H(1)}(b^{(2)})}$. Brand-name firms of type $b \in [b^{(1)}, b^{H(1)}(b^{(2)}))$ still use the limit pricing strategy, but not because of their anticompetitive behavior, as it is already unprofitable for generic firms to enter the market. Lastly, the brand-name firm of type $b = b^{H(1)}(b^{(2)})$ gains nothing from separating itself from types $b \in [b^{(2)}, b^{H(1)}(b^{(2)}))$ and thus charges its monopoly price $p_B^{Mb^{H(1)}(b^{(2)})}$.

Recall from above that, in the full-information period, brand-name firms of type $b \in [b^{(1)}, b^{H(1)}(b^{(2)}))$ charge their monopoly prices p_B^{Mb} and face no competition, whereas brand-name firms of type $b \in [b^{(2)}, b^{(1)})$ allow entry and charge their duopoly prices p_B^{Db}. This, by Proposition 3(ii), suggests that an increase in the brand-name firm's price may occur, even without generic entry (i.e., for $b \in [b^{(1)}, b^{H(1)}(b^{(2)}))$). It also suggests that, in the partial-pooling equilibrium, the GCP, if present, only occurs when the brand-name firm is of type $b \in [b^{(2)}, b^{(1)})$. Indeed, similar to Theorem 1, Theorem 2 identifies the scenarios where the GCP emerges in the partial-pooling equilibrium with a continuum of types. (See the proof of Theorem 2 for the definition of the threshold $b^{(3)}$.)

Theorem 2. *In the partial-pooling equilibrium of Proposition 3, the GCP occurs if, and only if, the actual type of the brand-name firm is* $b \in [b^{(2)}, \min\{b^{(3)}, b^{(1)}\})$.

6.1.2. Welfare implications. By Proposition 3, in the partial-pooling equilibrium, the information asymmetry can affect consumer surplus and social welfare only when the brand-name firm's type is $b \in [b^{(2)}, b^{H(1)}(b^{(2)})]$. Focusing only on such brand-name firm types, we explore welfare implications of information asymmetry, as summarized in Proposition 4. (See the proof of Proposition 4 for the definitions of thresholds $b^{(4)}$ and $b^{(5)}$.)

Proposition 4. *Suppose that the brand-name firm is type* $b \in [b^{(2)}, b^{H(1)}(b^{(2)})]$. *In the partial-pooling equilibrium of Proposition 3:*

(i) The consumer surplus in the signaling period with information asymmetry is larger than that without information asymmetry if, and only if, $b \in [b^{(2)}, \min\{b^{(4)}, b^{(1)}\}) \cup [b^{(1)}, b^{H(1)}(b^{(2)}))$.

(ii) The social welfare in the signaling period with information asymmetry is larger than that without information asymmetry if, and only if, $b \in [b^{(2)}, \min\{b^{(5)}, b^{(1)}\}) \cup [b^{(1)}, b^{H(1)}(b^{(2)}))$.

Proposition 4 reveals that, in a partial-pooling equilibrium with a continuum of types, information asymmetry can sometimes benefit consumers and society. Proposition 4 is akin to Proposition 2 and follows from the same intuition. Also, together with Theorem 2, it suggests that the GCP, when it occurs (i.e., $b \in (b^{(2)}, \min\{b^{(3)}, b^{(1)}\})$), is not always detrimental to consumers and society.

6.2. Dual Sources of Information Asymmetry

Here, we explore the dual sources of information asymmetry by assuming that the brand-name firm has private information about consumers' relative price sensitivity and its unit production cost. For simplicity, we suppose that the unit production cost is independent from consumers' relative price sensitivity and the brand-name firm has two types with respect to its unit production cost (i.e., high-cost and low-cost brand-name firm). We use c^H and c^L ($c^H > c^L$) to denote the unit production cost of high- and low-cost brand-name firm, respectively. The generic firm does not know the brand-name firm's exact cost and believes that the brand-name firm is high-cost with probability λ_c and low-cost with probability $1-\lambda_c$, where $\lambda_c \in [0,1]$.

In this case, the brand-name firm has four types overall. Letting $i \in \{H, L\}$ and $m \in \{H, L\}$, respectively, denote the brand-name firm's type with respect to consumers' relative price sensitivity and unit production cost, we use 'im' to denote the brand-name firm's overall type. For example, when the brand-name firm is $HL-$type, consumers' relative price sensitivity is high (b^H) and the brand-name firm's unit production cost is low (c^L). Then, letting λ^{im} denote the generic firm's prior belief that the brand-name firm is $im-$type for $i, m \in \{H, L\}$, we have $\lambda^{HL} = \lambda_b(1-\lambda_c)$, $\lambda^{HH} = \lambda_b\lambda_c$, $\lambda^{LL} = (1-\lambda_b)(1-\lambda_c)$, and $\lambda^{LH} = (1-\lambda_b)\lambda_c$.

For tractability, we focus on cases where the generic firm enters the market when he knows the brand-name firm is $LL-$, $HH-$, or $LH-$type and he does not enter the market when he knows the brand-name firm is $HL-$type, or when the brand-name firm's price is uninformative and the generic firm does not know the brand-name firm's actual type. To ensure this, we assume that the discounted fixed capacity cost satisfies

$$\sum_{i\in\{H,L\}} \sum_{m\in\{H,L\}} \lambda^{im}\Pi_G^{Dim} < k < \min\{\Pi_G^{DHH}, \Pi_G^{DLL}\}, \tag{23}$$

where Π^{Dim} for $i, m \in \{H, L\}$ is the generic firm's duopoly profit when the brand-name is $im-$type. Note that the generic firm obtains higher duopoly profit when the brand-name firm has a higher unit production cost, (e.g., $\Pi_G^{DLH} > \Pi_G^{DLL}$) and hence $k < \min\{\Pi_G^{DHH}, \Pi_G^{DLL}\}$ implies that $k < \Pi_G^{DLH}$. Consequently, under condition (23), only $LL-$, $HH-$, and $LH-$type brand-name firms have incentives to mimic the $HL-$type brand-name firm in case they want to prevent the generic entry. For brevity, we defer the detailed analysis of this setting to Online Appendix D, where we show that our main results continue to hold when there are dual sources of information asymmetry.

Next, we examine the impact of an additional source of information asymmetry by comparing the case where the brand-name firm has information asymmetry on both consumers' relative price sensitivity and unit production cost (Online Appendix D) with the case where the brand-name firm has information asymmetry only on consumers' relative price sensitivity (Sections 4 and 5). To ensure fairness in the case where the information asymmetry is only on consumers' relative price sensitivity, we consider high and low unit production costs (c^H and c^L) separately. Note by $\Pi_G^{DLH} > \Pi_G^{DLL}$ and condition (23) that $k < \min\{\Pi_G^{DHH}, \Pi_G^{DLH}\}$ and $\Pi_G^{DHL} < k < \Pi_G^{DLL}$. This indicates that, if the information asymmetry is only on consumers' relative price sensitivity, the generic firm always enters the market when the brand-name firm's unit production cost is equal to c^H; however, when the brand-name firm's unit production cost is c^L, the generic firm enters the market if he knows consumers' relative price sensitivity is b^L and stays out otherwise.

Proposition 5 characterizes the impact of more sources of information asymmetry on the brand-name firm's limit pricing strategy, the GCP, consumer surplus and social welfare.

PROPOSITION 5. *Suppose that the discounted fixed capacity cost k satisfies condition* (23)*. Relative to the case with information asymmetry only on consumers' relative price sensitivity, there are more cases of the GCP occuring, brand-name firm using limit pricing to deter generic entry, and information asymmetry benefiting consumers and society, when the brand-name firm has information asymmetry on consumers' relative price sensitivity and its unit production cost.*

Proposition 5 shows that more sources of information asymmetry deter generic entry and lead to the GCP, yet it ultimately benefits the consumers in more cases. Recall from above that, when the information asymmetry is only on consumers' relative price sensitivity, the brand-name firm with unit production cost c^H (i.e., HH or LH types) cannot prevent generic entry. However, when the brand-name firm's unit production cost is also unknown to the generic firm, the brand-name firm with the unit production cost c^H can limit its price and deter the generic entry by mimicking the $HL-$type brand-name firm with low unit production cost c^L. Consequently, having more sources of information asymmetry creates more types, which the brand-name firm can mimic and use to prevent the generic entry. This leads to the generic entry in the signaling period in fewer cases, and makes limit pricing and the GCP more likely to occur. However, fewer cases of generic entry don't necessarily imply a decrease in consumer surplus and social welfare, as the information asymmetry leads to higher profits for the brand-name firm and/or lower brand-name drug prices for consumers.

6.3. Multiple Generic Firms

We now extend our base model in Section 3 by considering $N < \infty$ identical generic firms with the same fixed capacity cost K,[9] and, in line with Kong (2009) and Ferrara and Missios (2012), we assume that these firms engage in Cournot (quantity) competition among themselves and in price competition with the brand-name firm. For brevity, we defer our analysis of the multiple generic firms, which confirms the robustness of our main results, to Online Appendix E.

In addition, as summarized in Proposition 6, we characterize the impact of the number of generic firms on brand-name firm's limit pricing strategy, the GCP and consumer surplus.[10]

PROPOSITION 6. *In the stable equilibrium, an increase in the number of generic firms N leads to more cases of $L-$type brand-name firm using limit pricing to deter generic entry and to fewer cases of the GCP occuring or information asymmetry benefiting the consumers.*

The entry of more generic firms intensifies market competition, significantly reducing the prices and profits of the brand-name firm post-entry. This increases brand-name firm's incentive to deter generic entry and decreases the extent and likelihood of the increase in brand-name firm's price after the generic entry. Consequently, Proposition 6 follows.

6.4. Sequential Generic Entry

Lastly, we extend our base model in Section 3 by considering two generic firms with different (high and low) fixed capacity costs. We normalize the fixed capacity cost of the 'low-cost' generic firm to zero and let $K > 0$ denote the fixed capacity cost of the 'high-cost' generic firm. At the beginning of the signaling period, both generic firms have the same information about the market and do not know the actual type of the brand-name firm. Specifically, we use λ_b to denote the low- and high-cost generic firms' prior probability that consumers' relative price sensitivity is b^H so that the brand-name firm is $H-$type. In this setting, as in Section 6.3, generic firms engage in price competition with the brand-name firm, while they compete in quantity between themselves.

Regardless of the brand-name firm's type, the low-cost generic firm enters the market at the beginning of the signaling period since his fixed capacity cost is zero. In addition, to ensure that the sequential entry can occur, we suppose that the high-cost generic firm enters the market when he

[9] When generic firms have different fixed capacity costs, our results still hold true if the generic firm with the lowest fixed capacity cost can be deterred.

[10] Analytically characterizing the impact of an increase in the number of generic firms N on the effect of information asymmetry on social welfare is challenging. However, through numerical examples, we observe that, with a larger N, information asymmetry leads to an increase in social welfare in fewer cases.

knows the brand-name firm is $L-$type but he stays out when he knows that the brand-name firm is $H-$type or he does not know the actual type of the brand-name firm.

Online Appendix F analyses the setting described above, and shows that our main results hold true, even when generic firms sequentially enter the market. (See Online Appendix F for further details.) Interestingly, we find that, in case of sequential generic entry, there can be a tacit collusion between the $L-$type brand-name and low-cost generic firms, and they collectively deter the entry of the high-cost generic firm in the signaling period. We present this result in Proposition 7. (See Online Appendix F for the definitions of the thresholds $\bar{b}^{H(0)}(b^L)$ and $\bar{b}^{H(1)}(b^L)$ in Proposition 7.)

PROPOSITION 7. *The $L-$type brand-name and low-cost generic firms have a tacit collusion and, respectively, charge prices p_B^{DH} and p_G^{DH} to deter the entry of the high-cost generic firm in the signaling period if, and only if, $b^L < b^H \leq \min\{\bar{b}^{H(0)}(b^L), \bar{b}^{H(1)}(b^L), 1\}$.*

Proposition 7 asserts that the $L-$type brand-name firm and low-cost generic firm engage in tacit collusion and jointly prevent the entry of the high-cost generic firm in the signaling period when b^H is not too high. The low-cost generic firm always enters the market; however, the $L-$type brand-name firm can prevent the entry of the high-cost generic firm. When b^H is not too high, the $L-$type brand-name firm is better off preventing the entry of the high-cost generic firm by setting its price at p_B^{DH} and signaling that it is of $H-$type. However, the low-cost generic firm's entry complicates matters, as he quickly discerns the brand-name firm's type upon entering. Consequently, he must collude with the $L-$type brand-name firm, choosing a price that does not reveal the actual type of the brand-name firm. In this case, it is always optimal for the low-cost generic firm to collude with the $L-$type brand-name firm tacitly and indicate to its high-cost generic competitor that the brand-name firm is $H-$type by setting his price at p_G^{DH}. By doing so, the low-cost generic firm can charge a higher price and face softer competition, ultimately leading to higher profits. This suggests that not only brand-name firms but also generic firms can be anticompetitive and prevent entry of their generic competitors.

Moreover, without collusion between the $L-$type brand-name firm and the low-cost generic firm, the brand-name firm's type is always revealed, leading the high-cost generic firm to enter the market right at the beginning of the signaling period. In this case, there is no increase in the brand-name firm's price, and the GCP never occurs. This highlights that, in the presence of sequential generic entry under information asymmetry, the key driver behind the GCP is the tacit collusion between brand-name and generic firms. Furthermore, it suggests that, once a generic firm is already present in the market, an increase in the brand-name firm's price due to an additional generic entry (e.g., see Regan 2008, Ching 2010a) requires collusion between the brand-name and generic firms, and the GCP becomes increasingly more difficult to observe.

7. Discussion and Concluding Remarks

Contrary to traditional economic theory's expectation that generic drug entry would lower brand-name drug prices through competition, the prices of some brand-name drugs increase after generic drugs enter the market, a paradoxical situation known as the GCP (Regan 2008, Ferrara and Missios 2012). The existing research, attributing this paradox solely to consumer heterogeneity and pseudo-generic drugs, cannot provide a thorough explanation for the GCP (Regan 2008, Fowler et al. 2023). Moreover, brand-name firms, benefiting from their prolonged market presence and extensive resources, possess more knowledge about the market and consumers compared to generic firms (Branstetter et al. 2016, Ellison and Ellison 2011). This disparity in information, a significant factor in shaping pharmaceutical market dynamics, is underexplored in existing research. To address this gap, we developed a game-theoretic model to analyse the information asymmetry of brand-name firms regarding market and consumers, and identify its role in the GCP that is frequently observed in pharmaceutical markets. Our analysis provides useful insights on pharmaceutical markets and has important policy implications.

- *Do brand-name firms exploit their information asymmetry regarding the market and consumers to engage in anticompetitive practices?* We find that, when market entry is profitable for the generic firm, a brand-name firm, by leveraging its private information, can strategically set prices just low enough to deter entry, effectively maintaining its monopolistic status. This practice of limit pricing is anticompetitive as it restricts profitable market entry of the generic firm and limits competition (Ellison and Ellison 2011, Peelish 2020). However, we also identify cases where a brand-name firm uses limit pricing to deter entry in situations where it would be unprofitable for the generic firm, suggesting that a brand-name firm's use of limit pricing strategy does not always harm the generic firm. Regulatory bodies should carefully assess the impact of limit pricing and intervene to eliminate its negative effects on consumers and society.
- *Does the information asymmetry of brand-name firms regarding the market and consumers play any role in the GCP?* We demonstrate that, during the signaling period, the brand-name firm can set its price below its monopoly level to deter generic entry, and then later increase its price, allowing generic entry in the full-information period. Consequently, the anticompetitive use of limit pricing strategy by the brand-name firm can lead to the GCP under information asymmetry. Thus, beyond consumer heterogeneity and pseudo-generic drugs (e.g., Frank and Salkever 1992, Ferrándiz 1999, Kong 2009), we identify information asymmetry as an additional explanation for the GCP frequently observed in pharmaceutical markets. This emphasizes that regulatory measures aiming to mitigate the GCP in pharmaceutical markets should consider addressing the information asymmetry and monitor limit pricing strategies by brand-name firms.

- *How do the brand-name firms' information asymmetry and the GCP affect consumers and society?* Our findings reveal that the information asymmetry in pharmaceutical markets, contributing to the GCP, can harm consumers and society by enabling brand-name firms to manipulate drug prices and market entry. Despite the presence of generic drugs, this manipulation often leads to higher drug prices, reduced consumer choice, and increased healthcare spending (Lexchin 2004, Feldman 2020). In certain cases, however, we find that the information asymmetry lowers prices for brand-name drugs prior to generic entry, thereby making them more accessible for consumers. Consequently, consumers and the society can benefit from the information asymmetry and resulting GCP. This indicates that an effective management of information asymmetry in pharmaceutical markets requires a balanced strategy that prevents brand-name firms from manipulating drug prices and market entry, while also using its potential to temporarily lower prices and increase consumer access. Ultimately, this optimizes outcomes for consumers and society.

Limitations and future research: Our model is not without limitations and can be extended in several ways. First, we assume a static market and do not account for the potential evolution of consumers and firms over time, an area that future research can investigate. Second, we do not consider the information asymmetry held by the generic firms (e.g., regarding their fixed capacity costs and drug development capabilities), a potential direction for future research. Third, our model does not consider pseudo-generic drugs developed by brand-name firms under information asymmetry. Future research could explore how this asymmetry influences brand-name firms' introduction of pseudo-generic drugs to compete with generics. Lastly, our analysis overlooks the competition among brand-name firms and the intermediary role of Pharmacy Benefit Managers, both crucial factors that can significantly influence market dynamics. Future extensions of our paper can explore these aspects.

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Online Appendix
Generic Competition Paradox and the Role of Information Asymmetry in Pharmaceutical Markets

Contents

A. Auxiliary Results

A.1. Comparison of Prices and Profits in the Monopoly and Duopoly Settings

Lemma A.1 compares the prices and profits in the monopoly and duopoly settings. We use this lemma when analyzing the equilibrium.

LEMMA A.1. *Suppose that the condition in (8) is satisfied for $i \in \{H, L\}$.*

(i) The $i-$type brand-name firm charges a higher price and obtains higher profits in the monopoly setting than in the duopoly setting, i.e., $p_B^{Mi} > p_B^{Di}$ and $\Pi_B^{Mi} > \Pi_B^{Di}$ for $i \in \{H, L\}$.

(ii) In the duopoly setting, the price of $i-$type brand-name firm is higher than the price of the generic firm, i.e., $p_B^{Di} > p_G^{Di}$ for $i \in \{H, L\}$.

(iii) In the duopoly setting, $i-$type brand-name firm's profit decreases as consumers become more price sensitive (i.e., Π_B^{Di} is decreasing in b^i) for $i \in \{H, L\}$.

Proof of Lemma A.1. We prove each part of the lemma separately.

Part (i). By comparing p_B^{Mi} in (4) and p_B^{Di} in (7), we have $p_B^{Mi} > p_B^{Di}$ for $i \in \{H, L\}$. Also by (4) and (9), we obtain

$$\begin{aligned}\Pi_B^{Mi} - \Pi_B^{Di} &> (p_B^{Di} - c)(\alpha_B - b^i p_B^{Di}) - \Pi_B^{Di} \\ &= \frac{\left[\alpha_G(4 - 3b^i\gamma^2) - (\alpha_B - b^i c)\gamma(2 - b^i\gamma^2)\right]}{8(2 - b^i\gamma^2)^2(1 - b^i\gamma^2)/\gamma}\left[(\alpha_B - b^i c)(2 - b^i\gamma^2) - b^i\gamma\alpha_G\right] > 0,\end{aligned}$$

where the first inequality follows from $p_B^{Mi} = \arg\max_{p_B}(p_B - c)(\alpha_B - b^i p_B)$ and $(p_B^{Mi} - c)(\alpha_B - b^i p_B^{Mi}) > (p_B^{Di} - c)(\alpha_B - b^i p_B^{Di})$, and the second inequality holds by (8).

Part (ii). Using (7), we obtain

$$p_B^{Di} - p_G^{Di} = \frac{1}{4}\Big(\frac{2\alpha_B}{b^i} - 3\alpha_G + \alpha_B\gamma + c(2 - b^i\gamma) + \frac{2\alpha_G(1-\gamma)}{2 - b^i\gamma^2}\Big), \text{ for } i \in \{H, L\}.$$

Then, by $\alpha_B > \alpha_G$, and, by taking the derivative with respect to b^i, we have

$$\frac{\mathrm{d}(p_B^{Di} - p_G^{Di})}{\mathrm{d}b^i} = \frac{1}{4}\Big(-\frac{2\alpha_B}{(b^i)^2} + \frac{2\alpha_G(1-\gamma)\gamma^2}{(2 - b^i\gamma^2)^2} - c\gamma\Big) < \frac{1}{2}\alpha_B\Big(\frac{(1-\gamma)\gamma^2}{(2 - b^i\gamma^2)^2} - \frac{1}{(b^i)^2}\Big) < 0,$$

where the first inequality follows from $\alpha_B > \alpha_G$, and the second inequality follows from $\frac{(1-\gamma)\gamma^2}{(2-b^i\gamma^2)^2} < 1$. Therefore, $p_B^{Di} - p_G^{Di}$ is decreasing in b^i. In addition,

$$\left(p_B^{Di} - p_G^{Di}\right)\big|_{b^i=1} = \frac{1}{4}\Big(\alpha_B(2+\gamma) + \alpha_G\frac{3\gamma^2 - 2\gamma - 4}{2 - \gamma^2} + c(2 - \gamma)\Big) > \frac{1}{4}\Big(\frac{\alpha_G(1-\gamma)\gamma^2}{2 - \gamma^2} + c(2-\gamma)\Big) > 0,$$

where the first inequality above follows from $\alpha_B > \alpha_G$ and the last inequality follows from $\gamma \in (0, 1)$. This, by $p_B^{Di} - p_G^{Di}$ being decreasing in b^i, implies that $p_B^{Di} > p_G^{Di}$ for $i \in \{H, L\}$.

Part (iii). Taking the derivative of Π_B^{Di} in (9) with respect to b^i, we have

$$\begin{aligned}\frac{\mathrm{d}\Pi_B^{Di}}{\mathrm{d}b^i} =& \frac{(\alpha_B - b^i c)(2 - b^i\gamma^2) - b^i\gamma\alpha_G}{8(b^i)^2(2 - b^i\gamma^2)(1 - b^i\gamma^2)^2} \\ &\times\Big(\alpha_B(4b^i\gamma^2 - (b^i)^2\gamma^4 - 2) - \frac{c(4 - 6b^i\gamma^2 + 4(b^i)^2\gamma^4 - (b^i)^3\gamma^6) + \gamma\alpha_G(2 - (b^i)^2\gamma^4)}{(2 - b^i\gamma^2)/b^i}\Big) < 0,\end{aligned}$$

where the inequality follows from the first term outside the parenthesis being positive and the second term inside the parenthesis being linear in α_B and negative by (8). The above inequality implies that the brand-name firm's duopoly profit, Π_B^{Di}, is decreasing in b^i so that $\Pi_B^{DL} > \Pi_B^{DH}$. □

A.2. A Necessary Condition for the GCP

Lemma A.2 shows that condition (11) is necessary for the GCP to occur.

LEMMA A.2. *The GCP occurs only if the discounted fixed capacity cost k satisfies* (11).

A.2.1. Proof of Lemma A.2 We will prove the lemma in three steps. In step 1, we will show that if $(1-\lambda_b)\Pi_G^{DL}+\lambda_b\Pi_G^{DH}\geq k$, the GCP cannot happen, and hence, $(1-\lambda_b)\Pi_G^{DL}+\lambda_b\Pi_G^{DH}<k$ must hold for the GCP to occur. In step 2, we will show that, in cases where $(1-\lambda_b)\Pi_G^{DL}+\lambda_b\Pi_G^{DH}<k$, the GCP occurs only if $\Pi_G^{DL}>\Pi_G^{DH}$. In step 3, we will show that, when $(1-\lambda_b)\Pi_G^{DL}+\lambda_b\Pi_G^{DH}<k$ and $\Pi_G^{DL}>\Pi_G^{DH}$, the GCP occurs only if $k<\Pi_G^{DL}$.

Step 1: Suppose to the contrary that $(1-\lambda_b)\Pi_G^{DL}+\lambda_b\Pi_G^{DH}\geq k$. In this case, none of the brand-name firm types can prevent the generic entry by mimicking the other type; therefore, $H-$ and $L-$type brand-name firms will choose different prices and reveal their types at the beginning of the signaling period. As a result, the generic firm can distinguish between the two brand-name firm types, and he will either enter at the beginning of the signaling period or never enter the market. There is a price decrease in the former case after generic entry while there is no generic entry in the latter case. Thus the GCP can never occur in such cases.

Step 2: Suppose $\Pi_G^{DL}\leq\Pi_G^{DH}$ and $(1-\lambda_b)\Pi_G^{DL}+\lambda_b\Pi_G^{DH}<k$. In this case, if $k\geq\Pi_G^{DH}$, the generic entry is never profitable and hence the GCP cannot occur.

Now consider cases where $(1-\lambda_b)\Pi_G^{DL}+\lambda_b\Pi_G^{DH}<k<\Pi_G^{DH}$. In such cases, there can only be two types of equilibrium, namely, separating or pooling equilibrium. In the separating equilibrium, H and L types of the brand-name firm charge different prices so that the generic firm can infer their types. Thus, in a separating equilibrium, the generic firm enters the market at the beginning of the signaling period if the brand-name firm is $H-$type and never enters if the brand-name firm is $L-$ type since $(1-\lambda_b)\Pi_G^{DL}+\lambda_b\Pi_G^{DH}<k<\Pi_G^{DH}$. There is a price decrease after generic entry in the former case while there is no generic entry in the latter case. Thus, no GCP occurs in a separating equilibrium. In a pooling equilibrium, both types pool and charge the same price so that the generic firm cannot infer the brand-name firm's type. In a pooling equilibrium, the generic firm always stays out in the signaling period (by $(1-\lambda_b)\Pi_G^{DL}+\lambda_b\Pi_G^{DH}<k$) and enters the market in the full-information period only if the brand-name firm is $H-$type (by $(1-\lambda_b)\Pi_G^{DL}+\lambda_b\Pi_G^{DH}<k<\Pi_G^{DH}$). Thus the GCP can occur in a pooling equilibrium only when the brand-name firm is $H-$type. In such a case, for the GCP to occur, the pooling price in the signaling period must be less than the postentry price (p_B^{DH}) of the brand-name drug in the full-information period. However, the pooling price in the signaling period cannot be less than p_B^{DH} since both $H-$ and $L-$type brand-name firms are monopoly in the signaling period and can improve their profits by increasing their prices above p_B^{DH} (since $p_B^{ML}>p_B^{MH}>p_B^{DH}$ by (4) and Lemma A.1(i)) but still pool together. Consequently, the GCP cannot occur in a pooling equilibrium when $(1-\lambda_b)\Pi_G^{DL}+\lambda_b\Pi_G^{DH}<k<\Pi_G^{DH}$.

Step 3: Consider cases where $(1-\lambda_b)\Pi_G^{DL}+\lambda_b\Pi_G^{DH}<k$ and $\Pi_G^{DL}>\Pi_G^{DH}$. There will never be entry in such cases if $k\geq\Pi_G^{DL}$. Thus, the GCP can occur only if $k<\Pi_G^{DL}$. $\square$

A.3. A Sufficient Condition for $\Pi_G^{DL} > \Pi_G^{DH}$

By Lemma A.3, we identify a sufficient condition on our model parameters to ensure $\Pi_G^{DL} > \Pi_G^{DH}$ for all $0 < b^L < b^H < 1$. In doing so, we aim to show that there are cases where the necessary condition in (11) is valid and hence our results apply. Throughout this paper, we restrict our attention to cases where conditions (11) and (A.1) are satisfied.

LEMMA A.3. *The generic firm earns more when facing an $L-$type brand-name firm than when facing an $H-$type one (i.e., $\Pi_G^{DL} > \Pi_G^{DH}$) for all $0 < b^L < b^H < 1$, if*

$$\frac{2c}{\gamma^2} + \frac{\alpha_G}{\gamma} \le \alpha_B \le \frac{\alpha_G(4-3\gamma^2)}{\gamma(2-\gamma^2)} + c \text{ and } \alpha_G \ge \frac{c(2-\gamma^2)^2}{2\gamma(1-\gamma^2)}. \tag{A.1}$$

Lemma A.3 shows that when consumers' valuation for the generic drug is sufficiently high and their valuation for the brand-name drug is moderate (i.e., α_B and α_G satisfy the condition in (A.1)), the generic firm's duopoly profit Π_G^{Di} in (10) is decreasing in consumers' relative price sensitivity to the brand-name drug $b^i \in (0,1)$. In the duopoly setting, an increase in consumers' price-sensitive b^i always leads to a lower price for the brand-name firm and, due to the competition, also for the generic firm. Moreover, the net effect of consumers' relative price sensitivity on the demand for the generic drug is not clear. However, in cases where α_B and α_G satisfy condition in (A.1), the generic firm's profit always decreases in consumers' relative price sensitivity to the brand-name drug either because both the price and demand of the generic drug decrease (e.g., see Tirole 1988, for relevant discussions), or because the decrease in generic drug's price dominates the increase in its demand. Consequently, in such cases, the generic firm earns more profit when facing an $L-$type brand-name than when facing an $H-$type for all $0 < b^L < b^H < 1$.

A.3.1. Proof of Lemma A.3

Firstly, we are only interested in positive profits Π_G^{DL} and Π_G^{DH} in the comparison. Recall from Lemma 1 that condition (8) ensures that both Π_G^{DL} and Π_G^{DH} are positive for $i \in \{H, L\}$. Thus, for $\forall\ 0 < b^L < b^H < 1$, condition (8) being satisfied is equivalent to (A.2) being satisfied, which is given below:

$$\max\left\{\alpha_G, \frac{\gamma\alpha_G}{2-\gamma^2}\right\} < \alpha_B \le \min\left\{\frac{2\alpha_G}{\gamma}, \frac{\alpha_G(4-3\gamma^2)}{\gamma(2-\gamma^2)} + c\right\}. \tag{A.2}$$

Next, we will characterize the cases where Π_G^{Di} is decreasing in b^i so that $\Pi_G^{DL} > \Pi_G^{DH}$. To avoid confusion, we drop the superscript i from b^i and Π_G^{Di} given by (10) and use b and Π_G^D instead. Then, we identify a subset of (A.2) such that $\mathrm{d}\Pi_G^D/\mathrm{d}b < 0$ in the domain $b \in (0,1)$. The first-order derivative (with respect to b) of the profit Π_G^D is given by

$$\frac{\mathrm{d}\Pi_G^D}{\mathrm{d}b} = \underbrace{\frac{\gamma^3\left[(\alpha_B - bc)(2-b\gamma^2)\gamma - \alpha_G(4-3b\gamma^2)\right]}{16(2-b\gamma^2)(1-b\gamma^2)^2}}_{<0}[\alpha_B - \alpha(b)], \tag{A.3}$$

where

$$\alpha(b) := \frac{\gamma\alpha_G(4-6b\gamma^2+3b^2\gamma^4) + c(2-b\gamma^2)^3}{(2-b\gamma^2)^2\gamma^2}. \tag{A.4}$$

Since the first term outside of the bracket in (A.3) is negative by (8), we focus on the properties of $\alpha(b)$. Note that (A.2) is a subset of (8). The derivatives of $\alpha(b)$ with respect to b are:

$$\frac{\mathrm{d}\alpha(b)}{\mathrm{d}b} = \frac{2\gamma\alpha_G(3b\gamma^2-2)}{(2-b\gamma^2)^3} - c, \ \left.\frac{\mathrm{d}\alpha(b)}{\mathrm{d}b}\right|_{b=0} < 0, \text{ and } \frac{\mathrm{d}^2\alpha(b)}{\mathrm{d}b^2} = \frac{12b\gamma^5\alpha_G}{(2-b\gamma^2)^4} > 0.$$

Thus, $\alpha(b)$ is convex in b, and we have

$$\max_{b\in[0,1]} \alpha(b) = \max\{\alpha(0), \alpha(1)\} = \alpha(0) \equiv \frac{\alpha_G}{\gamma} + \frac{2c}{\gamma^2}.$$

Hence, if $\alpha_B \geq \alpha(0)$, the term in the bracket in (A.3) is positive, and thus we always have $\mathrm{d}\Pi_G^D/\mathrm{d}b < 0$ for $b \in (0,1)$.

Therefore, by considering the intersection of $\alpha_B \geq \alpha(0)$ and (A.2), we obtain the following condition to ensure that Π_G^D is decreasing in $b \in (0,1)$, that is, for $\forall\ b \in (0,1)$, $\Pi_G^{DL} > \Pi_G^{DH}$ if

$$\frac{2c}{\gamma^2} + \frac{\alpha_G}{\gamma} \leq \alpha_B \leq \frac{\alpha_G(4-3\gamma^2)}{\gamma(2-\gamma^2)} + c \text{ and } \alpha_G \geq \frac{c(2-\gamma^2)^2}{2\gamma(1-\gamma^2)}, \tag{A.5}$$

where the lower bound of α_G follows from that the upper bound of α_B should be equal to or larger than its lower bound. $\square$

A.4. Conditions for Separating and Pooling Equilibria

Here, we derive necessary and sufficient conditions that we use to characterize the separating and pooling equilibrium in §§4.1 and 4.2. In a separating equilibrium, the $H-$ and $L-$type brand-name firm, respectively, charges different prices $\hat{p}_B^H$ and $\hat{p}_B^L$ ($\hat{p}_B^H \neq \hat{p}_B^L$) based on their true type $i = H, L$. Thus, the generic firm can infer its type after observing the brand-name drug's price $\hat{p}_B^i$. By (11), the generic firm enters if he knows the brand-name firm is $L-$type and stays out if he knows it is $H-$type. By analyzing the generic firm's market entry decision after he observes price $\hat{p}_B^i$, Lemma A.4(i) derives necessary and sufficient conditions for a price pair $(\hat{p}_B^L, \hat{p}_B^H)$ must satisfy to be the prices of two brand-name firm types in a separating equilibrium.

In a pooling equilibrium, both brand-name firm types charge the same price so that the generic firm cannot infer their types by observing the price. Thus, in a pooling equilibrium, the generic firm's prior and posterior beliefs about the brand-name firm are the same, i.e., the generic firm believes that the brand-name firm is $H-$type with probability λ_b. Lemma A.4(ii) characterizes necessary and sufficient conditions for the price in a pooling equilibrium.

LEMMA A.4. *(i) The price pair $(\hat{p}_B^L, \hat{p}_B^H)$ is part of a separating perfect Bayesian equilibrium if, and only if, $\hat{p}_B^L = p_B^{DL}$ and $\hat{p}_B^H$ satisfies (12) and (13).*

(ii) The price $\hat{p}_B$ is part of a pooling perfect Bayesian equilibrium if, and only if, it satisfies (15) and (16).

A.4.1. Proof of Lemma A.4

We prove each part of the lemma separately.

Part (i). We first prove the "If" part of Lemma A.4(i), i.e., any price pair $(\hat{p}_B^L, \hat{p}_B^H)$ is part of a separating equilibrium if $\hat{p}_B^L = p_B^{DL}$ and $\hat{p}_B^H$ satisfies (12) and (13). As the perfect Bayesian equilibrium (PBE) does not impose restrictions on off-equilibrium beliefs, it is innocuous to specify the generic firm's off-equilibrium belief: For $p_B \neq \hat{p}_B^H$, the generic firm believes that the brand-name firm is of $L-$type. Under such a belief, p_B^{DL} is the rational decision for the $L-$type brand-name firm since (i) there is generic entry if it does not charge $\hat{p}_B^H$ and p_B^{DL} maximizes the brand-name firm's post-entry profit in case of entry, and (ii) charging $\hat{p}_B^H$ to mimic the H type is worse than charging p_B^{DL} by (12). Moreover, by (13), $H-$type brand-name firm does not mimic the L type. Note that the generic firm's belief is also consistent with the Bayes' rule. Thus, any price pair $(\hat{p}_B^L, \hat{p}_B^H)$, where $\hat{p}_B^L = p_B^{DL}$ and $\hat{p}_B^H$ satisfies (12) and (13), is part of a separating equilibrium.

Next we prove the "Only if" part of Lemma A.4(i). Suppose to the contrary that the price pair $(\hat{p}_B^L, \hat{p}_B^H)$ is a separating PBE, but at least one of the three conditions, i.e., $\hat{p}_B^L = p_B^{DL}$, (12), and (13), is violated. Note that we do not need any specification of off-equilibrium beliefs to prove "Only if" part. First, suppose that $\hat{p}_B^L \neq p_B^{DL}$. As the generic firm will enter the market after observing the separating price $\hat{p}_B^L$ by (11), $p_B^{DL} = \arg\max_{p_B} \Pi_B(L, p_B, L)$, and $\Pi_B(L, p_B^{DL}, H) > \Pi_B(L, p_B^{DL}, L)$, the $L-$type brand-name firm is always better off by charging p_B^{DL} than any other price $\hat{p}_B^L$, regardless whether the generic firm believes that the brand-name firm is H or L type. Thus, offering price $\hat{p}_B^L$ other than p_B^{DL} is irrational for the $L-$type brand-name firm, which violates the sequential rationality in a PBE. Second, suppose (12) does not hold (i.e., $\Pi_B(L, p_B^{DL}, L) < \Pi_B(L, \hat{p}_B^H, H)$) in a separating equilibrium. Then, the $L-$type brand-name firm has incentives to mimic the $H-$ type by deviating to the price $\hat{p}_B^H$, which contradicts to $\hat{p}_B^L = p_B^{DL}$ and $\hat{p}_B^H$ being separating prices in the PBE. Lastly, suppose (13) does not hold (i.e., $\Pi_B(H, \hat{p}_B^H, H) < \max_{p_B \neq \hat{p}_B^H} \Pi_B(H, p_B, L)$) in a separating equilibrium. In this case, it is clear that the H type is better off by deviating to some other price, even if this leads to the generic firm's belief that the brand-name firm is of $L-$type, which is a contradiction to $\hat{p}_B^H$ being part of a separating equilibrium.

Part (ii). As in Part (i) above, we first prove the "If" part of Lemma A.4(ii), i.e., the price $\hat{p}_B$ satisfying (15) and (16) is part of a pooling PBE. To show this, it is innocuous to specify the most unfavourable off-equilibrium belief: when observing an off-equilibrium price, the generic firm believes that the price is offered by the $L-$type brand-name firm (and thus will surely enter the market). Then it is clear that due to (15) and (16), both $H-$ and $L-$type brand-name firms are better off by charging price $\hat{p}_B$ than any other price (under which the generic firm believes that the brand-name firm is of $L-$type). This confirms that offering $\hat{p}_B$ satisfies the sequential rationality for the brand-name firm.

We next prove the "Only if" part of Lemma A.4(ii). Suppose to the contrary that $\hat{p}_B$ is part of a pooling PBE, but violates condition (15) or (16). It is clear that if (15) or (16) is violated, either the $H-$ or $L-$type brand-name firm must be better off by deviating to some other price, even if the generic firm believes that the brand-name firm is of $L-$type and enters the market, which contradicts to $\hat{p}_B$ being part of a pooling PBE. Note that we do not need any specification of off-equilibrium beliefs to prove "Only if" part. $\square$

A.5. Technical Results and Properties of Thresholds

A.5.1. Thresholds in Equilibrium Analysis. In this appendix, we characterize several properties of the thresholds $b^{H(1)}(b^L)$ and $b^{L(2)}(b^H)$ and derive additional technical results that we use to characterize the separating and pooling equilibrium in Appendix B. Specifically, in line with their definitions in the paper, we define the thresholds as follows:

$$b^{H(1)}(b^L) = \frac{2\alpha_B b^L}{2\alpha_B - \sqrt{\frac{4\alpha_G^2 b^L}{2-b^L\gamma^2} - \frac{2b^L\left((\alpha_B - b^L c)\gamma - \alpha_G\right)^2}{1-b^L\gamma^2}}}, \tag{A.6}$$

$$b^{L(2)}(b^H) = \frac{2\alpha_B b^H}{2\alpha_B + \sqrt{\frac{4\alpha_G^2 b^H}{2-b^H\gamma^2} - \frac{2b^H\left((\alpha_B - b^H c)\gamma - \alpha_G\right)^2}{1-b^H\gamma^2}}}. \tag{A.7}$$

Similarly, in line with the paper, we define $b^{L(1)} \in (0, b^H)$ as the unique b^L value that satisfies $b^{H(1)}(b^{L(1)}) = 1$, $b^{L(3)}$ as the unique $b^L \in (0, b^{L(1)})$ satisfying $b^{H(1)}(b^L) = b^{L(2)}(1)$, and $b^{\tilde{H}(1)}(b^L)$ as the unique b^H that satisfies $b^{L(2)}(b^H) = b^{H(1)}(b^L)$ for $b^L \in (0, b^{L(3)})$ and $b^H \in (b^{H(1)}(b^L), 1)$.

To characterize the properties of the thresholds, we need the following Lemma A.5. Note that $b^{H(1)}(b^L) \equiv \beta^{(1)}(b^L)$ and $b^{L(2)}(b^H) \equiv \beta^{(2)}(b^H)$.

LEMMA A.5. *Suppose that condition (A.1) is satisfied, and for $b \in (0,1)$, define*

$$\beta^{(1)}(b) := \frac{2\alpha_B b}{2\alpha_B - \sqrt{\frac{4\alpha_G^2 b}{2-b\gamma^2} - \frac{2b\left((\alpha_B - bc)\gamma - \alpha_G\right)^2}{1-b\gamma^2}}}, \tag{A.8}$$

$$\beta^{(2)}(b) := \frac{2\alpha_B b}{2\alpha_B + \sqrt{\frac{4\alpha_G^2 b}{2-b\gamma^2} - \frac{2b\left((\alpha_B - bc)\gamma - \alpha_G\right)^2}{1-b\gamma^2}}}. \tag{A.9}$$

(i) $\beta^{(1)}(b)$ is strictly increasing in $b \in (0,1)$, and there exists unique $b_1 \in (0,1)$ such that $\beta^{(1)}(b_1) = 1$.

(ii) $\beta^{(2)}(b)$ is strictly increasing in $b \in (0,1)$.

By using Lemma A.5, we identify several properties of thresholds $b^{H(1)}(b^L)$ and $b^{L(2)}(b^H)$ as summarized in Lemma A.6.

LEMMA A.6. *Suppose that condition (A.1) is satisfied.*

(i) The threshold $b^{H(1)}(b^L)$ is strictly increasing in $b^L \in (0,1)$; moreover, $b^L < b^{H(1)}(b^L) < 1$ if, and only if, $b^L \in (0, b^{L(1)})$.

(ii) The threshold $b^{L(2)}(b^H)$ is strictly increasing in $b^H \in (0,1)$.

(iii) The threshold values satisfy $b^{L(2)}(b^H) > b^{H(1)}(b^L)$ for $b^L \in (0, b^{L(1)})$ and $b^H \in (b^{H(1)}(b^L), 1)$, if and only if $b^L \in (0, b^{L(3)})$ and $b^H \in (b^{\tilde{H}(1)}(b^L), 1)$.

Lastly, by using Lemma A.6, we obtain the technical results in Lemma A.7, which we use to derive the separating and pooling equilibria in Lemmas 2 and 3 in the paper.

LEMMA A.7. *Suppose that condition (A.1) is satisfied. For $i \in \{H, L\}$, given price $p \in \left[c, \frac{\alpha_B}{b^i}\right]$, define the $i-$type brand-name firm's monopoly profit as follows:*

$$\Pi_B^{Mi}(p) = (p-c)(\alpha_B - b^i p). \tag{A.10}$$

(i) For $i \in \{H, L\}$, $\Pi_B^{Mi}(p) \geq \Pi_B^{Di}$ if, and only if, $p \in [p_1^i, p_2^i]$, where $p_1^i \in (c, p_B^{Mi})$ and $p_2^i \in (p_B^{Mi}, \frac{\alpha_B}{b^i})$ are given by:

$$p_1^i = \frac{c}{2} + \frac{\alpha_B}{2\beta^{(1)}(b^i)} \tag{A.11}$$

$$p_2^i = \frac{c}{2} + \frac{\alpha_B}{2\beta^{(2)}(b^i)}, \tag{A.12}$$

and p_B^{Mi} and Π_B^{Di} are, respectively, given by (4) and (9), and $\beta^{(1)}(b^i)$ and $\beta^{(2)}(b^i)$ are, respectively, given by (A.8) and (A.9) where $b = b^i$.

(ii) $p_m^H < p_m^L$ for $m \in \{1, 2\}$.

(iii) $p_B^{MH} \leq p_1^L$ if, and only if, $b^L \in (0, b^{L(1)})$ and $b^H \in [b^{H(1)}(b^L), 1)$.

(iv) $p_1^L > p_2^H$ if, and only if, $b^L \in (0, b^{L(3)})$ and $b^H \in (b^{\tilde{H}(1)}(b^L), 1)$.

A.5.2. Thresholds in Welfare Analysis. In this appendix, we characterize several properties of the thresholds $b^{H(3)}(b^L)$ and $b^{H(4)}(b^L)$ and derive additional technical results that we use to analyze the impact of information asymmetry on the consumer surplus and social welfare in Appendix B. In line with their definitions in the paper, we define thresholds $b^{H(2)}(b^L)$, $b^{H(3)}(b^L)$ and $b^{H(4)}(b^L)$ as follows:

$$b^{H(2)}(b^L) = \frac{b^L\alpha_B(2-b^L\gamma^2)}{\alpha_B(2-b^L\gamma^2)-b^L\gamma\alpha_G}, \tag{A.13}$$

$$b^{H(3)}(b^L) := \frac{2\alpha_B b^L}{4\alpha_B-2b^Lc-\sqrt{b^L\Theta_1(b^L)}}, \tag{A.14}$$

$$b^{H(4)}(b^L) := \frac{2\alpha_B b^L}{2b^Lc+\sqrt{32b^Lk+b^L\Theta_2(b^L)}}, \tag{A.15}$$

where letting $\tilde{\alpha}_B^L := \alpha_B - b^L c$,

$$\Theta_1(b^L) := \frac{3(\tilde{\alpha}_B^L)^2}{b^L} + \frac{4\alpha_G^2}{(2-b^L\gamma^2)^2} + \frac{4\alpha_G(\alpha_G+\gamma\tilde{\alpha}_B^L)}{2-b^L\gamma^2} + \frac{(\tilde{\alpha}_B^L)^2+b^L\alpha_G^2-2b^L\gamma\alpha_G\tilde{\alpha}_B^L}{b^L(1-b^L\gamma^2)}, \tag{A.16}$$

$$\Theta_2(b^L) := \frac{11(\tilde{\alpha}_B^L)^2}{b^L} + \frac{4\alpha_G^2}{(2-b^L\gamma^2)^2} + \frac{4\alpha_G(\gamma\tilde{\alpha}_B^L-3\alpha_G)}{2-b^L\gamma^2} + \frac{7((\tilde{\alpha}_B^L)^2+b^L\alpha_G^2-2b^L\gamma\tilde{\alpha}_B^L\alpha_G)}{b^L(b^L\gamma^2-1)}. \tag{A.17}$$

Similarly, in line with the paper, we define $b^{L(5)} \in (0,1)$ as the unique b^L satisfying $b^{H(3)}(b^L)=1$, and $b^{L(6)}$ as the unique $b^L \in (0,1)$ satisfying $b^{H(4)}(b^L)=1$. Then the following Lemma A.8 characterizes the properties of $b^{H(3)}(b^L)$ and $b^{H(4)}(b^L)$.

LEMMA A.8. *Suppose that condition (A.1) is satisfied.*

(i) $b^{H(1)}(b^L) > b^{H(3)}(b^L) > b^{H(2)}(b^L) > b^{H(4)}(b^L) > b^L$ *for all* $b^L \in (0,1)$.

(ii) $b^{H(3)}(b^L) < 1$ *if, and only if,* $b^L \in (0, b^{L(5)})$.

(iii) $b^{H(4)}(b^L) < 1$ *if, and only if,* $b^L \in (0, b^{L(6)})$.

(iv) $0 < b^{L(1)} < b^{L(5)} < b^{L(4)} < b^{L(6)} < 1$.

A.5.3. Proofs

Proof of Lemma A.5. We prove each part of the lemma separately.

Part (i): Let us define the function

$$V_1(\beta,b) = \frac{b\beta^2\gamma}{\alpha_B^2} \times \frac{(\alpha_B-bc)(2-b\gamma^2)(2\alpha_G-\gamma(\alpha_B-bc))-\gamma b\alpha_G^2}{2(1-b\gamma^2)(2-b\gamma^2)} - (\beta-b)^2 \tag{A.18}$$

for $\beta \geq 0$ and $b \in (0,1)$. By (A.8), $\beta^{(1)}(b)$ is the unique β value greater than b that satisfies the quadratic equation $V_1(\beta,b)=0$ for $b\in(0,1)$, i.e., $\beta^{(1)}(b)$ is the larger root of the quadratic equation $V_1(\beta,b)=0$. Taking partial derivative of $V_1(\beta,b)$ with respect to b, we obtain

$$\frac{\partial V_1(\beta,b)}{\partial b} = \frac{\beta^2}{2\alpha_B^2}\phi_1(\alpha_B) + 2(\beta-b),$$

where

$$\phi_1(x) = \frac{4\alpha_G^2}{(2-b\gamma^2)^2} - \frac{(\alpha_G+bc\gamma-\gamma x)\left[\alpha_G-\gamma(x-bc(3-2b\gamma^2))\right]}{(1-b\gamma^2)^2}. \tag{A.19}$$

We have shown in the proof of Lemma A.3 that (A.1) implies

$$\underline{\alpha}(b) \leq \alpha_B \leq \bar{\alpha}(b) := \frac{\alpha_G(4-3b\gamma^2)}{\gamma(2-b\gamma^2)} + bc, \tag{A.20}$$

where $\alpha(b)$ is given by (A.4). Since $\phi_1(\alpha(b))>0$ by (A.5), $\phi_1(\bar{\alpha}(b))=4bc\gamma\alpha_G/(2-b\gamma^2)>0$, and $\phi_1(x)$ being a concave function of x, it follows that $\phi_1(\alpha_B)>0$ for $\alpha(b)\le\alpha_B\le\bar{\alpha}(b)$. This implies that $\partial V_1(\beta,b)/\partial b>0$ for all $b\in(0,1)$ and $\beta\ge b$ when condition (A.1) is satisfied so that $\alpha(b)\le\alpha_B\le\bar{\alpha}(b)$.

Similarly, taking the partial derivative of $V_1(\beta,b)$ in (A.8) with respect to β, we obtain

$$\frac{\partial V_1(\beta,b)}{\partial\beta}=2\beta\left[\frac{V_1(\beta,b)+(\beta-b)^2}{\beta^2}-1+\frac{b}{\beta}\right].$$

Using this and $\beta^{(1)}(b)>b$ being the larger β root of the quadratic equation $V_1(\beta,b)=0$ for $b\in(0,1)$, we, by the implicit function theorem, obtain

$$\frac{d\beta^{(1)}(b)}{db}=\beta^{(1)}(b)\frac{\frac{\partial V_1(\beta^{(1)}(b),b)}{\partial b}}{2b(\beta^{(1)}(b)-b)}>0,$$

where the inequality follows from $\partial V_1(\beta^{(1)}(b),b)/\partial b>0$ and $\beta^{(1)}(b)>b$. Hence, $\beta^{(1)}(b)$ is strictly increasing in $b\in(0,1)$.

Next, we show that there exists $b_1\in(0,1)$ such that $\beta^{(1)}(b_1)=1$. Recall that $\beta^{(1)}(b)$ is the larger β root greater than b that satisfies the quadratic equation $V_1(\beta,b)=0$. Then, by $V_1(1,b)$ being increasing in b, and $V_1(1,0)<0$, and $V_1(1,1)>0$, it follows that there exists $b_1\in(0,1)$ such that $V_1(1,b_1)=0$ so that $\beta^{(1)}(b_1)=1$.

Part (ii): By (A.9), we have $1/\beta^{(2)}(b)=1/b+\sqrt{\gamma V_2(b)}/\alpha_B$, where

$$V_2(b):=\frac{(\alpha_B-b^Hc)(2-b\gamma^2)(2\alpha_G-\gamma(\alpha_B-b^Hc))-\gamma b\alpha_G^2}{2b^H(1-b\gamma^2)(2-b\gamma^2)}.\tag{A.21}$$

Then, to prove $\beta^{(2)}(b)$ is strictly increasing in $b\in(0,1)$, it is sufficient to show that $V_2(b)$ is strictly decreasing in $b\in(0,1)$. Then taking the derivate of $V_2(b)$, we obtain

$$\frac{\mathrm{d}V_2(b)}{\mathrm{d}b}=-\frac{\phi_2(\alpha_B)}{2b^2\left[2+b\gamma^2(b\gamma^2-3)\right]^2},\tag{A.22}$$

where

$$\begin{aligned}\phi_2(x):=&\,x^2\gamma(2-b\gamma^2)^2(2b\gamma^2-1)-2x(2-b\gamma^2)^2\left[b^2c\gamma^3+\alpha_G(2b\gamma^2-1)\right]\\&+b^2\gamma\big(\alpha_G\gamma+c(2-b\gamma^2)\big)\left[c(2-b\gamma^2)+\alpha_G\gamma(3-2b\gamma^2)\right].\end{aligned}\tag{A.23}$$

The denominator of (A.22) is always strictly positive for $\forall b\in(0,1)$ and $\gamma\in(0,1)$. Then to prove that $V_2(b)$ is strictly decreasing in $b\in(0,1)$ when condition (A.1) is satisfied, it is sufficient to show that $\phi_2(\alpha_B)>0$ always holds true when condition (A.1) is satisfied. Since (A.1) is a subset of $[\alpha(0),\bar{\alpha}(b)]$, it is sufficient to show that $\phi_2(\alpha_B)>0$ when $\alpha_B\in[\alpha(0),\bar{\alpha}(b)]$.

By (A.1), we have

$$\alpha_G\ge\frac{c(2-\gamma^2)^2}{2\gamma(1-\gamma^2)}=\max_{b\in(0,1]}\frac{c(2-b\gamma^2)^2}{2\gamma(1-b\gamma^2)}>\frac{c(2-b\gamma^2)^2}{2\gamma(1-b\gamma^2)}.\tag{A.24}$$

Then it follows that

$$\phi_2(\bar{\alpha}(b))=4b\alpha_G(1-b\gamma^2)^2\big[\alpha_G\gamma-c(2-b\gamma^2)\big]>0,\tag{A.25}$$

$$\phi_2(\alpha(0))=\big[4\alpha_G^2\gamma^2(1-b\gamma^2)^3-c^2(2-b\gamma^2)^3(2-3b\gamma^2)\big]/\gamma^3>0.\tag{A.26}$$

This by $\phi_2(x)$ being concave when $b\gamma^2 \le 1/2$ implies that $\phi_2(\alpha_B) > 0$ for all $\alpha_B \in [\alpha(0), \bar{\alpha}(b)]$.

Then it only remains to show that $\phi_2(\alpha_B) > 0$ for $\alpha_B \in [\alpha(0), \bar{\alpha}(b)]$ when $b\gamma^2 > 1/2$. When $b\gamma^2 > 1/2$, $\phi_2(\alpha_B)$ is a convex and quadratic function of α_B. Suppose to the contrary that there exists $\alpha'_B \in [\alpha(0), \bar{\alpha}(b)]$ such that $\phi_2(\alpha'_B) \le 0$. This, by (A.25) and (A.26), can only happen when $\alpha(0) < \alpha^\star_B := \arg\min_x \phi_2(x) < \bar{\alpha}(b)$ and $\phi_2(\alpha^\star_B) \le 0$. Specifically, by solving the first-order condition of $\phi_2(x)$ in (A.23) with respect to x, we obtain the minimizer of $\phi_2(x)$ as follows:

$$\alpha^\star_B := \arg\min_x \phi_2(x) = \frac{b^2 c\gamma^3 + \alpha_G(2b\gamma^2 - 1)}{\gamma(2b\gamma^2 - 1)}.$$

Then, if $b\gamma^2 > 1/2$, $\alpha^\star_B > \alpha(0)$ is equivalent to $1/2 < b\gamma^2 < 2 - \sqrt{2}$, and $\alpha^\star_B < \bar{\alpha}(b)$ is equivalent to

$$\alpha_G > \frac{bc\gamma(2 - b\gamma^2)}{2(2b\gamma^2 - 1)}. \tag{A.27}$$

Moreover, for $b\gamma^2 > 1/2$, $\phi_2(\alpha^\star_B) \le 0$ is equivalent to

$$\alpha_G \le \frac{bc\gamma(2 - b\gamma^2)}{2\sqrt{(1 - b\gamma^2)(2b\gamma^2 - 1)}}. \tag{A.28}$$

However, the right-hand side of (A.27) is strictly larger than the right-hand side of (A.28) since $1/2 < b\gamma^2 < 2 - \sqrt{2}$ must be true to ensure $\alpha^\star_B > \alpha(0)$. This implies that (A.27) and (A.28) cannot be satisfied simultaneously when $\alpha^\star_B > \alpha(0)$. Hence, there does not exist such an α'_B such that $\phi_2(\alpha'_B) \le 0$, implying that $\phi_2(\alpha_B) > 0$ must be true when $b\gamma^2 > 1/2$ and $\alpha_B \in [\alpha(0), \bar{\alpha}(b)]$.

Therefore, when condition (A.1) is satisfied so that $\alpha_B \in [\alpha(0), \bar{\alpha}(b)]$, $\phi_2(\alpha_B) > 0$, and hence, $\mathrm{d}V_2(b)/\mathrm{d}b < 0$ and $\beta^{(2)}(b)$ is strictly increasing in b. □

Proof of Lemma A.6. Part (i) follows from Lemma A.5(i) and $b^{H(1)}(b^L) = \beta^{(1)}(b^L)$ by (14) and (A.8). Also, based on the proof of Lemma A.5(i), $b^{L(1)} = b_1 \in (0,1)$, and $b^{L(1)}$ is uniquely determined by $b^{H(1)}(b^{L(1)}) = 1$. Similarly, Part (ii) follows from Lemma A.5(ii) and $b^{L(2)}(b^H) = \beta^{(2)}(b^H)$ by (17) and (A.9).

We next prove Part (iii) by identifying the sufficient and necessary conditions such that $b^{L(2)}(b^H) > b^{H(1)}(b^L)$ for $b^L \in (0, b^{L(1)})$ and $b^H \in (b^{H(1)}(b^L), 1)$. First, we show that $b^{L(2)}(1) > b^{H(1)}(b^L)$ if, and only if, $b^L \in (0, b^{L(3)})$, where $b^{L(3)} \in (0, b^{L(1)})$ is the unique b^L value that satisfies $b^{L(2)}(1) = b^{H(1)}(b^L)$. To see this, $b^{L(2)}(1) < b^{H(1)}(b^L)$ at $b^L = b^{L(1)}$ since $b^{H(1)}(b^{L(1)}) = 1$ and $b^{L(2)}(1) < 1$ by definition. Also, $b^{H(1)}(0) = 0$ by (A.6) and $b^{L(2)}(1) \in (0,1)$ by (A.7) so that $b^{L(2)}(1) > b^{H(1)}(0)$. Moreover, since $b^{H(1)}(b^L)$ is strictly increasing in $b^L \in (0,1)$ by Lemma A.6(i), for $b^L \in (0, b^{L(1)})$, there exists a unique $b^{L(3)}$ such that $b^{H(1)}(b^{L(3)}) = b^{L(2)}(1) < 1$, and $b^{L(2)}(1) > b^{H(1)}(b^L)$ if, and only if, $b^L \in (0, b^{L(3)})$. Next, for $b^H \in (b^{H(1)}(b^L), 1)$, we consider two cases based on the analysis above: (i) $b^L \in (0, b^{L(3)})$, and (ii) $b^L \in [b^{L(3)}, b^{L(1)})$.

Case (i): $b^L \in (0, b^{L(3)})$ and $b^H \in (b^{H(1)}(b^L), 1)$. In this case, $b^{L(2)}(1) > b^{H(1)}(b^L)$ as shown above and, by (A.7), $b^{L(2)}(b^H) < b^{H(1)}(b^L)$ at $b^H = b^{H(1)}(b^L)$ for all $b^L \in (0, b^{L(3)})$. Therefore, given any $b^L \in (0, b^{L(3)})$ and $b^{L(2)}(b^H)$ being strictly increasing in b^H by Lemma A.6(ii), there exists a unique $b^{\tilde{H}(1)}(b^L) \in (b^{H(1)}(b^L), 1)$ such that $b^{L(2)}(b^H) > b^{H(1)}(b^L)$ if, and only if, $b^{\tilde{H}(1)}(b^L) < b^H < 1$, where $b^{\tilde{H}(1)}(b^L)$ is the unique value of b^H that satisfies $b^{L(2)}(b^H) = b^{H(1)}(b^L)$.

Case (ii): In this case, as shown above, $b^{L(2)}(1) \le b^{H(1)}(b^L)$ for any given $b^L \in [b^{L(3)}, b^{L(1)})$. Then, by $b^{L(2)}(b^H)$ being strictly increasing in b^H by Lemma A.6(ii), it follows that $b^{L(2)}(b^H) \le b^{H(1)}(b^L)$ for all $b^L \in [b^{L(3)}, b^{L(1)})$ and $b^H \in (b^{H(1)}(b^L), 1)$. □

Proof of Lemma A.7. We prove each part of the lemma separately.

Part (i). Let us define $g^i(p) = \Pi_B^{Mi}(p) - \Pi_B^{Di}$ for $i \in \{H, L\}$. To prove part (i), we need to characterize cases where $g^i(p) \geq 0$. By (A.10), we have

$$g^i(p) \ = \ -b^i p^2 + (\alpha_B + b^i c)p - (\alpha_B c + \Pi_B^{Di}).$$

Note that $g^i(p)$ is a concave quadratic function of p and is maximized at $p = (\alpha_B + b^i c)/(2b^i)$. Moreover, $g^i(c) = g(\alpha_B/b^i) < 0$ and $g^i(p_B^{Mi}) > 0$ by Lemma A.1, where p_B^{Mi} is given by (4). Then, it follows that concave quadratic equation $g^i(p) = 0$ has two real roots p_1^i and p_2^i, where $c < p_1^i < p_B^{Mi} < p_2^i < \alpha_B/b^i$, and $g^i(p) \geq 0$ if, and only if, $p \in [p_1^i, p_2^i]$. Solving $g^i(p) = 0$, we obtain p_1^i and p_2^i as in (A.11) and (A.12), respectively.

Part (ii). By (A.11) and (A.12), and $\beta^{(m)}(b)$ being increasing in $b \in (0,1)$ for $m \in \{1,2\}$ from Lemma A.5, it follows that, for $m \in \{1,2\}$, $p_m^H < p_m^L$ for $0 < b^L < b^H < 1$.

Part (iii). Note that $p_B^{MH} = c/2 + \alpha_B/(2b^H)$ by (4) and $p_1^L = c/2 + \alpha_B/(2b^{H(1)}(b^L))$ by (A.6), (A.8) and (A.11). Then $p_B^{MH} \leq p_1^L$ if, and only if, $b^H \geq b^{H(1)}(b^L)$. Since $b^H < 1$, $b^H \geq b^{H(1)}(b^L)$ if, and only if, $b^{H(1)}(b^L) < 1$. By Lemma A.6(i), $p_B^{MH} \leq p_1^L$ if, and only if, $b^L \in (0, b^{L(1)})$ and $b^H \in [b^{H(1)}(b^L), 1)$.

Part (iv). Note that $p_1^L = c/2 + \alpha_B/(2b^{H(1)}(b^L))$ by (A.6), (A.8) and (A.11), and $p_2^H = c/2 + \alpha_B/(2b^{L(2)}(b^H))$ (A.7), (A.9) and (A.12). Then it follows that $p_1^L > p_2^H$ if, and only if, $b^{H(1)}(b^L) < b^{L(2)}(b^H)$. By Lemma A.6(iii), $b^{H(1)}(b^L) < b^{L(2)}(b^H)$ if, and only if, $b^L \in (0, b^{L(3)})$ and $b^H \in (b^{\tilde{H}(1)}(b^L), 1)$. ☐

Proof of Lemma A.8. We prove each part of the lemma separately.

Part (i)-(a). Firstly, we prove that $b^{H(1)}(b^L) > b^{H(3)}(b^L)$. As preparation, we define the following functions:

$$\begin{aligned}
\Theta_3(\tilde{\alpha}_B^L) &= \frac{\alpha_G^2 b^L}{2 - b^L\gamma^2} - \frac{b^L\big(\tilde{\alpha}_B^L\gamma - \alpha_G\big)^2}{2(1 - b^L\gamma^2)},\\
\Theta_4(\tilde{\alpha}_B^L) &= \frac{3}{4}(\tilde{\alpha}_B^L)^2 - \frac{b^L\alpha_G^2}{(2 - b^L\gamma^2)^2} - \frac{b^L\gamma\alpha_G\tilde{\alpha}_B^L}{2 - b^L\gamma^2} - \frac{3\big((\tilde{\alpha}_B^L)^2 + b^L\alpha_G^2 - 2b^L\tilde{\alpha}_B^L\alpha_G\gamma\big)}{4(1 - b^L\gamma^2)}.
\end{aligned}$$

By (A.6) and (A.14), $b^{H(1)}(b^L) > b^{H(3)}(b^L)$ if, and only if,

$$\Theta_5(\alpha_B) := 4(\alpha_B - b^L c)^2\Theta_3(\tilde{\alpha}_B^L) - \Theta_4^2(\tilde{\alpha}_B^L) > 0. \tag{A.29}$$

Then we only need to prove that $\Theta_5(\alpha_B) > 0$ for all α_B satisfying (A.1). By expanding $\Theta_5(\alpha_B)$, we obtain that

$$\Theta_5(\alpha_B) = \frac{b^L\big(\alpha_G(4 - 3b^L\gamma^2) - (\alpha_B - b^L c)\gamma(2 - b^L\gamma^2)\big)}{16(2 - b^L\gamma^2)^4(1 - b^L\gamma^2)^2} \times \Theta_6(\tilde{\alpha}_B^L), \tag{A.30}$$

where $\Theta_6(\tilde{\alpha}_B^L)$ is given by

$$\begin{aligned}
\Theta_6(\tilde{\alpha}_B^L) = (\tilde{\alpha}_B^L)^3 &\Big(256\gamma + b^L\gamma^3(-568 + b^L\gamma^2(468 + b^L\gamma^2(23b^L\gamma^2 - 170)))\Big)\\
&+ (\tilde{\alpha}_B^L)^2\Big(b^L\gamma^2\alpha_G(2 - b^L\gamma^2)^2(17b^L\gamma^2 - 44)\Big)\\
&+ 3\tilde{\alpha}_B^L\alpha_G^2 b^L\gamma(4 - b^L\gamma^2)^2(2 - b^L\gamma^2) - \alpha_G^3 b^L(4 - b^L\gamma^2)^2(4 - 3b^L\gamma^2).
\end{aligned}$$

By condition (A.1), the first term of $\Theta_5(\alpha_B)$ in (A.30) is positive, and hence to show that $\Theta_5(\alpha_B) > 0$ for all α_B satisfying (A.1), it is sufficient to show that $\Theta_6(\tilde{\alpha}_B^L) > 0$ for all α_B satisfying (A.1).

Next, we show that $\Theta_6(\tilde{\alpha}_B^L) > 0$ for all α_B satisfying (A.1). To this end, we firstly show that $\Theta_6(\tilde{\alpha}_B^L)$ is increasing in $\tilde{\alpha}_B^L$, when α_B satisfies (A.1). Note that, $\tilde{\alpha}_B^L = \alpha_B - b^L c$. Taking the first-order derivative of $\Theta_6(\tilde{\alpha}_B^L)$ with respect to $\tilde{\alpha}_B^L$, we obtain that

$$\begin{aligned}\frac{\mathrm{d}\Theta_6(\tilde{\alpha}_B^L)}{\mathrm{d}\tilde{\alpha}_B^L} &= \gamma(2-b^L\gamma^2)\\ &\times\Big(3(\tilde{\alpha}_B^L)^2(2-b^L\gamma^2)^2(32-23b^L\gamma^2) - 2\tilde{\alpha}_B^L b^L\gamma\alpha_G(2-b^L\gamma^2)(44-17b^L\gamma^2) + 3b^L\alpha_G^2(4-b^L\gamma^2)^2\Big). \quad \text{(A.31)}\end{aligned}$$

By (A.31), $\mathrm{d}\Theta_6(\tilde{\alpha}_B^L)/\mathrm{d}\tilde{\alpha}_B^L$ is a convex and quadratic function of $\tilde{\alpha}_B^L$. Then it follows that

$$\arg\min_{\tilde{\alpha}_B^L} \frac{\mathrm{d}\Theta_6(\tilde{\alpha}_B^L)}{\mathrm{d}\tilde{\alpha}_B^L} = \frac{\alpha_G}{\gamma} \times \frac{b^L\gamma^2(44-17b^L\gamma^2)}{3(2-b^L\gamma^2)(32-23b^L\gamma^2)} < \frac{\alpha_G}{\gamma}, \quad \text{(A.32)}$$

where the inequality follows from $b^L\gamma^2 \in (0,1)$. In addition, when condition (A.1) is satisfied, $\tilde{\alpha}_B^L > \alpha_G/\gamma$ so that $\mathrm{d}\Theta_6(\tilde{\alpha}_B^L)/\mathrm{d}\tilde{\alpha}_B^L$ is increasing in $\tilde{\alpha}_B^L$. Then it follows from that

$$\frac{\mathrm{d}\Theta_6(\tilde{\alpha}_B^L)}{\mathrm{d}\tilde{\alpha}_B^L} > \frac{\mathrm{d}\Theta_6(\tilde{\alpha}_B^L)}{\mathrm{d}\tilde{\alpha}_B^L}\Big|_{\tilde{\alpha}_B^L=\alpha_G/\gamma} = 4\alpha_G^2(2-b^L\gamma^2)\big(96-197b^L\gamma^2+126(b^L\gamma^2)^2-25(b^L\gamma^2)^3\big)/\gamma > 0 \quad \text{(A.33)}$$

for $\forall b^L \in (0,1)$ and $\gamma \in (0,1)$ when condition (A.1) is satisfied. Therefore, $\Theta_6(\tilde{\alpha}_B^L)$ is increasing in $\tilde{\alpha}_B^L$ when condition (A.1) is satisfied. Then, for $\tilde{\alpha}_B^L > \alpha_G/\gamma$,

$$\Theta_6(\tilde{\alpha}_B^L) > \Theta_6(\alpha_G/\gamma) = 8\alpha_G^3(1-b^L\gamma^2)^2(32-25b^L\gamma^2+5(b^L\gamma^2)^2)/\gamma^2 > 0,$$

which, by (A.30), implies that $\Theta_5(\alpha_B) > 0$ for all α_B satisfying condition (A.1). Then, it follows that, when condition (A.1) is satisfied, $b^{H(1)}(b^L) > b^{H(3)}(b^L)$ for all $b^L \in (0,1)$.

Part (i)-(b). Secondly, we prove that $b^{H(3)}(b^L) > b^{H(2)}(b^L)$ when condition (A.1) is satisfied. Recall from (B.4) that $\mathcal{U}^L(q_B^{DL}, q_G^{DL}) - \mathcal{U}^L(q_B^M, 0)$ is a concave and quadratic function of $1/b^H$, and $1/b^{H(3)}(b^L)$ is the smaller root of $\mathcal{U}^L(q_B^{DL}, q_G^{DL}) - \mathcal{U}^L(q_B^M, 0) = 0$ with respect to $1/b^H$, where $\mathcal{U}^L(\cdot)$ is given by (1), q_B^{DL} and q_G^{DL} are respectively given by (B.1), and $q_B^M = \alpha_B - b^L p_B^{MH}$. Suppose that $b^H = b^{H(2)}(b^L)$, then we have $p_B^{MH} = p_B^{DL}$ by Theorem 1. Hence, by substituting $\mathcal{U}^L(\cdot)$ in (1) into $\mathcal{U}^L(q_B^{DL}, q_G^{DL}) - \mathcal{U}^L(q_B^M, 0)$, we obtain that

$$\begin{aligned}&\mathcal{U}^L(q_B^{DL}, q_G^{DL}) - \mathcal{U}^L(q_B^M, 0)\\ &= \max_{q_B,q_G}\Big\{\alpha_G q_G - \frac{1}{2}q_G^2 + \frac{\alpha_B}{b^L}q_B - \frac{1}{2b^L}q_B^2 - \gamma q_B q_G - p_B^{DL}q_B - p_G^{DL}q_G\Big\} - \max_{q_B}\Big\{\frac{\alpha_B}{b^L}q_B - \frac{1}{2b^L}q_B^2 - p_B^{DL}q_B\Big\}\\ &> \Big(\frac{\alpha_B}{b^L}q_B^M - \frac{1}{2b^L}(q_B^M)^2 - p_B^{DL}q_B^M\Big) - \max_{q_B}\Big\{\frac{\alpha_B}{b^L}q_B - \frac{1}{2b^L}q_B^2 - p_B^{DL}q_B\Big\}\\ &= 0,\end{aligned}$$

in which, p_B^{MH} and p_B^{DL} are, respectively, given by (4) and (7), the inequality follows from that given prices p_B^{DL} and p_G^{DL} in (7),

$$(q_B^{DL}, q_G^{DL}) = \arg\max_{q_B,q_G}\Big\{\alpha_G q_G - \frac{1}{2}q_G^2 + \frac{\alpha_B}{b^L}q_B - \frac{1}{2b^L}q_B^2 - \gamma q_B q_G - p_B^{DL}q_B - p_G^{DL}q_G\Big\}$$

and $q_G^{DL} > 0$ by (A.1), and the last equality follows from that given price p_B^{DL},

$$q_B^M = \arg\max_{q_B}\Big\{\frac{\alpha_B}{b^L}q_B - \frac{1}{2b^L}q_B^2 - p_B^{DL}q_B\Big\}.$$

Therefore, we obtain that $1/b^{H(2)}(b^L) > 1/b^{H(3)}(b^L)$, i.e., $b^{H(3)}(b^L) > b^{H(2)}(b^L)$.

Part (i)-(c). Then we prove that $b^{H(2)}(b^L) > b^{H(4)}(b^L)$ when condition (A.1) is satisfied. Equivalently, we only need to show that $1/b^{H(4)}(b^L) > 1/b^{H(2)}(b^L)$. Furthermore, since $1/b^{H(4)}(b^L)$ is increasing in k, it is sufficient to show that $1/b^{H(4)}(b^L) > 1/b^{H(2)}(b^L)$ when $k = 0$, which is equivalent to

$$-7(\tilde{\alpha}_B^L)^2\gamma^2(2-b^L\gamma^2)^2 + 2\tilde{\alpha}_B^L\alpha_G\gamma(13(b^L)^2\gamma^4 - 46b^L\gamma^2 + 40) - \alpha_G^2(15(b^L)^2\gamma^4 - 56b^L\gamma^2 + 48) > 0.$$

The above inequality is always true when

$$\frac{\alpha_G}{\gamma} \le \tilde{\alpha}_B^L < \frac{\alpha_G(4-3b^L\gamma^2)}{\gamma(2-b^L\gamma^2)}, \text{ i.e., } \frac{\alpha_G}{\gamma} + b^L c \le \alpha_B < \frac{\alpha_G(4-3b^L\gamma^2)}{\gamma(2-b^L\gamma^2)} + b^L c,$$

of which (A.1) is a subset. Therefore, we always have $b^{H(2)}(b^L) > b^{H(4)}(b^L)$ when condition (A.1) is satisfied.

Part (i)-(d). Finally, we prove that $b^{H(4)}(b^L) > b^L$ when condition (A.1) is satisfied. By the definition of $b^{H(4)}(b^L)$ in (A.15), we obtain that $b^{H(4)}(b^L) > b^L$ if, and only if

$$32k + \Theta_2(b^L) < 4(\alpha_B - b^L c)^2/b^L.$$

By (11), $k < \Pi_G^{DL}$, where Π_G^{DL} is given by (10). Thus, to prove $b^{H(4)}(b^L) > b^L$, it is sufficient to prove that

$$32\Pi_G^{DL} + \Theta_2(b^L) < 4(\alpha_B - b^L c)^2/b^L. \tag{A.34}$$

Then we show that (A.34) holds true when condition (A.1) is satisfied. By substituting Π_G^{DL} in (10) and $\Theta_2(b^L)$ in (A.17), we obtain that

$$32\Pi_G^{DL} + \Theta_2(b^L) - 4(\alpha_B - b^L c)^2/b^L = \frac{\Theta_7(\tilde{\alpha}_B^L)}{(2-b^L\gamma^2)^2(b^L\gamma^2-1)}, \tag{A.35}$$

where $\Theta_7(\tilde{\alpha}_B^L)$ is given by

$$\Theta_7(\tilde{\alpha}_B^L) := 5(\tilde{\alpha}_B^L)^2\gamma^2(2-b^L\gamma^2)^2 - 2\tilde{\alpha}_B^L\alpha_G\gamma(2-b^L\gamma^2)(8-3b^L\gamma^2) + \alpha_G^2\big(16 - b^L\gamma^2(12-b^L\gamma^2)\big). \tag{A.36}$$

Note that, by (A.35), the denominator, $(2-b^L\gamma^2)^2(b^L\gamma^2-1)$, is negative for $\forall b^L \in (0,1)$ and $\gamma \in (0,1)$. Hence, to show that (A.34) holds true, we only need to show that $\Theta_7(\tilde{\alpha}_B^L)$ in (A.35) is positive. By (A.36), $\Theta_7(\tilde{\alpha}_B^L)$ is a convex and quadratic function of $\tilde{\alpha}_B^L$. By solving the first-order condition of $\Theta_7(\tilde{\alpha}_B^L)$ in (A.36) with respect to $\tilde{\alpha}_B^L$, we obtain the minimizer of $\Theta_7(\tilde{\alpha}_B^L)$ as follows:

$$\tilde{\alpha}_B^{L\star} := \arg\min_{\tilde{\alpha}_B^L} \Theta_7(\tilde{\alpha}_B^L) = \frac{\alpha_G(8-3b^L\gamma^2)}{5\gamma(2-b^L\gamma^2)},$$

and hence

$$\Theta_7(\tilde{\alpha}_B^L) \ge \Theta_7(\tilde{\alpha}_B^{L\star}) = \frac{4}{5}\alpha_G^2(1-b^L\gamma^2)(4+b^L\gamma^2) > 0, \ \forall b^L \in (0,1) \text{ and } \gamma \in (0,1).$$

Therefore, (A.34) always holds true when condition (A.1) is satisfied, which implies that $b^{H(4)}(b^L) > b^L$.

By now, we have shown that when condition (A.1) is satisfied, $b^{H(1)}(b^L) > b^{H(3)}(b^L)$, $b^{H(3)}(b^L) > b^{H(2)}(b^L)$, $b^{H(2)}(b^L) > b^{H(4)}(b^L)$, and $b^{H(4)}(b^L) > b^L$, which boils down to $b^{H(1)}(b^L) > b^{H(3)}(b^L) > b^{H(2)}(b^L) > b^{H(4)}(b^L) > b^L$.

Part (ii). By doing the algebra for $b^{H(3)}(b^L)$ in (A.14), we obtain that $b^{H(3)}(b^L)<1$ if, and only if, $V_3(b^L)>0$, where

$$V_3(b^L):=\Big((\tilde{\alpha}_B^L(2-b^L)+b^Lc(1-b^L))^2-b^L\Theta_1(b^L)+3(\tilde{\alpha}_B^L)^2\Big)(1-b^L\gamma^2)(2-b^L\gamma^2)^2.$$

Note that $V_3(0)=48(\tilde{\alpha}_B^L)^2>0$, and

$$V_3(1)=-\big[\tilde{\alpha}_B^L(2-\gamma^2)\gamma-\gamma^2\alpha_G\big]^2-4\alpha_G^2(4-\gamma^2)(1-\gamma^2)<0.$$

Furthermore, by $d^2V_3(b^L)/d^2(b^L)^2>0$ and $\frac{dV_3(b^L)}{db^L}\Big|_{b^L=0}<0$, there exists a unique $b^{L(5)}\in(0,1)$ such that $V_3(b^{L(5)})=0$, and thus $V_3(b^L)>0$ if, and only if, $b^L\in(0,b^{L(5)})$. This implies that $b^{H(3)}(b^{L(5)})=1$ and $b^{H(3)}(b^L)<1$ if, and only if, $b^L\in(0,b^{L(5)})$.

Part (iii). We identify the conditions on b^L such that $b^{H(4)}(b^L)<1$. Note that $b^{H(4)}(b^L)\geq 1$ is equivalent to $\Theta_2(b^L)+32k\leq 4b^L(\alpha_B-c)^2$, where $\Theta_2(b^L)$ is given by (A.17). In addition, both $\Theta_2(b^L)$ and Π_G^{DL} are decreasing in b^L, and hence when k takes the value of its upper bound Π_G^{DL}, $\Theta_2(b^L)+32\Pi_G^{DL}$ is decreasing in b^L, achieving its minimum at $b^L=1$. Letting $y:=\alpha_B-c$, we further show that $\Theta_2(b^L)+32\Pi_G^{DL}$ is a function of y when $b^L=1$, and

$$\left(\Theta_2(b^L)+32\Pi_G^{DL}\right)\Big|_{b^L=1}-4(\alpha_B-c)^2\leq\max_y\left\{\left(\Theta_2(b^L)+32\Pi_G^{DL}\right)\Big|_{b^L=1}-4y^2\right\}=-\frac{4\alpha_G^2(4+\gamma^2)}{5(2-\gamma^2)^2}<0. \quad \text{(A.37)}$$

Moreover, due to the result (A.37) and the fact that $\Theta_2(b^L)$ is decreasing in b^L, and that $\Theta_2(b^L)\big|_{b^L\to 0}\to+\infty$, there exists a unique $b^{L(6)}$ such that $b^{H(4)}(b^L)<1$ if, and only if, $b^L\in(0,b^{L(6)})$, where $b^{L(6)}$ is uniquely determined by $\Theta_2(b^L)+32k=4b^L(\alpha_B-c)^2$, or equivalently $b^{L(6)}$ is the unique b^L value that satisfies $b^{H(4)}(b^L)=1$.

Part (iv). By Lemma A.6(i), Lemma A.8(i) that $b^{H(1)}(b^L)>b^{H(3)}(b^L)$, and Lemma A.8(ii), we obtain that $0<b^{L(1)}<b^{L(5)}$. By Lemma A.8(i) that $b^{H(3)}(b^L)>b^{H(2)}(b^L)$, Lemma A.8(ii), and Theorem (1) that $b^{L(4)}\in(0,1)$ is the unique b^L value that satisfies $b^{H(2)}(b^L)=1$, we obtain that $b^{L(5)}<b^{L(4)}$. Similarly, by Lemma A.8(i) that $b^{H(2)}(b^L)>b^{H(4)}(b^L)$, Lemma A.8(iii), and Theorem (1) that $b^{L(4)}\in(0,1)$ is the unique b^L value that satisfies $b^{H(2)}(b^L)=1$, we obtain that $b^{L(4)}<b^{L(6)}<1$. Therefore, we obtain that $0<b^{L(1)}<b^{L(5)}<b^{L(4)}<b^{L(6)}<1$ when condition (A.1) is satisfied. □

B. Proofs of the Results in Sections 4 and 5 of the Paper

Proof of Lemma 1. Using backward induction, we characterize the equilibrium demand for brand-name and generic drugs in a duopoly setting by assuming positive demand for each, and then establish conditions for this positive demand to ensure competition between the two.

With generic entry, the equilibrium prices are obtained directly by backward induction. Specifically, for given p_B, by the first-order condition of (6) with respect to p_G, we obtain the generic firm's best response of drug price. Then, plugging the generic firm's best response into (5), and by the first-order condition of (5) with respect to p_B, we obtain p_B^{Di} in (7). Next, by plugging p_B^{Di} into the generic firm's best response of price, we obtain p_G^{Di} in (7). Then plugging p_B^{Di} and p_G^{Di} into (2) and (3), we, respectively, obtain q_B^{Di} and q_G^{Di} as below:

$$q_B^{Di}=\frac{(2-b^i\gamma^2)(\alpha_B-b^ic)-b^i\gamma\alpha_G}{4(1-b^i\gamma^2)} \text{ and } q_G^{Di}=\frac{\alpha_G(4-3b^i\gamma^2)-(\alpha_B-b^ic)(2-b^i\gamma^2)\gamma}{4(2-b^i\gamma^2)(1-b^i\gamma^2)}. \quad \text{(B.1)}$$

Given the fact $\alpha_B > \alpha_G$, that both q_B^{Di} and q_G^{Di} are positive for $\forall\ i \in \{H, L\}$ is equivalent to

$$\max\left\{\alpha_G, \frac{b^i\gamma\alpha_G}{2-b^i\gamma^2} + b^i c\right\} < \alpha_B < \frac{\alpha_G(4-3b^i\gamma^2)}{\gamma(2-b^i\gamma^2)} + b^i c,\ \forall\ i \in \{H, L\}, \tag{B.2}$$

which completes the proof. $\square$

Proof of Lemma 2. By Lemma A.4(i), the $L-$type brand-name firm's price is $\hat{p}_B^L = p_B^{DL}$ in a separating equilibrium. Then, it only remains to characterize the $H-$type brand-name firm's price $\hat{p}_B^H$ in the separating equilibrium. By Lemma A.4(i), $\hat{p}_B^H$, where $\hat{p}_B^H \neq \hat{p}_B^L$, must satisfy conditions (12) and (13), in which, $\Pi_B(L, p_B^{DL}, L) = \Pi_B^{DL}$, $\Pi_B(i, \hat{p}_B^H, H) = \Pi_B^{Mi}(\hat{p}_B^H) = (\hat{p}_B^H - c)(\alpha_B - b^i\hat{p}_B^H)$, and $\max_{p_B \neq \hat{p}_B^H} \Pi_B(H, p_B, L) = \Pi_B^{DH}$. Thus, in a separating equilibrium, the price $\hat{p}_B^H$ must satisfy both $\Pi_B^{MH}(\hat{p}_B^H) \geq \Pi_B^{DH}$ and $\Pi_B^{ML}(\hat{p}_B^H) \leq \Pi_B^{DL}$. By Lemma A.7(i), $\Pi_B^{MH}(\hat{p}_B^H) \geq \Pi_B^{DH}$ if, and only if, $\hat{p}_B^H \in [p_1^H, p_2^H]$; and $\Pi_B^{ML}(\hat{p}_B^H) \leq \Pi_B^{DL}$ if, $\hat{p}_B^H \in (c, p_1^L]$, or $\hat{p}_B^H \in (p_2^L, \alpha_B/b^L]$. Since $p_2^H < p_2^L$ by Lemma A.7(ii), $\hat{p}_B^H \notin (p_2^L, \alpha_B/b^L]$ if $\hat{p}_B^H \in [p_1^H, p_2^H]$. Then, by $p_1^H < p_1^L$ as in Lemma A.7(ii), $\Pi_B^{ML}(\hat{p}_B^H) \leq \Pi_B^{DL}$ and $\Pi_B^{MH}(\hat{p}_B^H) \geq \Pi_B^{DH}$ if, and only if, $\hat{p}_B^H \in [p_1^H, p_1^L]$. Consequently, any $\hat{p}_B^H \in [p_1^H, p_1^L]$ and $\hat{p}_B^L = p_B^{DL}$ are the prices in a separating equilibrium.

We next characterize the unique least-cost separating equilibrium. Note that, in a separating equilibrium, the $H-$type is a monopoly in the signaling period. Therefore, $\hat{p}_B^H = p_B^{MH}$ is the unique least-cost separating price if the $H-$type's monopoly price p_B^{MH} is within the range of separating equilibria, i.e., $p_B^{MH} \in [p_1^H, p_1^L]$. By Lemma A.7(iii), $p_B^{MH} \in [p_1^H, p_1^L]$ so that $\hat{p}_B^H = p_B^{MH}$ is the unique least-cost separating price if, and only if, $b^L \in (0, b^L(1))$ and $b^H \in [b^{H(1)}(b^L), 1)$; and, in all other cases, $p_B^{MH} > p_1^L$ so that $\hat{p}_B^H = p_1^L$ is the least-cost separating price that maximizes the $H-$type's monopoly profit. Thus, in the unique least-cost separating equilibrium, $\hat{p}_B^H = p_B^{MH}$ if $b^L \in (0, b^{L(1)})$ and $b^H \in [b^{H(1)}(b^L), 1)$, and $\hat{p}_B^H = p_1^L = c/2 + \alpha_B/(2b^{H(1)}(b^L))$ (by (14), (A.8) and (A.11)) otherwise. $\square$

Proof of Lemma 3. By Lemma A.4(ii) in Appendix A.4, $\hat{p}_B$ is the price in a pooling equilibrium if and only if it satisfies (15) and (16), in which $\Pi_B(i, \hat{p}_B, \{H, L\}) = (\hat{p}_B - c)(\alpha_B - b^i\hat{p}_B)$. That is, the pooling price $\hat{p}_B$ must satisfy $\Pi_B^{Mi}(\hat{p}_B) \geq \Pi_B^{Di}$ for $i \in \{H, L\}$. By Lemma A.7(i), for $i \in \{H, L\}$, $\Pi_B^{Mi}(\hat{p}_B) \geq \Pi_B^{Di}$ if, and only if, $\hat{p}_B \in [p_1^i, p_2^i]$. Then, using $p_m^H < p_m^H$ for $m \in \{1, 2\}$ by Lemma A.7(ii), any $\hat{p}_B \in \{p : p_1^L \leq p \leq p_2^H\}$ is a pooling equilibrium. Note by Lemma A.7 that $p_1^L > p_2^H$ makes the set of pooling equilibria (i.e., $\{p : p_1^L \leq p \leq p_2^H\}$) empty and hence there is no pooling equilibrium if, and only if, $b^L \in (0, b^{L(3)})$ and $b^H \in (b^{\tilde{H}(1)}(b^L), 1)$. In all other cases, $p_1^L \leq p_2^H$ so that any $\hat{p}_B \in [p_1^L, p_2^H]$ leads to a pooling equilibrium, where $p_1^L = c/2 + \alpha_B/(2b^{H(1)}(b^L))$ by (14), (A.8) and (A.11), and $p_2^H = c/2 + \alpha_B/(2b^{L(2)}(b^H))$ by (17), (A.9) and (A.12). $\square$

Proof of Proposition 1. By Lemmas 2 and 3, there can be multiple equilibria, and pooling and separating equilibria can coexist. We refine the equilibrium using the Intuitive Criterion (Cho and Kreps 1987) and Pareto-dominance (Harsanyi and Selten 1988, Bolton and Dewatripont 2004). The Intuitive Criterion comprises two sequential rules, and the first rule is the equilibrium dominance, which states that the message (i.e., price of the brand-name drug) cannot be sent by the type whose payoff at the given equilibrium is strictly better than the best it can obtain if it sends this message. The second rule depicts the idea that, for the type-message pairs that survive the equilibrium dominance, the equilibrium outcome is said to fail the Intuitive Criterion if for any one message there is some type such that its payoff at the given equilibrium is strictly worse than the worst it can obtain by sending this message. Surviving equilibria are then refined using Pareto-dominance, which selects equilibria where each player's payoff is maximized compared to other equilibria. The equilibrium that survives this refinement process is called the stable equilibrium. Note that a unique equilibrium must survive the refinement and be the stable equilibrium.

Note by Lemmas 2 and 3, there is no pooling equilibrium and there exists a unique least-cost separating equilibrium, in which prices of the $H-$ and $L-$type brand-name firms are given, respectively, by $\hat{p}_B^H = p_B^{MH}$ and $\hat{p}_B^L = p_B^{DL}$, if $b^L \in (0, b^{L(3)})$ and $b^H \in (b^{\tilde{H}(1)}(b^L), 1)$. In such cases, the equilibrium is unique and the same as the least-cost separating equilibrium, and hence, it is also the stable equilibrium. Next consider the other two cases: (i) $b^L \in (b^{L(3)}, b^{L(1)})$ and $b^H \in (b^{H(1)}(b^L), 1)$, or $b^L \in (0, b^{L(3)})$ and $b^H \in (b^{H(1)}(b^L), b^{\tilde{H}(1)}(b^L))$, and (ii) $b^L \in (0, b^{L(1)})$ and $b^H \in (b^L, b^{H(1)}(b^L))$, or $b^L \in (b^{L(1)}, 1)$.

Case (i): By Lemmas 2 and 3, there exist both separating and pooling equilibria. Specifically, the price pair for the $L-$ and $H-$type brand-name firms in the unique least-cost separating equilibrium is $(\hat{p}_B^L, \hat{p}_B^H) = (p_B^{DL}, p_B^{MH})$, while any $\hat{p}_B \in [p_1^L, p_2^H]$, where $p_1^L = c/2 + \alpha_B/(2b^{H(1)}(b^L))$ and $p_2^H = c/2 + \alpha_B/(2b^{L(2)}(b^H))$, is a pooling equilibrium.

Let us first apply the Intuitive Criterion to the pooling equilibria in case (i), in which both the $H-$ and $L-$type brand-name firms offer price $\hat{p}_B$. Note by Lemma A.7(iii) that $p_B^{MH} < p_1^L$, and hence p_B^{MH} cannot be a pooling price. Now consider the off-equilibrium price p_B^{MH} for the $L-$type brand-name firm. If the $L-$type brand-name firm deviates from the pooling price $\hat{p}_B$ and charges the price p_B^{MH}, the best that it can get is $\Pi_B(L, p_B^{MH}, H) = \Pi_B^{ML}(p_B^{MH})$, which is less than its payoff in the pooling equilibrium $\Pi_B(L, \hat{p}_B, \{H, L\}) = \Pi_B^{ML}(\hat{p}_B)$. Thus, in the pooling equilibrium, the $L-$type brand-name firm will never willingly deviate to the price p_B^{MH}. Anticipating this, the generic firm knows that the brand-name firm is not $L-$type and does not enter when observing the price p_B^{MH}. Knowing this, it is always optimal for the $H-$type brand-name firm to deviate from the pooling price to its monopoly price p_B^{MH} as there will be no generic entry. Consequently, the generic firm will expect the $H-$type brand-name firm to charge its monopoly price p_B^{MH} and will believe that it is $L-$type and enter the market when observing the pooling price $\hat{p}_B$, which makes the pooling equilibrium collapse. Thus, in case (i), none of the pooling equilibria can survive the Intuitive Criterion and cannot emerge in the stable equilibrium.

Let us now apply the Intuitive Criterion to the unique least-cost separating equilibrium in case (i) (i.e., $(\hat{p}_B^L, \hat{p}_B^H) = (p_B^{DL}, p_B^{MH})$). The $H-$type brand-name firm does not have incentives to deviate from p_B^{MH} to any other price since the equilibrium profit Π_B^{MH} is larger than the best it can earn by charging any price other than p_B^{MH}. Thus, the $H-$type brand-name firm always charges p_B^{MH} regardless of the L type's response. As a result, when observing any off-equilibrium price other than p_B^{MH}, the generic firm always believes that the brand-name firm is $L-$type. Then, we apply the second rule of the Intuitive Criterion. It is not difficult to show that the equilibrium passes the test. By Lemma A.4(i), the $i-$type brand-name firm's profit (for $i \in \{H, L\}$) from deviating from the equilibrium price and facing generic entry is always less than Π_B^{Di}. Thus, the profit from deviating the equilibrium for both types cannot be strictly larger than the equilibrium profits. Then, it follows that, in case (i), the unique least-cost separating equilibrium with prices $(\hat{p}_B^L, \hat{p}_B^H) = (p_B^{DL}, p_B^{MH})$ survives the Intuitive Criterion. Since the unique least-cost separating equilibrium (i.e., $(\hat{p}_B^L, \hat{p}_B^H) = (p_B^{DL}, p_B^{MH})$) is the only equilibrium that survives the Intuitive Criterion, it is also the unique stable equilibrium in case (i).

Case (ii): By Lemmas 2 and 3, there are both separating and pooling equilibria. In particular, the price pair for the $L-$ and $H-$type brand-name firms in the unique least-cost separating equilibrium is $(\hat{p}_B^L, \hat{p}_B^H) = (p_B^{DL}, p_1^L)$, and any $\hat{p}_B \in [p_1^L, p_2^H]$ leads to a pooling equilibrium. As in case (i), we will sequentially apply Intutivie Criterion and Pareto dominance to refine the equilibria.

Consider the pooling equilibria in case (ii) and apply the Intuitive Criterion. By Lemma (A.7), $p_B^{MH} \in [p_1^L, p_2^H]$ in this case. As in case (i), it is easy to argue that any pooling equilibrium with the price different from p_B^{MH} (i.e., $\hat{p}_B \in [p_1^L, p_2^H]$ and $\hat{p}_B \neq p_B^{MH}$) cannot survive the Intuitive Criterion and thus cannot emerge in the stable equilibrium. Then it only remains to consider the pooling equilibrium with $\hat{p}_B = p_B^{MH}$. Observing any off-equilibrium price $p_B > p_B^{MH}$, the generic firm reasonably believes that it is the $L-$type brand-name firm and thus enters. Consequently, by charging the off-equilibrium price $p_B > p_B^{MH}$, the $L-$type brand-name firm cannot earn more than Π_B^{DL}, which is less than its profit in the pooling equilibrium, i.e., $\Pi_B(L, p_B^{MH}, \{H, L\}) = \Pi_B^{ML}(p_B^{MH})$. This implies that $p_B > p_B^{MH}$ is equilibrium dominated by $\hat{p}_B = p_B^{MH}$ for the $L-$type brand-name firm. Similarly, for the $L-$type brand-name firm, the off-equilibrium price $p_B < p_B^{MH}$ is also equilibrium dominated by $\hat{p}_B = p_B^{MH}$. Hence, the Intuitive Criterion cannot eliminate the pooling equilibrium with $\hat{p}_B = p_B^{MH}$.

Now we consider the unique least-cost separating equilibrium in case (ii) (i.e., $(\hat{p}_B^L, \hat{p}_B^H) = (p_B^{DL}, p_1^L)$). By Lemma A.7, both the $H-$ and $L-$type brand-name firms can be better off by deviating from the equilibrium price if the generic firm believes them to be the $H-$type (e.g., the $i-$type brand-name firm deviates to the monopoly price p_B^{Mi} and the generic firm does not enter the market). Thus, in the worst case for the brand-name firm, the generic firm will believe that the off-equilibrium price is offered by the L type and hence will enter. As a result, by Lemma A.7, the profit of the $i-$type brand-name firm in the worst case is less than Π_B^{Di}, and thus, cannot be strictly larger than the equilibrium profits (i.e., Π_B^{DL} for L type and $\Pi_B^{MH}(p_1^L)$ for H type). Therefore, the unique least-cost separating equilibrium survives the Intuitive Criterion.

Next, we apply the Pareto dominance to the two equilibria that survived the Intuitive Criterion in case (ii), namely, the pooling equilibrium with the price $\hat{p}_B = p_B^{MH}$, and the least-cost separating equilibrium with prices $(\hat{p}_B^L, \hat{p}_B^H) = (p_B^{DL}, p_1^L)$. Notice that $\Pi_B(H, p_B^{MH}, \{H, L\}) = \Pi_B^{MH} > \Pi_B(H, p_1^L, H)$, and, by Lemma A.7(i), $\Pi_B(L, p_B^{MH}, \{H, L\}) > \Pi_B(L, p_B^{DL}, L) = \Pi_B^{DL}$. Thus, the payoffs of the two types both are strictly larger under the pooling equilibrium. Consequently, the pooling equilibrium with $\hat{p}_B = p_B^{MH}$ Pareto dominates the unique least-cost separating equilibrium and emerges as the stable equilibrium in case (ii). $\square$

Proof of Theorem 1. We first prove the "If" part of the theorem, i.e., in the stable equilibrium characterized by Proposition 1, the GCP occurs if the brand-name firm is $L-$type, and $b^L \in (0, b^{L(4)})$ and $b^H \in (b^{H(2)}(b^L), \min\{b^{H(1)}(b^L), 1\})$. In such cases, by Proposition 1, there will be the pooling equilibrium where both the $L-$ and $H-$type brand-name firms charge the same price p_B^{MH} in the signaling period, and generic entry will not occur. Whereas, in the full-information period, since the generic firm is able to observe the type of the brand-name firm, by (11), he will enter the market to compete with the $L-$type brand-name firm. As a result, the $L-$type brand-name firm will optimally choose its duopoly price p_B^{DL} in the full-information period. Then it only remains to show that $p_B^{DL} > p_B^{MH}$. Note by (4), (7), and (18) that

$$p_B^{DL} - p_B^{MH} = \frac{\alpha_B}{2}\Big(\frac{1}{b^{H(2)}(b^L)} - \frac{1}{b^H}\Big). \tag{B.3}$$

Then, by $b^H > b^{H(2)}(b^L) > 0$, $p_B^{DL} > p_B^{MH}$ so that there is a price increase after generic entry and the GCP occurs.

Next, we prove the "only if" part. Equivalently, we only need to prove that the GCP does not occur if one of the following three conditions is violated: (i) the brand-name firm is $L-$type, (ii) $b^L \in (0, b^{L(4)})$, and (iii) $b^H \in (b^{H(2)}(b^L), \min\{b^{H(1)}(b^L), 1\})$. First, suppose that the brand-name firm is $H-$type. By Proposition 1, the $H-$type brand-name firm always charges its monopoly price p_B^{MH} in the signaling period in the stable equilibrium, and the generic firm stays out of the market in both periods. Hence, the GCP does not occur when the brand-name firm is $H-$type.

Second, suppose that the brand-name firm is $L-$type, but $b^L \in [b^{L(4)}, 1)$. Recall from Proposition 1 that only the separating or the pooling equilibrium can occur as the stable equilibrium. Suppose that the stable equilibrium is separating when $b^L \in [b^{L(4)}, 1)$. Then by Lemma A.2, the GCP cannot happen. Thus, it only remains to show that the GCP cannot occur if the stable equilibrium is pooling when $b^L \in [b^{L(4)}, 1)$. Suppose that the stable equilibrium is pooling when $b^L \in [b^{L(4)}, 1)$, then the $L-$type brand-name firm will charge price p_B^{MH}, not facing generic entry, in the signaling period; while in the full-information period, the $L-$type brand-name firm will charge price p_B^{DL} and face generic entry. Note by (18) that $b^{H(2)}(b^L)$ is strictly increasing in b^L and $b^{H(2)}(b^L) = 1$ at $b^L = b^{L(4)}$. Therefore, $b^{H(2)}(b^L) > 1$ so that $b^H < b^{H(2)}(b^L)$ for $b^L \in (b^{L(4)}, 1)$. Then, it follows from (B.3) that if $b^L \in (b^{L(4)}, 1)$, there is a price decrease (i.e., $p_B^{DL} < p_B^{MH}$) after the generic entry so that the GCP does not occur.

Third, suppose to the contrary that the brand-name firm is $L-$type and $b^L \in (0, b^{L(4)})$, but $b^H \notin (b^{H(2)}(b^L), \min\{b^{H(1)}(b^L), 1\})$. In such cases, there can be either a separating or a pooling stable equilibrium, depending on b^H. If $b^H \in (\min\{b^{H(1)}(b^L), 1\}, 1)$, by Proposition 1, the stable equilibrium is a separating equilibrium where the $L-$type brand-name firm allows entry and charges p_B^{DL}, which is lower than its monopoly price p_B^{ML}. Thus the GCP does not occur. On the other hand, if $b^H \in (b^L, b^{H(2)}(b^L)]$, by Proposition 1, the stable equilibrium is a pooling equilibrium where the $L-$type brand-name firm charges the price p_B^{MH} in the signaling period and p_B^{DL} in the full-information period. By (B.3) and $b^H < b^{H(2)}(b^L)$, $p_B^{DL} < p_B^{MH}$ and there is a price decrease after the generic entry so that the GCP does not occur. $\square$

Proof of Proposition 2. Supposing that $b^L \in (0,1)$ and $b^H \in (b^L, \min\{b^{H(1)}(b^L), 1\})$ (i.e., the stable equilibrium is pooling) and the brand-name firm is $L-$type, we prove each part of the proposition separately.

Part (i): Note that the representative consumer has the same consumption profile (i.e., q_B and q_G) throughout the signaling period. Given q_B and q_G, the consumer surplus in the signaling period is equal to $\int_0^T e^{-\rho t}\mathcal{U}^L(q_B, q_G)dt = (1 - e^{-\rho T})\mathcal{U}^L(q_B, q_G)/\rho$, where $\mathcal{U}^L(q_B, q_G)$ is the representative consumer's net utility as given by (1). Thus, to analyse the impact of information asymmetry on consumer surplus in the signaling period when the brand-name firm is $L-$type, and $b^L \in (0,1)$ and $b^H \in (b^L, \min\{b^{H(1)}(b^L), 1\})$, it is enough to compare the representative consumer's net utility per-unit time, $\mathcal{U}^L(q_B, q_G)$, with and without the information asymmetry.

By Proposition 1, with information asymmetry, the brand-name firm is a monopoly in the market, and the amount of the brand-name drug that the representative consumer purchases per-unit time at price p_B^{MH} is equal to $q_B^M = \alpha_B - b^L p_B^{MH}$ when $b^L \in (0,1)$ and $b^H \in (b^L, \min\{b^{H(1)}(b^L), 1\})$ and the brand-name firm is $L-$type. As a result, the consumer surplus per-unit time under information asymmetry is given by $S^L(q_B^M,0)=\mathcal{U}^L(q_B^M,0)$.

On the other hand, without information asymmetry, by condition (11), the generic firm enters the market and competes with the brand-name firm when the brand-name firm is $L-$type. Consequently, in absence of information asymmetry there is a duopoly in the signaling period, and the amount of brand-name and generic drugs that the representative consumer purchases per-unit time, at prices p_B^{DL} and p_G^{DL}, is respectively equal to q_B^{DL} and q_G^{DL} as given by (B.1). The consumer surplus per-unit time without information asymmetry is equal to $S^L(q_B^{DL},q_G^{DL})=\mathcal{U}^L(q_B^{DL},q_G^{DL})$.

Next, to determine the impact of information asymmetry, we compare the consumer surplus per-unit time with and without information asymmetry, i.e., $S^L(q_B^M,0)$ with $S^L(q_B^{DL},q_G^{DL})$. To that end, we define $\Delta S:=S^L(q_B^{DL},q_G^{DL})-S^L(q_B^M,0)$, and then obtain that

$$32\Delta S=-4b^L\Big(\frac{\alpha_B}{b^H}-c\Big)^2+3\tilde{\alpha}_B^L\Big(\frac{\alpha_B}{b^H}-c\Big)+13\alpha_B\tilde{\alpha}_B^L\Big(\frac{1}{b^H}-\frac{1}{b^L}\Big)+\Theta_1(b^L)-\frac{3(\tilde{\alpha}_B^L)^2}{b^L}, \tag{B.4}$$

where $\tilde{\alpha}_B^L:=\alpha_B-b^Lc$, and

$$\Theta_1(b^L):=\frac{3(\tilde{\alpha}_B^L)^2}{b^L}+\frac{4\alpha_G^2}{(2-b^L\gamma^2)^2}+\frac{4\alpha_G(\alpha_G+\gamma\tilde{\alpha}_B^L)}{2-b^L\gamma^2}+\frac{(\tilde{\alpha}_B^L)^2+b^L\alpha_G^2-2b^L\gamma\alpha_G\tilde{\alpha}_B^L}{b^L(1-b^L\gamma^2)}.$$

We can find that (B.4) is a quadratic and concave function of $1/b^H$, and $\Delta S=0$ has two different real roots, $1/b^{H(3)}(b^L)$ and $1/b^{E(3)}(b^L)$, since $\Delta S>0$ when $b^H=b^L$. Then, $\Delta S>0$ if, and only if, $1/b^H\in(1/b^{H(3)}(b^L),1/b^{E(3)}(b^L))$, where $b^{H(3)}(b^L)$ and $b^{E(3)}(b^L)$, respectively, satisfy

$$b^{E(3)}(b^L):=\frac{2b^L\alpha_B}{4\alpha_B-2b^Lc+\sqrt{b^L\Theta_1(b^L)}}, \tag{B.5}$$

$$b^{H(3)}(b^L):=\frac{2b^L\alpha_B}{4\alpha_B-2b^Lc-\sqrt{b^L\Theta_1(b^L)}}. \tag{B.6}$$

Since (i) $\Delta S>0$ when $b^H=b^L$, and (ii) $1/b^{H(3)}(b^L)$ and $1/b^{E(3)}(b^L)$ are the two different positive roots of $\Delta S=0$ (with respect to $1/b^H$) and ΔS is the concave and quadratic function of $1/b^H$, it follows that $1/b^{H(3)}(b^L)<1/b^L<1/b^{E(3)}(b^L)$, i.e., $b^{H(3)}(b^L)>b^L>b^{E(3)}(b^L)$. Hence, given $b^H\in(b^L,1)$, $\Delta S<0$ so that the consumer surplus increases under information asymmetry if, and only if, $b^{H(3)}(b^L)<b^H<1$.

Note that $b^{H(1)}(b^L)>b^{H(3)}(b^L)>b^L$ by Lemma A.8(i) and that $b^{H(3)}(b^L)<1$ if, and only if, $b^L\in(0,b^{L(5)})$ by Lemma A.8(ii), where $b^{L(5)}\in(0,1)$ is the unique value of b^L that satisfies $b^{H(3)}(b^L)=1$. This implies that, when the brand-name firm is $L-$type and, $b^L\in(0,1)$ and $b^H\in(b^L,\min\{b^{H(1)}(b^L),1\})$, the consumer surplus increases under information asymmetry, i.e., $\Delta S<0$, if, and only if, $b^L\in(0,b^{L(5)})$ and $b^H\in(b^{H(3)}(b^L),\min\{b^{H(1)}(b^L),1\})$.

Part (ii): By Proposition 1, with information asymmetry in the signaling period: the brand-name firm is a monopoly in the market, and the amount of the brand-name drug that the representative consumer purchases per-unit time at price p_B^{MH} is equal to $q_B^M=\alpha_B-b^Lp_B^{MH}$ when $b^L\in(0,1)$ and $b^H\in(b^L,\min\{b^{H(1)}(b^L),1\})$ and the brand-name firm is $L-$type. As a result, the consumer surplus per-unit time in the signaling period is given by $S^L(q_B^M,0)=\mathcal{U}^L(q_B^M,0)$, and the total firm profit per-unit time is given by $\Pi_B^{ML}(p_B^{MH})=(p_B^{MH}-c)(\alpha_B-b^Lp_B^{MH})$, where p_B^{MH} is given by (4). Whereas, in the full-information period, by condition (11), the generic firm, by incurring the fixed capacity cost K, enters the market and competes with the $L-$type brand-name firm. Hence, there is duopoly in the full-information period, and the amount of brand-name and generic drugs that the representative consumer purchases per-unit time, at prices p_B^{DL} and p_G^{DL} is, respectively, equal to q_B^{DL} and q_G^{DL} as given by (B.1). Then the consumer surplus per-unit time in the full-information period is equal to $S^L(q_B^{DL}, q_G^{DL}) = \mathcal{U}^L(q_B^{DL}, q_G^{DL})$, and the total firm profit per-unit time is given by $\Pi_B^{DL} + \Pi_G^{DL}$, where Π_j^{DL} is, respectively, given by (9) and (10), for $j \in \{B, G\}$. Therefore, when there is information asymmetry in the signaling period, the total social welfare $\mathcal{W}_S$ over both periods is given by

$$\mathcal{W}_S = \int_0^T e^{-\rho t}\Big(S^L(q_B^M, 0) + \Pi_B^{ML}(p_B^{MH})\Big)\mathrm{d}t + \int_T^\infty e^{-\rho t}\Big(S^L(q_B^{DL}, q_G^{DL}) + \Pi_B^{DL} + \Pi_G^{DL}\Big)\mathrm{d}t - Ke^{-\rho T}. \tag{B.7}$$

On the other hand, without information asymmetry in the signaling period, by condition (11), the generic firm, by incurring the fixed capacity cost K, enters the market and competes with the brand-name firm at the beginning of the signaling period. Then the generic and brand-name firms compete as duopoly throughout both the signaling and full-information periods. Consequently, the amount of brand-name and generic drugs that the representative consumer purchases per-unit time at prices p_B^{DL} and p_G^{DL} is, respectively, equal to q_B^{DL} and q_G^{DL} as given by (B.1). Then the consumer surplus per-unit time is equal to $S^L(q_B^{DL}, q_G^{DL}) = \mathcal{U}^L(q_B^{DL}, q_G^{DL})$, and the total firm profit per-unit time is given by $\Pi_B^{DL} + \Pi_G^{DL}$, where Π_j^{DL} is, respectively, given by (9) and (10), for $j \in \{B, G\}$. Therefore, without information asymmetry, the total social welfare $\mathcal{W}_F$ over both periods is given by

$$\mathcal{W}_F = \int_0^\infty e^{-\rho t}\Big(S^L(q_B^{DL}, q_G^{DL}) + \Pi_B^{DL} + \Pi_G^{DL}\Big)\mathrm{d}t - K. \tag{B.8}$$

Then, by using (B.7) and (B.8), we obtain

$$\begin{aligned}\mathcal{W}_S - \mathcal{W}_F &= \frac{1-e^{-\rho T}}{\rho}\Big(S^L(q_B^M, 0) + \Pi_B^{ML}(p_B^{MH}) - S^L(q_B^{DL}, q_G^{DL}) - \Pi_B^{DL} - \Pi_G^{DL} + k\Big)\\ &= \frac{1-e^{-\rho T}}{32\rho}\Big(-4b^L\big(\frac{\alpha_B}{b^H} - c\big)^2 + \Theta_2(b^L) + 32k\Big),\end{aligned} \tag{B.9}$$

where $k \equiv \rho K$, and

$$\Theta_2(b^L) := \frac{11(\tilde{\alpha}_B^L)^2}{b^L} + \frac{4\alpha_G^2}{(2-b^L\gamma^2)^2} + \frac{4\alpha_G(\gamma\tilde{\alpha}_B^L - 3\alpha_G)}{2-b^L\gamma^2} + \frac{7((\tilde{\alpha}_B^L)^2 + b^L\alpha_G^2 - 2b^L\gamma\tilde{\alpha}_B^L\alpha_G)}{b^L(b^L\gamma^2-1)}.$$

By (B.9), $\mathcal{W}_S - \mathcal{W}_F$ is a concave and quadratic function of $1/b^H$. Moreover, by (A.1), $\Theta_2(b^L) > 0$, and thus $\mathcal{W}_S - \mathcal{W}_F = 0$ has two different real roots with respect to $1/b^H$, with one being negative and the other being positive. Therefore, we obtain that $\mathcal{W}_S > \mathcal{W}_F$ if, and only if, $0 < 1/b^H < 1/b^{H(4)}(b^L)$, i.e., $b^H > b^{H(4)}(b^L)$, where $1/b^{H(4)}(b^L)$ is the larger root of $\mathcal{W}_S - \mathcal{W}_F = 0$ and satisfies

$$b^{H(4)}(b^L) := \frac{2\alpha_B b^L}{2b^L c + \sqrt{b^L}\sqrt{32k + \Theta_2(b^L)}}.$$

Furthermore, by Lemma A.8(i) and (iii), $b^{H(4)}(b^L) > b^L$ for $b^L \in (0,1)$ and $b^{H(4)}(b^L) < 1$ if, and only if, $b^L \in (0, b^{L(6)})$, where $b^{L(6)}$ is uniquely determined by $b^{H(4)}(b^{L(6)}) = 1$. Then it follows from that, when the brand-name firm is $L-$type and, $b^L \in (0,1)$ and $b^H \in (b^L, \min\{b^{H(1)}(b^L), 1\})$, the information asymmetry increases the social welfare, i.e., $\mathcal{W}_S > \mathcal{W}_F$, if, and only if, $b^L \in (0, b^{L(6)})$ and $b^H \in (b^{H(4)}(b^L), \min\{b^{H(1)}(b^L), 1\})$. □

C. Information Asymmetry on Production Cost

In contrast to our base model in the paper, we now assume that consumers' relative price sensitivity is common knowledge and the brand-name firm possesses private information solely on its unit production cost at the start of the signaling period. We drop the superscript i and use b for consumers' relative price sensitivity. The brand-name firm's unit production cost can be either high (c^H) or low (c^L). The generic firm believes that the brand-name firm's unit production cost is c^H with probability λ_c and c^L with probability $1-\lambda_c$. Similarly, we refer to the brand-name firm as $H-$type and $L-$type when its unit production cost is c^H and c^L, respectively, and use superscript $m \in \{H, L\}$ to denote the brand-name firm's type. All the other model setup is identical to that in our base model in the paper.

Monopoly setting. The monopoly prices and profits of $m-$type brand-name firm in this case is, respectively given by:

$$p_B^{Mm} = \frac{c^m}{2} + \frac{\alpha_B}{2b} \text{ and } \Pi_B^{Mm} = \frac{(\alpha_B - bc^m)^2}{4b}, \ m \in \{H, L\}. \tag{C.1}$$

Duopoly setting. Lemma C.1 characterizes the equilibrium prices of the two types of drugs when the brand-name firm and the generic firm compete in the market. The proof of all results in this appendix is given in Appendix C.3.

Lemma C.1 **(Duopoly)**. *For $m \in \{H, L\}$, the $m-$type brand-name firm and the generic firm compete as duopoly and the optimal prices of brand-name and generic drugs are, respectively, given by:*

$$p_B^{Dm} = \frac{1}{2}\left(c^m + \frac{\alpha_B}{b} - \frac{\alpha_G \gamma}{2 - b\gamma^2}\right), \ p_G^{Dm} = \frac{1}{4}\left(3\alpha_G - \alpha_B\gamma + bc^m\gamma - \frac{2\alpha_G}{2 - b\gamma^2}\right), \tag{C.2}$$

if, and only if,

$$\max\left\{\alpha_G, \frac{b\gamma\alpha_G}{2 - b\gamma^2} + bc^m\right\} < \alpha_B < \frac{\alpha_G(4 - 3b\gamma^2)}{\gamma(2 - b\gamma^2)} + bc^m. \tag{C.3}$$

By using Lemma C.1, we obtain the profits of brand-name and generic firms in the duopoly setting when the brand-name firm is $m-$type, respectively, as follows:

$$\Pi_B^{Dm} \equiv \Pi_B^m(p_B^{Dm}) = \frac{\left[2\alpha_B - b\gamma(\alpha_G + \alpha_B\gamma) - bc^m(2 - b\gamma^2)\right]^2}{8b(2 - b\gamma^2)(1 - b\gamma^2)}, \tag{C.4}$$

$$\Pi_G^{Dm} \equiv \Pi_G^m(p_G^{Dm}) = \frac{\left[(\alpha_B - bc^m)(2 - b\gamma^2)\gamma - \alpha_G(4 - 3b\gamma^2)\right]^2}{16(2 - b\gamma^2)^2(1 - b\gamma^2)}. \tag{C.5}$$

Further, to ensure there is competition so that both drugs exist in the market when the brand-name firm is $H-$ or $L-$type (i.e., condition (C.3) is satisfied for $m \in \{H, L\}$), we restrict our analysis in this appendix to cases where the following condition is satisfied:

$$\alpha_G < \alpha_B < \frac{\alpha_G(4 - 3b\gamma^2)}{\gamma(2 - b\gamma^2)}, \text{ and } c^H < \frac{\alpha_B}{b} - \frac{\gamma\alpha_G}{2 - b\gamma^2}. \tag{C.6}$$

A necessary condition. Akin to the necessary condition in (11) in the paper, the following condition is necessary for the GCP to occur:

$$(1 - \lambda_c)\Pi_G^{DL} + \lambda_c\Pi_G^{DH} < k < \Pi_G^{DH}. \tag{C.7}$$

The above condition (C.7) ensures that the generic firm enters the market only when he knows the brand-name firm is $H-$type and stays out otherwise. It further implies that the generic firm earns more profits when facing an $H-$type brand-name firm than when facing an $L-$type one, which is always valid by (C.5).

C.1. The Stable Equilibrium and The GCP

We use backward induction to characterize the perfect Bayesian equilibrium (PBE) of the sequential game between the brand-name and the generic firm in pure strategies. In line with Section 4 in the paper, we focus on the equilibrium outcomes in the signaling period, since the equilibrium results in the full-information period are straightforward. Specifically, in the full-information period, all information is revealed to public and, by (C.7), the generic firm, if he has not already, enters the market if, and only if, the brand-name firm is $H-$type.

Proposition C.1 characterizes the stable equilibrium, which survives the Intuitive Criterion. In preparation, we define the following threshold values:

$$\alpha_B^{(1)} := \frac{2b\gamma\alpha_G}{2-b\gamma^2},\ \alpha_B^{(2)} := \frac{\alpha_G(4-3b\gamma^2)}{\gamma(2-b\gamma^2)},\ \alpha_B^{(3)} := \frac{9b^2\gamma^3-16b\gamma-2\sqrt{\Lambda_2}}{(8-26b\gamma^2+11b^2\gamma^4)/(2\alpha_G)},$$
$$c^{H(1)} := \frac{b\gamma(\alpha_B\gamma-\alpha_G)+\sqrt{\Lambda_1}}{b(2-b\gamma^2)},\ c^{H(2)} := \frac{\alpha_B}{b}-\frac{\gamma\alpha_G}{2-b\gamma^2},$$

where

$$\Lambda_1 := 2b\gamma\alpha_B(2\alpha_G-\alpha_B\gamma)(1-b\gamma^2),$$
$$\Lambda_2 := b(36-75b\gamma^2+49b^2\gamma^4-10b^3\gamma^6).$$

Also see (C.13) for the definition of the threshold $c^{L(1)}$.

Proposition C.1. *Suppose that (C.6) and (C.7) are satisfied.*

(i) For $b\gamma^2 < 4/5$, $\max\{\alpha_G,\alpha_B^{(1)}\} < \alpha_B < \alpha_B^{(2)}$, $c^{H(1)} < c^H < c^{H(2)}$, and $c^L \in (0, c^{L(1)})$, the stable equilibrium is a separating equilibrium, in which in the signaling period, the $H-$type brand-name firm charges its duopoly price p_B^{DH}, while the $L-$type brand-name firm charges its monopoly price p_B^{ML}.

(ii) For $c^L \in (\max\{0, c^{L(1)}\}, c^H)$, the stable equilibrium is a pooling equilibrium, in which in the signaling period, $H-$ and $L-$type brand-name firms charge the price p_B^{ML}.

Proposition C.1 shows that the stable equilibrium is pooling when the gap between c^H and c^L is small enough, whereas the stable equilibrium is a separating equilibrium when consumers' valuation for the brand-name drug is sufficiently large and two brand-name firm types are sufficiently different (i.e., c^L is small enough ($c^L \in (0, c^{L(1)})$) and c^H is large enough ($c^H \in (c^{H(1)}, c^{H(2)})$). The intuition behind the stable equilibrium in Proposition C.1 is similar to that of Proposition 1 in the paper. Specifically, to prevent entry of the generic firm, the $H-$type brand-name firm mimics the L type and charges its monopoly price in a pooling equilibrium. Doing so is profitable for the H type only when L type's monopoly price p_B^{ML} is not too low, i.e., when the two types of brand-name firm are sufficiently similar.

It should be noted that, slightly different from the base model, consumers' valuation for the brand-name drug affects the stable equilibrium in this appendix. When consumers' valuation for the brand-name drug is relatively high (i.e., $\max\{\alpha_G, \alpha_B^{(1)}\} < \alpha_B < \alpha_B^{(2)}$), the demand for the brand-name drug is very high and the competition does not reduce it significantly. As a result, in such cases, to deter generic entry in cases when the brand-name firm types are very different, the $H-$type brand-name firm needs lower its price substantially.

Instead, the H type allows generic entry and competes with the generic firm by charging its duopoly price. Hence, both brand-name firm types choose different prices and reveal their types when consumers' valuation for the brand-name drug is high enough and the two types of the brand-name firm are different enough. In contrast, when consumers' valuation for the brand-name drug is not sufficiently high, competition from the generic firm significantly reduces the demand for the brand-name drug, and thus the H type always prefers pooling and mimicking the L type to deter the generic entry.

Next, by using Proposition C.1, Theorem C.1 identifies cases where the GCP occurs in stable equilibrium.

THEOREM C.1. *In the stable equilibrium in Proposition C.1, the GCP occurs if, and only if, the brand-name firm is $H-$type, $b\gamma^2 < 4/5$, $\max\{\alpha_G, \alpha_B^{(1)}\} < \alpha_B < \alpha_B^{(2)}$, $\frac{\alpha_G\gamma}{2-b\gamma^2} < c^H < c^{H(2)}$, and $c^L \in \big(\max\{0, c^{L(1)}\}, c^H - \frac{\alpha_G\gamma}{2-b\gamma^2}\big)$.*

Theorem C.1, similar to Theorem 1 in the paper, shows that the GCP will occur only when the brand-name firm is $H-$type and the gap between c^H and c^L is small, but not too small. The key intuition behind Theorem 1 is similar to that behind Theorem 1.

C.2. Welfare Implications

After characterizing the stable equilibrium and identifying the cases where the GCP can occur, we further investigate the impact of information asymmetry on consumer surplus and social welfare. Proposition C.2 summarizes our results. (See the proof of Proposition C.2 in Appendix C.3 for the definitions of ν, $\mathcal{M}_6$, $c^{H(3)}$, $c^{H(4)}$ and $\bar{c}^L$.)

PROPOSITION C.2. *Suppose that the brand-name firm is $H-$type and $c^L \in \big(\max\{0, c^{L(1)}\}, c^H\big)$ (i.e., the stable equilibrium in Proposition C.1 is pooling).*

(i) The consumer surplus in the signaling period under information asymmetry increases relative to that under complete information if $\nu < b\gamma^2 < \frac{\sqrt{13}-1}{3}$,

$$\frac{2\sqrt{b}\alpha_G}{2-b\gamma^2} < \alpha_B < \alpha_B^{(2)},\ c^{H(3)} < c^H < c^{H(1)},\ \textit{and}\ \max\{0, c^{L(1)}\} < c^L < \frac{1}{b}\Big(\alpha_B - \frac{\sqrt{b\mathcal{M}_6}}{2}\Big).$$

(ii) The social welfare in the signaling period under information asymmetry increases relative to that under complete information if $\nu < b\gamma^2 < \frac{\sqrt{13}-1}{3}$,

$$\max\{\alpha_B^{(3)}, \frac{2\sqrt{b}\alpha_G}{2-b\gamma^2}\} < \alpha_B < \alpha_B^{(2)}\ c^{H(3)} < c^H < \min\{c^{H(4)}, \alpha_B/(2b)\},\ \textit{and}\ \max\{0, c^{L(1)}\} < c^L < \bar{c}^L.$$

Akin to Proposition 2 in the paper, Proposition C.2 shows that both consumer surplus and social welfare can benefit from the information asymmetry in the signaling period. This indicates that the welfare implications in our base model continue to hold.

C.3. Proofs of the Results in Appendix C.

Proof of Lemma C.1. Using backward induction, we characterize the equilibrium demand for brand-name and generic drugs in a duopoly setting by assuming positive demand for each, and then establish conditions for this positive demand to ensure competition between the two. By the similar procedure to the proof of Lemma 1 in Appendix B, for $m \in \{H, L\}$, we obtain q_B^{Dm} and q_G^{Dm} as below:

$$q_B^{Dm} = \frac{(2-b\gamma^2)(\alpha_B - bc^m) - b\gamma\alpha_G}{4(1-b\gamma^2)} \text{ and } q_G^{Dm} = \frac{\alpha_G(4-3b\gamma^2) - (\alpha_B - bc^m)(2-b\gamma^2)\gamma}{4(2-b\gamma^2)(1-b\gamma^2)}. \tag{C.8}$$

Given the fact $\alpha_B > \alpha_G$, both q_B^{Dm} and q_G^{Dm} being positive for $\forall\ m \in \{H, L\}$ is equivalent to

$$\max\left\{\alpha_G, \frac{b\gamma\alpha_G}{2-b\gamma^2} + bc^m\right\} < \alpha_B < \frac{\alpha_G(4-3b\gamma^2)}{\gamma(2-b\gamma^2)} + bc^m,\ \forall\ m \in \{H, L\}, \tag{C.9}$$

which completes the proof. $\square$

Proof of Proposition C.1. To obtain the stable equilibrium, we firstly identify the $L-$type brand-name firm's dominant strategy in equilibrium, and then use this to obtain the unique equilibrium. For the unique equilibrium, it is clear that it must survive the Intuitive Criterion and thus is the stable equilibrium. Note that, when the equilibrium is unique, the Pareto dominance criterion is no longer needed.

Firstly, we show that charging the monopoly price p_B^{ML} in (C.1) is the $L-$type brand-name firm's dominant strategy. Suppose that the $L-$type brand-name firm charges its monopoly price p_B^{ML}, then there are two possible outcomes based on the response of the $H-$type brand-name firm, i.e., the $H-$type brand-name firm charges the same or a different price from p_B^{ML}. If the $H-$type brand-name firm charges the same price as p_B^{ML}, then by (C.7), after observing the price, the generic firm will not enter the market. Thus, the $L-$type brand-name firm will earn its monopoly profit Π_B^{ML} as given by (C.1), which is the best it can earn. On the other hand, if the $H-$type brand-name firm charges a price different from p_B^{ML}, the generic firm can distinguish between $H-$ and $L-$type brand-name firms after observing their prices. Thus, when observing price p_B^{ML}, the generic firm will realize that the brand-name firm is $L-$type and will stay out of the market by (C.7). As a result, by charging the price p_B^{ML}, the $L-$type brand-name firm can still obtain its monopoly profit, which is the best it can earn. Therefore, in both cases, the $L-$type brand-name firm always earns the monopoly/best profit, which is larger than that from charging any other price. This means, charging price p_B^{ML} is the $L-$type brand-name firm's dominant strategy, and thus is the $L-$type's strategy in equilibrium.

Secondly, based on the $L-$type brand-name firm's dominant strategy of charging its monopoly price p_B^{ML}, there will be a pooling equilibrium in which the $H-$type charges the same price, if and only if

$$\Pi_B(H, p_B^{ML}, \{H, L\}) \geq \max_{p_B \neq p_B^{ML}} \Pi_B(H, p_B, H). \tag{C.10}$$

Note that by charging the same price p_B^{ML}, according to (C.7), the $H-$type brand-name firm can deter entry of the generic firm. Condition (C.10) ensures that the $H-$type brand-name firm earns more profits when charging the price p_B^{ML} to deter generic entry than the best it can obtain by charging any other price and revealing its type. Then condition (C.10) is equivalent to

$$(p_B^{ML} - c^H)(\alpha_B - bp_B^{ML}) \geq (p_B^{DH} - c^H)\frac{\alpha_B - bp_B^{DH} - b\gamma(\alpha_G - p_G^{DH})}{1 - b\gamma^2}. \tag{C.11}$$

The left-hand side of (C.11) is increasing in c^L for $c^L < c^H$, and (C.11) strictly holds when $c^L = c^H$. Moreover, when $c^L = 0$, (C.11) holds if and only if $\mathcal{F}_1(c^H; b) \geq 0$, where

$$\mathcal{F}_1(c^H; b) := 2\alpha_B(\alpha_B - 2bc^H)(2 - b\gamma^2)(1 - b\gamma^2) - \left[2\alpha_B - b\gamma(\alpha_G + \alpha_B\gamma) - bc^H(2 - b\gamma^2)\right]^2. \tag{C.12}$$

It shows that $\mathcal{F}_1(c^H; b)$ is concave in c^H, and $\mathcal{F}_1(0; b) = -b\gamma\left[b\gamma\alpha_G^2 - 2\alpha_B\alpha_G(2 - b\gamma^2) + \gamma\alpha_B^2(2 - b\gamma^2)\right] > 0$ for α_B that satisfies (C.3) in Lemma C.1. Thus, solving $\mathcal{F}_1(c^H; b) > 0$ yields $0 < c^H < c^{H(1)}$.

Recall from (C.6) that we only focus on the market where $\alpha_G < \alpha_B < \alpha_B^{(2)}$, and $0 < c^H < c^{H(2)}$. To identify the conditions such that $\mathcal{F}_1(c^H; b) > 0$, we need to compare $c^{H(1)}$ with $c^{H(2)}$. It shows that $c^{H(1)} \geq c^{H(2)}$ if, and only if, $\alpha_B \le \alpha_B^{(1)}$. For $\alpha_B > \alpha_B^{(1)}$ and $c^{H(1)} < c^H < c^{H(2)}$, (C.11) holds if, and only if, $c^L \in (c^{L(1)}, c^H)$, where $c^{L(1)}$ is given by

$$c^{L(1)} := c^H - \frac{1}{\sqrt{2}b}\sqrt{(\alpha_B - bc^H)^2 + \frac{2b\alpha_G^2}{2-b\gamma^2} + \frac{(\alpha_B - bc^H)^2 - 2b\gamma\alpha_G(\alpha_B - bc^H) + b\alpha_G^2}{b\gamma^2 - 1}}. \tag{C.13}$$

Next, by comparing the upper bound $\alpha_B^{(2)}$ of α_B given in (C.6) with $\alpha_B^{(1)}$, we obtain that $\alpha_B^{(1)} < \alpha_B^{(2)}$ if, and only if, $0 < b\gamma^2 < 4/5$.

Therefore, for the parameter space specified by (C.6), the equilibrium is a pooling equilibrium if, and only if: (i) $4/5 \le b\gamma^2 < 1$, $\alpha_G < \alpha_B < \alpha_B^{(2)}$, $0 < c^H < c^{H(2)}$, and $c^L \in (0, c^H)$, or (ii) $0 < b\gamma^2 < 4/5$, $\alpha_G < \alpha_B < \alpha_B^{(2)}$, $0 < c^H < c^{H(2)}$, and $c^L \in (\max\{0, c^{L(1)}\}, c^H)$; the equilibrium is a separating equilibrium if, and only if, $0 < b\gamma^2 < 4/5$, $\max\{\alpha_G, \alpha_B^{(1)}\} < \alpha_B < \alpha_B^{(2)}$, $c^{H(1)} < c^H < c^{H(2)}$, and $c^L \in (0, c^{L(1)})$.

Note that both the pooling and separating equilibrium are the unique equilibrium, and hence they are the stable equilibrium. $\square$

Proof of Theorem C.1. Based on Proposition C.1, when the brand-name firm is $L-$type, there is no generic entry both in the signaling and full-information periods, and thus the GCP cannot occur. When the brand-name firm is $H-$type and the stable equilibrium is separating, the price of the brand-name drug will decrease from its monopoly level p_B^{MH} to the duopoly level p_B^{DH} at the beginning of the signaling period and then will remain unchanged, i.e., the GCP does not exist either. Therefore, the GCP could only occur when the stable equilibrium is pooling and the brand-name firm is $H-$type.

Therefore, based on Proposition C.1, we only need to focus on the situation where the brand-name firm is $H-$type, and $c^L \in (\max\{0, c^{L(1)}\}, c^H)$, with (C.6) being satisfied. In such cases, by Proposition C.1, both the $L-$ and $H-$type brand-name firms charge the same price p_B^{ML} in the signaling period, and generic entry does not occur. Whereas, in the full-information period, since the brand-name firm's type is observable to the generic firm, by (C.7), the generic firm will enter the market to compete with the $H-$type brand-name firm. Hence, the $H-$type brand-name firm will optimally choose its duopoly price p_B^{DH} in the full-information period. Thus, the emergence of the GCP is equivalent to $p_B^{ML} < p_B^{DH}$, i.e., by (C.1) and (C.2),

$$c^H - \frac{\alpha_G\gamma}{2-b\gamma^2} > c^L \text{ and } c^H > \frac{\alpha_G\gamma}{2-b\gamma^2}. \tag{C.14}$$

To identify the conditions such that $p_B^{ML} < p_B^{DH}$ (i.e., (C.14) is satisfied), we analyze the following two cases.

Case (i): $4/5 \le b\gamma^2 < 1$, $\alpha_G < \alpha_B < \alpha_B^{(2)}$, $0 < c^H < c^{H(2)}$, and $c^L \in (0, c^H)$: In this case, we have $\alpha_B < \alpha_B^{(2)} \le \alpha_B^{(1)}$. By the condition on c^H in (C.14), it requires $c^H \in (\frac{\gamma\alpha_G}{2-b\gamma^2}, c^{H(2)})$ for the GCP to occur, which implies that $c^{H(2)} > \frac{\gamma\alpha_G}{2-b\gamma^2}$, i.e., it requires $\alpha_B > \alpha_B^{(1)}$, being a contradiction of $\alpha_B < \alpha_B^{(2)} \le \alpha_B^{(1)}$. Therefore, the GCP does not exist in this case.

Case (ii): $0 < b\gamma^2 < 4/5$, $\alpha_G < \alpha_B < \alpha_B^{(2)}$, $0 < c^H < c^{H(2)}$, and $c^L \in (\max\{0, c^{L(1)}\}, c^H)$: In this case, we have $c^{H(2)} > \frac{\alpha_G\gamma}{2-b\gamma^2}$ if, and only if, $\alpha_B > \alpha_B^{(1)}$. Since inequality (C.11) strictly holds when $c^L = c^H - \frac{\alpha_G\gamma}{2-b\gamma^2}$, we have $c^{L(1)} < c^H - \frac{\alpha_G\gamma}{2-b\gamma^2}$. Therefore, given the conditions in this case, there is GCP if, and only if, $\max\{\alpha_G, \alpha_B^{(1)}\} < \alpha_B < \alpha_B^{(2)}$, $\frac{\alpha_G\gamma}{2-b\gamma^2} < c^H < c^{H(2)}$, and $c^L \in (\max\{0, c^{L(1)}\}, c^H - \frac{\alpha_G\gamma}{2-b\gamma^2})$. $\square$

Proof of Proposition C.2. Supposing $c^L \in (\max\{0, c^{L(1)}\}, c^H)$, with (C.6) being satisfied (i.e., the stable equilibrium is pooling in the signaling period under information asymmetry) and the brand-name firm is $H-$type, we prove each part of the proposition separately.

Part(i). Note that in this appendix, we drop the superscript i for b^i and use b in the representative consumer's net utility as given by (1), writing it as $\mathcal{U}(q_B, q_G)$. The representative consumer has the same consumption profile (i.e., q_B and q_G) throughout the signaling period. Given q_B and q_G, the consumer surplus in the signaling period is equal to $\int_0^T e^{-\rho t}\mathcal{U}(q_B, q_G)dt = (1-e^{-\rho T})\mathcal{U}(q_B, q_G)/\rho$. Thus, to analyse the impact of information asymmetry on consumer surplus in the signaling period when the brand-name firm is $H-$type and $c^L \in (\max\{0, c^{L(1)}\}, c^H)$, with (C.6) being satisfied, it is enough to compare the representative consumer's net utility per-unit time, $\mathcal{U}(q_B, q_G)$, with and without the information asymmetry.

By Proposition C.1, with information asymmetry, the brand-name firm monopolizes the market, and the amount of the brand-name drug that the representative consumer purchases per-unit time at price p_B^{ML} is equal to $\check{q}_B = \alpha_B - bp_B^{ML}$. As a result, the consumer surplus per-unit time under information asymmetry is given by $S(\check{q}_B, 0) = \mathcal{U}(\check{q}_B, 0)$.

On the other hand, without information asymmetry, by condition (C.7), the generic firm enters the market and competes with the brand-name firm when the brand-name firm is $H-$type. Consequently, in absence of information asymmetry there is a duopoly in the signaling period, and the amount of brand-name and generic drugs that the representative consumer purchases per-unit time, at prices p_B^{DH} and p_G^{DH}, is respectively equal to q_B^{DH} and q_G^{DH} as given by (C.8). The consumer surplus per-unit time without information asymmetry is equal to $S(q_B^{DH}, q_G^{DH}) = \mathcal{U}(q_B^{DH}, q_G^{DH})$.

Next, to examine the impact of information asymmetry, we compare the consumer surplus per-unit time with and without information asymmetry, i.e., $S(\check{q}_B, 0)$ with $S(q_B^{DH}, q_G^{DH})$. To that end, letting $\check{\alpha}_B := \alpha_B - bc^H$, we define $\Delta S := S(q_B^{DH}, q_G^{DH}) - S(\check{q}_B, 0)$, and then obtain that

$$32\Delta S = \frac{-4(\alpha_B - bc^L)^2}{b} + \underbrace{\frac{3\check{\alpha}_B^2}{b} + \frac{4\alpha_G^2}{(2-b\gamma^2)^2} + \frac{4\alpha_G(\alpha_G + \gamma\check{\alpha}_B)}{2-b\gamma^2} + \frac{\check{\alpha}_B^2 + b\alpha_G^2 - 2b\gamma\alpha_G\check{\alpha}_B}{b(1-b\gamma^2)}}_{=:\mathcal{M}_6}. \tag{C.15}$$

By (C.15), ΔS is a concave and quadratic function of c^L. Note that when $c^L = c^H$, $\Delta S > 0$ always holds true. This, also by the assumption that $c^L < c^H$, implies that $\Delta S > 0$ if, and only if

$$\frac{1}{b}\left(\alpha_B - \frac{\sqrt{b\mathcal{M}_6}}{2}\right) < c^L < c^H,$$

in which $\frac{1}{b}\left(\alpha_B - \frac{\sqrt{b\mathcal{M}_6}}{2}\right)$ is the smaller root of $\Delta S = 0$ with respect to c^L. In addition, $\frac{1}{b}\left(\alpha_B - \frac{\sqrt{b\mathcal{M}_6}}{2}\right) > 0$ if, and only if, $\alpha_B > \frac{2\sqrt{b}\alpha_G}{2-b\gamma^2}$ and $c^H > c^{H(3)}$, where $c^{H(3)}$ is the unique c^H value that satisfies $4\alpha_B^2 - b\mathcal{M}_6 = 0$ and $c^{H(3)} < c^{H(2)}$.

Furthermore, for the stable pooling equilibrium as described in Proposition C.1, i.e., for the situation $c^L \in (\max\{0, c^{L(1)}\}, c^H)$ and (C.6) being satisfied, under the conditions such that $\frac{1}{b}\left(\alpha_B - \frac{\sqrt{b\mathcal{M}_6}}{2}\right) > 0$, we obtain that $\frac{1}{b}\left(\alpha_B - \frac{\sqrt{b\mathcal{M}_6}}{2}\right) > c^{L(1)}$ if and only if $\nu < b\gamma^2 < 1$, where ν is the unique solution to

$$64 - 352\sqrt{b\gamma^2} + 96b\gamma^2 + 232b^{\frac{3}{2}}\gamma^3 - 40b^2\gamma^4 - 6b^{\frac{5}{2}}\gamma^5 - 3b^3\gamma^6 = 0$$

with respect to $b\gamma^2$. Therefore, we obtain that the consumer surplus increases under information asymmetry, i.e., $\Delta S < 0$, if, and only if,

$$\nu < b\gamma^2 < \frac{\sqrt{13}-1}{3},\ \frac{2\sqrt{b}\alpha_G}{2-b\gamma^2} < \alpha_B < \alpha_B^{(2)},\ c^{H(3)} < c^H < c^{H(1)},\ \text{and}\ \max\{0, c^{L(1)}\} < c^L < \frac{1}{b}\left(\alpha_B - \frac{\sqrt{b\mathcal{M}_6}}{2}\right),$$

where $\frac{\sqrt{13}-1}{3}$ is the unique solution to $\frac{2\sqrt{b}\alpha_G}{2-b\gamma^2}-\alpha_B^{(2)}=0$ with respect to $b\gamma^2$.

Part(ii). By Proposition C.1, with information asymmetry in the signaling period: the brand-name firm monopolizes the market, and the amount of the brand-name drug that the representative consumer purchases per-unit time at price p_B^{ML} is equal to $\check{q}_B=\alpha_B-bp_B^{ML}$. As a result, the consumer surplus per-unit time in the signaling period is given by $S(\check{q}_B,0)=\mathcal{U}(\check{q}_B,0)$, and the total firm profit per-unit time is given by $\Pi_B^{MH}(p_B^{ML})=(p_B^{ML}-c^H)(\alpha_B-bp_B^{ML})$, where p_B^{ML} is given by (C.1). Whereas, in the full-information period, by condition (C.7), the generic firm, by incurring the fixed capacity cost K, enters the market and competes with the $H-$type brand-name firm. Hence, there is duopoly in the full-information period, and the amount of brand-name and generic drugs that the representative consumer purchases per-unit time, at prices p_B^{DH} and p_G^{DH} is, respectively, equal to q_B^{DH} and q_G^{DH} as given by (C.8). Then the consumer surplus per-unit time in the full-information period is equal to $S(q_B^{DH},q_G^{DH})=\mathcal{U}(q_B^{DH},q_G^{DH})$, and the total firm profit per-unit time is given by $\Pi_B^{DH}+\Pi_G^{DH}$, where Π_j^{DH} is, respectively, given by (C.4) and (C.5), for $j\in\{B,G\}$. Therefore, when there is information asymmetry in the signaling period, the total social welfare $\mathcal{W}_S$ over both periods is given by

$$\mathcal{W}_S=\int_0^T e^{-\rho t}\Big(S(\check{q}_B,0)+\Pi_B^{MH}(p_B^{ML})\Big)\mathrm{d}t+\int_T^\infty e^{-\rho t}\Big(S(q_B^{DH},q_G^{DH})+\Pi_B^{DH}+\Pi_G^{DH}\Big)\mathrm{d}t-Ke^{-\rho T}. \tag{C.16}$$

On the other hand, without information asymmetry in the signaling period, by condition (C.7), the generic firm, by incurring the fixed capacity cost K, enters the market and competes with the brand-name firm at the beginning of the signaling period. Then the generic and brand-name firms compete as duopoly throughout both the signaling and full-information periods. Consequently, the amount of brand-name and generic drugs that the representative consumer purchases per-unit time at prices p_B^{DH} and p_G^{DH} is, respectively, equal to q_B^{DH} and q_G^{DH} as given by (C.8). Then the consumer surplus per-unit time is equal to $S(q_B^{DH},q_G^{DH})=\mathcal{U}(q_B^{DH},q_G^{DH})$, and the total firm profit per-unit time is given by $\Pi_B^{DH}+\Pi_G^{DH}$, where Π_j^{DH} is, respectively, given by (C.4) and (C.5), for $j\in\{B,G\}$. Therefore, without information asymmetry, the total social welfare $\mathcal{W}_F$ over both periods is given by

$$\mathcal{W}_F=\int_0^\infty e^{-\rho t}\Big(\mathcal{U}(q_B^{DH},q_G^{DH})+\Pi_B^{DH}+\Pi_G^{DH}\Big)\mathrm{d}t-K. \tag{C.17}$$

Then, by using (C.16) and (C.17), we obtain

$$\begin{aligned}\mathcal{W}_S-\mathcal{W}_F&=\frac{1-e^{-\rho T}}{\rho}\Big(\mathcal{U}(\check{q}_B,0)+\Pi_B^{MH}(p_B^{ML})-\mathcal{U}(q_B^{DH},q_G^{DH})-\Pi_B^{DH}-\Pi_G^{DH}+k\Big)\\&=\frac{1-e^{-\rho T}}{32\rho}\Big(\Delta\mathcal{W}(c^L;c^H)+32k\Big),\end{aligned} \tag{C.18}$$

where $k\equiv\rho K$, and $\Delta\mathcal{W}(c^L;c^H)$ is given by

$$\begin{aligned}\Delta\mathcal{W}(c^L;c^H):=-4b(c^L)^2+8c^L(2bc^H-\alpha_B)-5b(c^H)^2-6c^H\alpha_B+\frac{7\alpha_B^2}{b}+\frac{4\alpha_G^2}{(2-b\gamma^2)^2}\\-\frac{4\alpha_G(3\alpha_G-\gamma\check{\alpha}_B)}{2-b\gamma^2}+\frac{7(\check{\alpha}_B^2+b\alpha_G^2-2b\gamma\check{\alpha}_B\alpha_G)}{b(b\gamma^2-1)}.\end{aligned}$$

This, by (C.18), indicates that the social welfare tends to be larger with asymmetric information than that without information asymmetry in the signaling period, when the generic firm's fixed capacity cost is higher.

Next, we identify the sufficient conditions such that $\mathcal{W}_S > \mathcal{W}_F$. To this end, by (C.18), we only need to show the sufficient conditions such that $\Delta\mathcal{W}(c^L; c^H) + 32k > 0$. Suppose that $2bc^H \le \alpha_B$. Then $\Delta\mathcal{W}(c^L; c^H) + 32k > 0$ if, and only if, $\Delta\mathcal{W}(0; c^H) + 32k > 0$ and

$$0 < c^L < \bar{c}^L := 2c^H - \frac{\alpha_B}{b} + \frac{1}{2\sqrt{b}}\sqrt{\frac{11\check{\alpha}_B^2}{b} + 32k + \frac{4\alpha_G^2}{(2-b\gamma^2)^2} - \frac{4\alpha_G(3\alpha_G - \gamma\check{\alpha}_B)}{2-b\gamma^2} + \frac{7(\check{\alpha}_B^2 + b\alpha_G^2 - 2b\gamma\check{\alpha}_B\alpha_G)}{b(b\gamma^2-1)}}.$$

We further identify the sufficient conditions such that $\Delta\mathcal{W}(0; c^H) + 32k > 0$, for k that satisfies (C.7). Note that $\Delta\mathcal{W}(0; c^H)$ is concave in c^H. Then by some algebra, we obtain that $\Delta\mathcal{W}(0; c^H) > 0$ if (i) $\nu < b\gamma^2 < \frac{\sqrt{13}-1}{3}$, (ii) $\max\{\alpha_B^{(3)}, \frac{2\sqrt{b}\alpha_G}{2-b\gamma^2}\} < \alpha_B < \alpha_B^{(2)}$, and (iii) $c^{H(4)} < c^H < \min\{c^{H(5)}, \alpha_B/(2b)\}$, where $c^{H(4)} < c^{H(5)}$ and

$$c^{H(5)},\ c^{H(4)} = \frac{\alpha_B \frac{4+3b\gamma^2}{1-b\gamma^2} - \frac{b\gamma\alpha_G(16-9b\gamma^2)}{2-b\gamma^2(3-b\gamma^2)} \pm 2\sqrt{11\alpha_B^2 - \frac{8b\alpha_G(2\alpha_G-\alpha_B\gamma)}{2-b\gamma^2} - \frac{7(\alpha_B^2+4b\alpha_G^2-4b\gamma\alpha_B\alpha_G)}{1-b\gamma^2}}}{b\left(5+\frac{7}{1-b\gamma^2}\right)}. \tag{C.19}$$

Finally, by further incorporating the condition $0 < c^L < \bar{c}^L$ and the condition such that the stable equilibrium is pooling in Proposition C.1, we complete the proof. □

D. Dual Sources of Information Asymmetry

In this appendix, we analyze the impact of information asymmetry on both the brand-name firm's unit production cost and consumers' relative price sensitivity. As in our base model, consumers' relative price sensitivity is either b^L or b^H. The brand-name firm has private information about this sensitivity, while the generic firm is unaware of the actual relative price sensitivity and his prior probability that the relative price sensitivity is b^H is denoted by λ_b. Similarly, the unit production cost of the brand-name firm is either high, c^H, or low, c^L; moreover, the brand-name firm knows its unit production cost, while the generic firm does not have this information. We let λ_c denote the generic firm's prior probability that the unit production cost is equal to c^H. For simplicity, we assume that the unit production cost and consumers' relative price sensitivity are independent. Letting $i \in \{H, L\}$ and $m \in \{H, L\}$, respectively, denote the type of the brand-name firm in consumers' relative price sensitivity and unit production cost, we use the superscript "im" to denote the overall type of the brand-name firm. There are four brand-name firm types in this case. Letting λ^{im} be the generic firm's prior probability that the brand-name firm's type is im, we have $\lambda^{HH} = \lambda_b\lambda_c$, $\lambda^{HL} = \lambda_b(1-\lambda_c)$, $\lambda^{LH} = (1-\lambda_b)\lambda_c$, and $\lambda^{LL} = (1-\lambda_b)(1-\lambda_c)$. All other aspects of the model setup remain the same as in Section 3 of the paper.

The monopoly price and profit of the $im-$type brand-name firm in this case is, respectively given by:

$$p_B^{Mim} = \frac{c^m}{2} + \frac{\alpha_B}{2b^i} \text{ and } \Pi_B^{Mim} = \frac{(\alpha_B - b^i c^m)^2}{4b^i},\ i \in \{H, L\},\ m \in \{H, L\}. \tag{D.1}$$

Lemma D.1 characterizes the duopoly prices of brand-name and generic firms and specifies the conditions under which they compete when the brand-name firm is of the $im-$type.

Lemma D.1 **(Duopoly)**. *In the duopoly setting, for $i, m \in \{H, L\}$, the $im-$type brand-name firm and the generic firm are competing in the market, and the optimal prices of brand-name and generic drugs are, respectively, given by:*

$$p_B^{Dim} = \frac{1}{2}\left(c^m + \frac{\alpha_B}{b^i} - \frac{\alpha_G\gamma}{2-b^i\gamma^2}\right),\ p_G^{Dim} = \frac{1}{4}\left(3\alpha_G - \alpha_B\gamma + b^i c^m\gamma - \frac{2\alpha_G}{2-b^i\gamma^2}\right),\ i, m \in \{H, L\}, \tag{D.2}$$

if, and only if,

$$\max\left\{\alpha_G, \frac{b^i\gamma\alpha_G}{2-b^i\gamma^2} + b^i c^m\right\} < \alpha_B < \frac{\alpha_G(4-3b^i\gamma^2)}{\gamma(2-b^i\gamma^2)} + b^i c^m. \tag{D.3}$$

By Lemma D.1, the optimal profits of brand-name and generic firms are, respectively, given by

$$\Pi_B^{Dim} \equiv \Pi_B^{im}(p_B^{Dim}) = \frac{\left[2\alpha_B - b^i\gamma(\alpha_G + \alpha_B\gamma) - b^i c^m(2 - b^i\gamma^2)\right]^2}{8b^i(2 - b^i\gamma^2)(1 - b^i\gamma^2)},$$
$$\Pi_G^{Dim} \equiv \Pi_G^{im}(p_G^{Dim}) = \frac{\left[(\alpha_B - b^i c^m)(2 - b^i\gamma^2)\gamma - \alpha_G(4 - 3b^i\gamma^2)\right]^2}{16(2 - b^i\gamma^2)^2(1 - b^i\gamma^2)}.$$

It is evident that the profit Π_B^{Dim} decreases with c^m, while the profit Π_G^{Dim} increases with c^m, i.e., $\Pi_B^{DiH} < \Pi_B^{DiL}$ and $\Pi_G^{DiH} > \Pi_G^{DiL}$ for $i \in \{H, L\}$. Similar to our base model (see Section 3.5 in the paper), to ensure that the GCP can occur, we restrict our analysis to cases where the generic firm earns more profits when consumers' relative price sensitivity is low. Lemma D.2 derives a sufficient condition for $\Pi_G^{DLm} > \Pi_G^{DHm}$ for $m \in \{H, L\}$ and thereby shows that there are cases where our results in this appendix apply.

Lemma D.2. *For $m \in \{H, L\}$, the generic firm earns more when facing $Lm-$type brand name firm than when facing $Hm-$type brand-name firm, i.e., $\Pi_G^{DLm} > \Pi_G^{DHm}$, for all $0 < b^L < b^H < 1$, if*

$$\frac{2c^H}{\gamma^2} + \frac{\alpha_G}{\gamma} \le \alpha_B \le \frac{\alpha_G(4 - 3\gamma^2)}{\gamma(2 - \gamma^2)} + c^L \ \textit{ and } \alpha_G \ge \frac{(2c^H - \gamma^2 c^L)(2 - \gamma^2)}{2\gamma(1 - \gamma^2)}. \tag{D.4}$$

For illustration purpose, we only focus on scenarios where $LL-$, $HH-$, and $LH-$type brand-name firms have incentives to mimic the HL type. We acknowledge that there can be other scenarios where the GCP can happen. To this end, we assume that the (discounted) capacity cost k and the prior probability λ^{im} satisfy:

$$\sum_{i\in\{H,L\}} \sum_{m\in\{H,L\}} \lambda^{im}\Pi_G^{Dim} < k < \min\{\Pi_G^{DHH}, \Pi_G^{DLL}\}. \tag{D.5}$$

Condition (D.5) ensures that the generic firm does not enter the market when he knows the brand-name firm is $HL-$type or the price of the brand-name drug observed in the signaling period is uninformative. Throughout this appendix, we restrict our analysis to cases where conditions (D.4) and (D.5) hold true.

D.1. The GCP in Equilibrium

Similar to Section 4 of the paper, we use backward induction to characterize the PBE of the sequential game between brand-name and generic firms in pure strategies. The equilibrium strategies in the full-information period can be easily characterized. By (D.5), the generic firm will not enter the market when he knows that the brand-name firm is $HL-$type, or when the price observed is uninformative. Thus, if the generic firm has not yet entered the market in the signaling period, he will not enter the market in the full-information period when the brand-name firm is $HL-$type, thus enabling the brand-name firm to maintain its monopoly status. Otherwise, he will enter the market and compete with the $HH-$, $LL-$, or $LH-$type. On the other hand, if the generic firm has entered the market in the signaling period, he will continue to be in the market, and thus the brand-name and generic firms continue competing as a duopoly.

We next focus on the signaling period and characterize the stable equilibrium in Proposition D.1. In preparation, we let $\widehat{\alpha}_B := \alpha_B - b^L c^H$ and

$$\widehat{b}^{H(1)}(b^L, c^H) := 1\Big/\left(\frac{1}{b^L} - \frac{1}{\alpha_B\sqrt{2b^L}}\sqrt{\frac{2\alpha_G^2}{2 - b^L\gamma^2} - \frac{(\widehat{\alpha}_B\gamma - \alpha_G)^2}{1 - b^L\gamma^2} + \frac{c^H - c^L}{\alpha_B}}\right).$$

Proposition D.1. *Suppose that the discounted fixed capacity cost satisfies the condition* (D.5). *In the stable equilibrium, in the signaling period, the prices of $HL-$ and $HH-$type brand-name firms are the same and equal to $\widehat{p}_B^{HH} = \widehat{p}_B^{HL} = p_B^{MHL}$, while the price of $Lm-$type brand-name firm $m \in \{H, L\}$ is given by:*

$$\widehat{p}_B^{Lm} = \begin{cases} p_B^{MHL}, & \textit{if } b^H \in (b^L, \min\{\widehat{b}^{H(1)}(b^L, c^m), 1\}), \\ p_B^{DLm}, & \textit{otherwise.} \end{cases}$$

Moreover, in the signaling period, the generic firm stays out when observing p_B^{MHL} and enters the market by charging price p_G^{DLm} when observing p_B^{DLm}.

Proposition D.1 shows that, in the stable equilibrium, the $HL-$type brand-name firm always charges its monopoly price. This is the $HL-$type's dominant strategy since after observing this price, by (D.5), the generic firm does not enter the market regardless of whether other types mimic the $HL-$type or not. The $HH-$type brand-name firm always mimics the HL type by charging its monopoly price and thereby deters generic entry. The cost of mimicking the HL type is not significant for the HH type because HL type's monopoly price p_B^{MHL} is reasonably high.

In addition, because it has the same unit production cost as the $HL-$type, $LL-$type brand-name firm only needs to consider the gap between b^H and b^L when determining whether to mimic the $HL-$type. Akin to the equilibrium strategy of the $L-$type brand-name firm characterized in Proposition 1 in Section 4.3 of the paper, when the types HL and LL are sufficiently different (i.e., the gap between b^H and b^L is sufficiently large), the $LL-$type brand-name firm chooses its duopoly price to separate from the $HL-$type and thus allows generic entry. However, when the HL and LL types are sufficiently similar, i.e., $b^H \in (b^L, \min\{\widehat{b}^{H(1)}(b^L, c^L), 1\})$, the $LL-$type brand-name firm mimics the $HL-$type by charging its price p_B^{MHL} which is lower than the $LL-$type's own monopoly price p_B^{ML} (i.e., *limit pricing*). That is, $LL-$type uses limit pricing as an anticompetitive practice to deter generic entry by hiding.

Lastly, the $LH-$type brand-name firm behaves significantly different from the HL type, and both b^H and c^H play a role in its equilibrium strategy. Different from the LL and HH types, the $LH-$type brand-name firm differentiates itself from the $HL-$type in two aspects: the LH type has a lower consumer price sensitivity (i.e., b^L) and a higher unit production cost (i.e., c^H). Thus, as shown by Proposition D.1, the $LH-$type brand-name firm prefers to mimic the HL type by charging its price p_B^{MHL} only when the gap between b^H and b^L is sufficiently small by taking into account the cost difference between c^H and c^L (i.e., $b^H \in (b^L, \min\{\widehat{b}^{H(1)}(b^L, c^H), 1\})$). In such cases, although the pooling price p_B^{MHL} is lower than the $LH-$type brand-name firm's own monopoly price (i.e., *limit pricing*), it is not significantly low due to the small gap between b^H and b^L. Therefore, the $LH-$type brand-name firm gains from pooling, instead of revealing its type and allowing generic entry.

Proposition D.1 also shows that, compared to the LL type, $LH-$type brand-name firm uses limit pricing in less cases (i.e., $\widehat{b}^{H(1)}(b^L, c^H) < \widehat{b}^{H(1)}(b^L, c^L)$). The intuition is as follows. The post-entry price of the brand-name drug is higher for the LH type than LL type (i.e., $p_B^{DLH} > p_B^{DLL}$). Therefore, a smaller gap between b^H and b^L can guarantee a relatively high pooling price (i.e., p_B^{MHL}) for the LH type, so that it is profitable to mimic HL type and deter the generic entry.

Finally, Theorem D.1 characterizes the conditions under which the GCP occurs. In preparation, we define

$$\widehat{b}^{H(2)} \equiv \widehat{b}^{H(2)}(b^L, c^L) := 1 \Big/ \Big(\frac{c^H - c^L}{\alpha_B} + \frac{1}{b^L} - \frac{\alpha_G \gamma}{\alpha_B (2 - b^L \gamma^2)} \Big).$$

In addition, $\widehat{b}^{L(4)} \in (0,1)$ uniquely solves $\widehat{b}^{H(2)}(b^L, c^L) = 1$ with respect to b^L, and $b^{L(4)}$ is defined in Section 4.4 of the paper.

Theorem D.1. *In the stable equilibrium in Proposition D.1, the GCP occurs if, and only if, (i) the brand-name firm's type is LL,* $b^L \in (0, b^{L(4)})$*, and* $b^H \in (b^{H(2)}(b^L), \min\{b^{H(1)}(b^L, c^L), 1\})$*, or (ii) the brand-name firm's type is LH, and* $b^L \in (0, \widehat{b}^{L(4)})$ *and* $b^H \in (\widehat{b}^{H(2)}(b^L, c^L), \min\{\widehat{b}^{H(1)}(b^L, c^H), 1\})$.

Akin to Theorem 1 in the paper, Theorem D.1 shows that the GCP still occurs when the brand-name firm has private information about consumers' relative price sensitivity and its own unit production cost. Utilizing Theorem D.1, and upon comparing the $LL-$ and $LH-$type brand-name firms, it is observed that for an $LH-$type brand-name firm, a relatively smaller gap between b^H and b^L can trigger the GCP, i.e., $\widehat{b}^{H(2)}(b^L, c^L) < b^{H(2)}(b^L)$. This occurs because the post-entry price of the $LH-$type brand-name firm in the full-information period, p_B^{DLH}, is higher than that of the LL type, p_B^{DLL}, reducing the necessary gap between b^H and b^L for the GCP to occur when the brand-name firm is of the $LH-$type.

D.2. Information Asymmetry and Welfare Implications

Next, following a similar procedure as in Section 5 of the paper, we examine how the information asymmetry affects consumer surplus and social welfare when there are two sources of information asymmetry. To ensure a fair comparison, we assume both conditions (C.3) and (D.4) are satisfied. Proposition D.2 summarizes our results. As a preparation, suppressing their dependence on b^L, we define the thresholds: $\Lambda_3 := \widehat{\alpha}_B^2 + b^L \alpha_G^2 - 2 b^L \gamma \alpha_G \widehat{\alpha}_B$, and

$$\widehat{b}^{H(3)} = 1 \Bigg/ \left(\frac{2}{b^L} - \frac{c^L}{\alpha_B} - \frac{1}{2 b^L \alpha_B} \sqrt{3\widehat{\alpha}_B^2 + \frac{4 b^L \alpha_G^2}{(2 - b^L\gamma^2)^2} + \frac{4 b^L \alpha_G (\alpha_G + \gamma \widehat{\alpha}_B)}{2 - b^L \gamma^2} + \frac{\widehat{\alpha}_B^2 + b^L \alpha_G^2 - 2 b^L \gamma \alpha_G \widehat{\alpha}_B}{1 - b^L \gamma^2}} \right),$$

$$\widehat{b}^{H(4)} = 1 \Bigg/ \left(\frac{2c^H - c^L}{\alpha_B} + \frac{1}{2 b^L \alpha_B} \sqrt{11\widehat{\alpha}_B^2 + 32 b^L k + \frac{4 b^L \alpha_G^2}{(2 - b^L\gamma^2)^2} + \frac{4 b^L \alpha_G (\gamma \widehat{\alpha}_B - 3\alpha_G)}{2 - b^L \gamma^2} + \frac{7\Lambda_3}{b^L \gamma^2 - 1}} \right).$$

In addition, setting $c = c^L$ for $b^{H(3)}(b^L)$ and $b^{H(4)}(b^L)$, respectively, given by (20) and (21), we obtain that $b^{H(3)}(b^L, c^L) = b^{H(3)}(b^L)$, $b^{H(4)}(b^L, c^L) = b^{H(4)}(b^L)$, $\widehat{b}^{L(5)} = b^{L(5)}$, and $\widehat{b}^{L(6)} = b^{L(6)}$. Similarly, setting $c = c^L$ for $b^{H(1)}(b^L)$ given by (20), we obtain that $b^{H(1)}(b^L, c^L) = b^{H(1)}(b^L)$, i.e., $b^{H(1)}(b^L, c^L) = \widehat{b}^{H(1)}(b^L, c^L)$. All the other threshold values are defined in Online Appendix C.

Proposition D.2. *Suppose that the discounted fixed capacity cost satisfies the condition* (D.5)*.*

(i) The consumer surplus in the signaling period with information asymmetry increases relative to that without information asymmetry if:

(a) $b^L \in (0, \widehat{b}^{L(5)})$ *and* $b^H \in (b^{H(3)}(b^L, c^L), \min\{b^{H(1)}(b^L, c^L), 1\})$ *when the brand-name firm is LL−type;*

(b) $\max\{b^L, \widehat{b}^{H(3)}\} < b^H < \min\{\widehat{b}^{H(1)}(b^L, c^H), 1\}$ *when the brand-name firm is LH−type.*

(ii) The social welfare in the signaling period with information asymmetry increases relative to that without information asymmetry if:

(a) $\nu < b^H\gamma^2 < \frac{\sqrt{13}-1}{3}$, $\max\{\alpha_B^{(3)}, \frac{2\sqrt{b^H}\alpha_G}{2-b\gamma^2}\} < \alpha_B < \alpha_B^{(2)}$, $c^{H(3)} < c^H < \min\{c^{H(4)}, \alpha_B/(2b^H)\}$ *and* $\max\{0, c^{L(1)}\} < c^L < \bar{c}^L$ *when the brand-name firm is* $HH-$*type;*

(b) $b^L \in (0, \widehat{b}^{L(6)})$ *and* $b^H \in (b^{H(4)}(b^L, c^L), \min\{b^{H(1)}(b^L, c^L), 1\})$ *when the brand-name firm is* $LL-$*type;*

(c) $\widehat{b}^{H(4)} < b^H < \min\{\widehat{b}^{H(1)}(b^L, c^H), 1\}$ *when the brand-name firm is* $LH-$*type.*

Similar to Proposition 2 in the paper, Proposition D.2 shows that both consumer surplus and social welfare can benefit from the information asymmetry in the signaling period. This indicates that the welfare implications in our base model continue to hold. Specifically, when the brand-name firm is $LL-$type, the impact of the information asymmetry on consumer surplus and social welfare reduces to that in Proposition 2 of the paper for $c = c^L$. Thus, the intuition follows from that of Proposition 2.

When the brand-name firm is $HH-$type, due to a stricter restriction on α_B as given in (D.4), consumers lose from the information asymmetry, whereas the impact of information asymmetry on social welfare reduces to that shown in Proposition C.2(ii) in Online Appendix C for $b = b^H$. Finally, when the brand-name firm is $LH-$type, although the unit production cost c^H also plays a role, both consumers and the society can still benefit from the information asymmetry, depending on how similar $HL-$ and $LH-$types of brand-name firms are. When the brand-name firm is $LH-$type, consumers benefit from the information asymmetry in more cases than when the brand-name firm is $LL-$type. This is because in the signaling period, with both LH or LL types, consumers face the same price for the brand-name drug (i.e., p_B^{MHL}) when there is information asymmetry; however, with $LH-$type brand-name firm, they pay a higher price p_B^{DLH} when there is no information asymmetry. Lastly, we discuss the impact of additional source of information asymmetry on consumer surplus and social welfare in Section 6.2 of the paper.

D.3. Proofs of the Results in Appendix D

Proof of Lemma D.1. Using backward induction, we characterize the equilibrium demand for brand-name and generic drugs in a duopoly setting by assuming positive demand for each, and then establish conditions for this positive demand to ensure competition between the two. By the similar procedure to the proof of Lemma 1 in Appendix B, for $i, m \in \{H, L\}$, we obtain q_B^{Dim} and q_G^{Dim} as below:

$$q_B^{Dim} = \frac{(2 - b^i\gamma^2)(\alpha_B - b^i c^m) - b^i\gamma\alpha_G}{4(1 - b^i\gamma^2)} \text{ and } q_G^{Dim} = \frac{\alpha_G(4 - 3b^i\gamma^2) - (\alpha_B - b^i c^m)(2 - b^i\gamma^2)\gamma}{4(2 - b^i\gamma^2)(1 - b^i\gamma^2)}. \tag{D.6}$$

Given the fact $\alpha_B > \alpha_G$, both q_B^{Dim} and q_G^{Dim} being positive for $\forall\ i, m \in \{H, L\}$ is equivalent to

$$\max\left\{\alpha_G, \frac{b^i\gamma\alpha_G}{2 - b^i\gamma^2} + b^i c^m\right\} < \alpha_B < \frac{\alpha_G(4 - 3b^i\gamma^2)}{\gamma(2 - b^i\gamma^2)} + b^i c^m,\ \forall\ i, m \in \{H, L\}, \tag{D.7}$$

which completes the proof. □

Proof of Lemma D.2. The proof is similar to that of Lemma A.3 in Appendix A.3. □

Proof of Proposition D.1. To obtain the stable equilibrium, we firstly identify the $HL-$type brand-name firm's dominant strategy in equilibrium, and then use this to obtain the unique equilibrium. For the unique equilibrium, it is clear that it must survive the Intuitive Criterion and thus is the stable equilibrium. Note that, when the equilibrium is unique, the Pareto dominance criterion is no longer needed.

Firstly, we show that charging the monopoly price p_B^{MHL} is the $HL-$type brand-name firm's dominant strategy. Suppose that the $HL-$type brand-name firm charges its monopoly price p_B^{MHL}. Based on (D.5), mimicking type HL is the only strategy for a brand-name firm (other than type HL) to deter generic entry. We can obtain that, if the LH-type is willing to pool with the $HL-$type, both the $LL-$ and $HH-$type must be willing to pool with the $HL-$type (by backward induction, this statement is true based on each player's best response in equilibrium). Therefore, there can be five possible outcomes: (i) all the other types mimic the $HL-$type, (ii) only $LL-$ and $HH-$types mimic the $HL-$type, (iii) only $LL-$type mimics the $HL-$type, (iv) only the $HH-$type mimics the $HL-$type, and (v) no one mimics the $HL-$type. By (D.5), in all five cases, the generic firm's expected revenue per unit time is less than the discounted fixed capacity cost, and hence will not enter the market when observing the price p_B^{MHL}. Therefore, by charging the monopoly price p_B^{MHL}, whether being mimicked or not, the $HL-$type brand-name firm can always earn its monopoly profit, which is the maximum it can obtain. That means, charging p_B^{MHL} is the $HL-$type brand-name firm's dominant strategy.

Secondly, based on the $HL-$type brand-name firm's dominant strategy of charging its monopoly price p_B^{MHL}, we consider the $HH-$, $LL-$, and $LH-$type brand-name firm's strategy in equilibrium respectively.

For the $LL-$type brand-name firm: The analysis is the same as that of Proposition 1, just replacing c with c^L. Thus, the $LL-$type brand-name firm's strategy in equilibrium is characterized by that of the $L-$type brand-name firm in Proposition 1 of the paper.

For the $HH-$type brand-name firm: The analysis is similar to that of Proposition C.1. To deter generic entry, the $HH-$type brand-name firm can only choose p_B^{MHL} to mimic type HL. With slight abuse of notation, let $\widehat{im}$ denote the generic firm's expectation of the type of the brand-name firm when observing price p_B^{MHL}. Therefore, the $HH-$type brand-name firm is willing to pool with the $HL-$type, if and only if

$$\Pi_B(HH, p_B^{MHL}, \widehat{im}) \geq \max_{p_B \neq p_B^{MHL}} \Pi_B(HH, p_B, HH). \tag{D.8}$$

Then condition (D.8) is equivalent to

$$(p_B^{MHL} - c^H)(\alpha_B - b^H p_B^{MHL}) \geq (p_B^{DHH} - c^H)\frac{\alpha_B - b^H p_B^{DHH} - b^H\gamma(\alpha_G - p_G^{DHH})}{1 - b^H\gamma^2}, \tag{D.9}$$

in which p_B^{MHL} and p_j^{DHH}, $j \in \{B, G\}$, are respectively given by (D.1) and (D.2). The left-hand side of (D.9) is increasing in c^L for $c^L < c^H$, and (D.9) strictly holds when $c^L = c^H$. Moreover, when $c^L = 0$, (D.9) holds if and only if $\mathcal{F}_1(c^H; b^H) \geq 0$, where $\mathcal{F}_1(c^H; b^H)$ is defined by (C.12) in Appendix C and is increasing in c^H. When $c^H = 0$, we have

$$\mathcal{F}_1(0; b^H) = -b^H\gamma\left[b^H\gamma\alpha_G^2 - 2\alpha_B\alpha_G(2 - b^H\gamma^2) + \gamma\alpha_B^2(2 - b^H\gamma^2)\right] > 0$$

for α_B satisfying condition (D.4) in Lemma D.2. Thus, inequality (D.9) always holds, and thus the $HH-$type brand-name firm is always willing to pool with the HL type.

For the $LH-$type brand-name firm: The $LH-$type brand-name firm can only choose p_B^{MHL} to mimic type HL. Therefore, the $LH-$type brand-name firm will choose to pool with the $HL-$type brand-name firm in equilibrium if and only if

$$\Pi_B(LH, p_B^{MHL}, \widehat{im}) \geq \max_{p_B \neq p_B^{MHL}} \Pi_B(LH, p_B, LH). \tag{D.10}$$

Then condition (D.10) is equivalent to

$$(p_B^{MHL} - c^H)(\alpha_B - b^L p_B^{MHL}) \ge (p_B^{DLH} - c^H)\frac{\alpha_B - b^L p_B^{DLH} - b^L\gamma(\alpha_G - p_G^{DLH})}{1 - b^L\gamma^2}, \tag{D.11}$$

in which p_B^{MHL} and p_j^{DLH}, $j \in \{B, G\}$, are respectively given by (D.1) and (D.2). Given $0 < b^L < b^H < 1$ and $c^L < c^H$, inequality (D.11) holds true if and only if $p_B^{MHL} \ge \bar{p}_B$, i.e., if and only if $b^H \le \widehat{b}^{H(1)}(b^L, c^H)$, where $\widehat{\alpha}_B := \alpha_B - b^L c^H$ and

$$\frac{1}{\widehat{b}^{H(1)}(b^L, c^H)} := \frac{1}{b^L} + \frac{c^H - c^L}{\alpha_B} - \frac{1}{\alpha_B\sqrt{2b^L}}\sqrt{\frac{2\alpha_G^2}{2 - b^L\gamma^2} - \frac{(\widehat{\alpha}_B\gamma - \alpha_G)^2}{1 - b^L\gamma^2}},\ \bar{p}_B := \frac{\alpha_B + \widehat{b}^{H(1)}(b^L, c^H)c^L}{2\widehat{b}^{H(1)}(b^L, c^H)}.$$

For simplicity, let $\widehat{b}^{H(1)} \equiv \widehat{b}^{H(1)}(b^L, c^H)$. Then $1/b^{H(1)} - 1/\widehat{b}^{H(1)}$ is increasing in c^L for $c^L \in (0, c^H)$, and $1/b^{H(1)} = 1/\widehat{b}^{H(1)}$ when $c^L = c^H$; thus we have $b^{H(1)} > \widehat{b}^{H(1)}$, i.e., $b^{H(1)}(b^L, c^L) > \widehat{b}^{H(1)}$. It can be further verified that $\bar{p}_B < p_B^{DLH}$. Thus, the equilibrium is a pooling equilibrium if and only if $b^H \in (b^L, \min\{\widehat{b}^{H(1)}, 1\})$.

The above equilibrium is unique, and hence it is the stable equilibrium. In the equilibrium, the generic firm's posterior belief (note that the probability that the brand-name firm is of type im when observing the price p_B^{MHL}, $\hat{\lambda}^{im}(p_B^{MHL}) \equiv \hat{\lambda}^{im}$) is given by:

(i) For $b^H \in (b^L, \min\{\widehat{b}^{H(1)}, 1\})$: the generic firm can only observe the price p_B^{MHL}, and then $\hat{\lambda}^{im} = \lambda^{im}$;

(ii) For $b^H \in (\widehat{b}^{H(1)}, \min\{b^{H(1)}(b^L, c^L), 1\})$: when the generic firm observes the drug price p_B^{MHL}, $\hat{\lambda}^{im} = \lambda^{im}/\sum_{im \ne LH}\lambda^{im}$ if $im \ne LH$, and $\hat{\lambda}^{LH} = 0$; when the generic firm observes the price p_B^{DLH}, $\hat{\lambda}^{LH}(p_B^{DLH}) = 1$;

(iii) For $b^H \in (\min\{b^{H(1)}(b^L, c^L), 1\}, 1)$: when the generic firm observes the brand-name drug price p_B^{MHL}, $\hat{\lambda}^{HL} = \lambda^{HL}/(\lambda^{HL} + \lambda^{HH})$, $\hat{\lambda}^{HH} = \lambda^{HH}/(\lambda^{HL} + \lambda^{HH})$, and $\hat{\lambda}^{LL} = \hat{\lambda}^{LH} = 0$; when the generic firm observes the drug price p_B^{DLm}, $m \in \{H, L\}$, then $\hat{\lambda}^{Lm}(p_B^{DLm}) = 1$. $\square$

Proof of Theorem D.1. When the brand-name firm is $HH-$type: The GCP, i.e., $p_B^{MHL} < p_B^{DHH}$, means

$$c^H - c^L > \frac{\alpha_G\gamma}{2 - b^H\gamma^2} \text{ and } c^H(2 - b^H\gamma^2) > \alpha_G\gamma. \tag{D.12}$$

Based on (D.12), the occurrence of GCP demands the condition $c^H(2 - b^H\gamma^2) > \alpha_G\gamma$, which contradicts with (D.4) in Lemma D.2. Therefore, the GCP does not exist.

When the brand-name firm is $LL-$type: The analysis is similar to the proof of Theorem 1, just replacing c with c^L.

When the brand-name firm is $LH-$type: The GCP, i.e., $p_B^{MHL} < p_B^{DLH}$, occurs if and only if $b^L \in (0, \widehat{b}^{L(4)})$ and $b^H \in (\widehat{b}^{H(2)}, \min\{\widehat{b}^{H(1)}, 1\})$, where

$$\frac{1}{\widehat{b}^{H(2)}} := \frac{c^H - c^L}{\alpha_B} + \frac{1}{b^L} - \frac{\alpha_G\gamma}{\alpha_B(2 - b^L\gamma^2)},$$

and $\widehat{b}^{L(4)} \in (0, 1)$ is the unique b^L value that satisfies $\widehat{b}^{H(2)} = 1$. It is obvious that $\widehat{b}^{H(2)} < b^{H(2)}(b^L)$. $\square$

Proof of Proposition D.2. We analyze consumer surplus and social welfare change for each type of brand-name firm separately. Note that the information asymmetry does not play a role when the brand-name firm is $HL-$type, since this type of brand-name firm always charges its monopoly price, and generic entry never occurs regardless of information asymmetry.

When the brand-name firm is $HH-$type, based on the proof of Theorem D.1, the GCP does not happen. This means that in the signaling period, consumers must bear a higher price of the brand-name drug than that under complete information. Thus, consumers must lose from information asymmetry. In addition, the analysis on social welfare can be obtained by following the proof of part(ii) of Proposition C.2 in Appendix C.

When the brand-name firm is $LL-$type, the results of consumer surplus and social welfare can be obtained by following the proof of Proposition 2 in Appendix B.

When the brand-name firm is $LH-$type, we obtain the results for consumer surplus and social welfare, using the same methods in the proof of Proposition 2 in Appendix B. □

E. Multiple Generic Firms

In this appendix, we extend our base model in the paper by considering $N < \infty$ identical generic firms with the same fixed capacity cost K. As in Section 3.1 of the paper, consumers' relative price sensitivity to the brand-name drug is either high (b^H) or low (b^L). At the beginning of the signaling period, the brand-name firm knows while all generic firms do not know the consumers' relative price sensitivity, and all generic firms have the same prior belief $\lambda_b \in (0,1)$, which is the probability that the consumers' relative price sensitivity is b^H.

We consider a similar sequence of events to that in Section 3.4 of the paper, in which all generic firms move simultaneously. In this appendix, our analysis will concentrate on the symmetric perfect Bayesian equilibrium, and shall later probe into the asymmetric equilibrium when there are two generic firms with different fixed capacity costs considering to enter the market in Appendix F. Since all generic firms are identical, in the symmetric equilibrium, if it is optimal for one generic firm to enter (respectively, not enter) the market, it is also optimal for all other generic firms to enter (respectively, not enter) the market. Similar to Kong (2009) and Ferrara and Missios (2012), we assume that, if generic firms enter the market, they engage in Cournot (quantity) competition among themselves while they engage in price competition with the brand-name firm. Consequently, all generic firms will choose the same price for their drugs. All the other model setup is the same as that in our base model in Section 3 of the paper. We use superscript N for the results in this appendix and defer the proof of all results in this appendix to Appendix E.3.

Monopoly setting. The monopoly price and profit of $i-$type brand-name firm in this case is, respectively given by:

$$p_B^{Mi} = \frac{c}{2} + \frac{\alpha_B}{2b^i} \text{ and } \Pi_B^{Mi} = \frac{(\alpha_B - b^i c)^2}{4b^i},\ i \in \{H, L\}. \tag{E.1}$$

Competition. By assuming that all generic firms learn the type of the brand-name firm once they are in the market as in Section 3 of the paper, Lemma E.1 characterizes cases where brand-name and all generic firms are in the market and compete against each other.

Lemma E.1 **(Competition)**. *Suppose that there are N identical generic firms considering to enter the market. For $i \in \{H, L\}$, the $i-$type brand-name firm and N generic firms compete in the market, and the optimal prices of brand-name and generic drugs under competition are, respectively, given by:*

$$p_B^{Ni} = \frac{1}{2}\left(c + \frac{\alpha_B}{b^i} - \frac{N\alpha_G\gamma}{1+N-b^i\gamma^2}\right), \text{ and } p_G^{Ni} = \frac{1}{2}\left(\frac{(2+N)\alpha_G}{1+N} - \frac{(\alpha_B - b^i c)\gamma}{1+N} - \frac{N\alpha_G}{1+N-b^i\gamma^2}\right), \tag{E.2}$$

if, and only if,

$$\max\left\{\alpha_G, \frac{Nb^i\gamma\alpha_G}{1+N-b^i\gamma^2} + b^i c\right\} < \alpha_B < \frac{\alpha_G\left[2(1+N) - (2+N)b^i\gamma^2\right]}{\gamma(1+N-b^i\gamma^2)} + b^i c. \tag{E.3}$$

Akin to Lemma 1 in the paper, Lemma E.1 characterizes the equilibrium prices of the brand-name and generic drugs when all generic firms are in the market and compete with the brand-name firm. Lemma E.1 reduces to Lemma 1 for $N = 1$.

By using Lemma E.1, we obtain the profits of the brand-name firm and each generic firm under competition, respectively, as follows:

$$\Pi_B^{Ni} = \frac{\left[(\alpha_B - b^i c)(1+N-b^i\gamma^2) - Nb^i\gamma\alpha_G\right]^2}{4b^i(1+N)(1+N-b^i\gamma^2)(1-b^i\gamma^2)},$$
$$\Pi_G^{Ni} = \frac{\left[\alpha_G(2(1+N)-(2+N)b^i\gamma^2) - (\alpha_B - b^i c)(1+N-b^i\gamma^2)\gamma\right]^2}{4(1+N)^2(1+N-b^i\gamma^2)^2(1-b^i\gamma^2)}.$$

A necessary condition. Akin to the necessary condition in (11) in the paper, to focus on the cases where the GCP can occur in symmetric equilibrium (i.e., all generic firms take the same action in equilibrium), we need the following condition:

$$(1-\lambda_b)\Pi_G^{DL} + \lambda_b\Pi_G^{DH} < k < \Pi_G^{NL}. \tag{E.4}$$

The above condition ensures that, when there are N identical generic firms, all generic firms enter the market if they know the brand-name firm is $L-$type and stays out when the brand-name firm's price is uninformative so that generic firms cannot update their prior belief about the type of the brand-name firm. For the latter case, even only one generic firm is considering to enter the market, the expected revenue still cannot cover the capacity cost. The condition (E.4) also ensures that this extension is comparable to the base model, i.e., the fixed capacity cost K (or k) is identical for this extension and the base model. Thus, k satisfying (E.4) also satisfies (11) in Section 3.5 of the paper. Furthermore, the condition in (E.4) also requires that each generic firm earns more profits when facing an $L-$type brand-name firm than when facing an $H-$type one, i.e., $\Pi_G^{NL} > \Pi_G^{NH}$, because $(1-\lambda_b)\Pi_G^{DL} + \lambda_b\Pi_G^{DH} \geq \Pi_G^{NH}$ for $\forall\lambda_b \in [0,1]$ and $N \geq 1$.

Next, akin to Lemma A.3 in Appendix A.3, Lemma E.2 characterizes the scenarios where $\Pi_G^{NL} > \Pi_G^{NH}$ for all $0 < b^L < b^H < 1$. In preparation, we define $\underline{\alpha}_B$ and $\underline{\alpha}_G$, respectively, as follows:

$$\underline{\alpha}_B = \frac{\alpha_G\left[2(1+N) + (N^2-3N-4)\gamma^2 + (2+N)\gamma^4\right]}{\gamma(1+N-\gamma^2)^2} + c\left(\frac{2}{\gamma^2} - 1\right),$$
$$\underline{\alpha}_G = \frac{c}{N\gamma}\frac{(1+N)(1+N-\gamma^2)(2-\gamma^2)}{2(1+N)-\gamma^2(3+N)}.$$

Lemma E.2. *Suppose that there are N identical generic firms considering to enter the market. Each generic firm earns more profits when facing an $L-$type brand-name firm than when facing an $H-$type one (i.e., $\Pi_G^{NL} > \Pi_G^{NH}$) for all $0 < b^L < b^H < 1$, if*

$$\max\left\{\alpha_G,\ \underline{\alpha}_B, \frac{2\alpha_G}{\gamma(1+N)} + \frac{2c}{\gamma^2}\right\} \leq \alpha_B \leq \frac{\alpha_G\left[2(1+N)-(2+N)\gamma^2\right]}{\gamma(1+N-\gamma^2)} + c \text{ and } \alpha_G \geq \underline{\alpha}_G. \tag{E.5}$$

E.1. The Stable Equilibrium and The GCP

We use backward induction to characterize the perfect Bayesian equilibrium (PBE) of the sequential game between the brand-name and all generic firms in pure strategies. As in Section 4 of the paper, we focus on the brand-name and generic firms' equilibrium strategies in the signaling period because their equilibrium strategies in the full-information period are straightforward. For example, (i) if all generic firms are already in the market at the beginning of the signaling period, the brand-name and generic firms will continue competing by charging prices p_B^{Ni} and p_G^{Ni} in the full-information period when the brand-name firm's type is $i \in \{H, L\}$, and (ii) if the generic firms are not in the market at the beginning of the signaling period, they will stay out of the market and the brand-name firm will charge its monopoly price p_B^{MH} in the full-information period when the brand-name firm is $H-$type, while generic firms will enter the market, and brand-name and generic firms will compete by, respectively, charging prices p_B^{NL} and P_G^{NL} in the full-information period when the brand-name firm is $L-$type.

Similar to Section 4 of the paper, there are two possible types of equilibrium, namely, *separating* and *pooling* equilibrium. Then applying Intuitive and Pareto dominance criteria, we characterize the stable equilibrium as in Proposition E.1 below. In preparation, we define the thresholds $b^{NH(1)}(b^L) \in (b^L, 1)$ and $b^{NL(1)}$ as follows:

$$b^{NH(1)}(b^L) = \frac{\alpha_B b^L}{\alpha_B - \sqrt{b^L}\gamma\sqrt{\frac{(\alpha_B - b^L c)(1+N-b^L\gamma^2)(2\alpha_G - \gamma(\alpha_B - b^L c)) - N\gamma b^L \alpha_G^2}{(1+N)(1-b^L\gamma^2)(1+N-b^L\gamma^2)/N}}}, \tag{E.6}$$

and for $b^H \in (0,1)$, $b^{NL(1)} \in (0, b^H)$ uniquely satisfies

$$\alpha_B^2(1-b^{NL(1)})^2 = (\alpha_B - b^{NL(1)}c)^2 - \frac{\left[(\alpha_B - b^{NL(1)}c)(1+N-b^{NL(1)}\gamma^2) - Nb^{NL(1)}\gamma\alpha_G\right]^2}{(1+N)(1+N-b^{NL(1)}\gamma^2)(1-b^{NL(1)}\gamma^2)}. \tag{E.7}$$

Proposition E.1 **(The Stable Equilibrium)**. *Suppose that there are N identical generic firms considering to enter the market and (E.4) is satisfied.*

(i) For $b^L \in (0, b^{NL(1)})$ and $b^H \in [b^{NH(1)}(b^L), 1)$, the stable equilibrium is a separating equilibrium, in which the price of $H-$ and $L-$type brand-name firm in the signaling period is, respectively, given by $\hat{p}_B^H = p_B^{MH}$ and $\hat{p}_B^L = p_B^{NL}$.

(ii) For $b^L \in (0,1)$ and $b^H \in (b^L, \min\{b^{NH(1)}(b^L), 1\})$, the stable equilibrium is a pooling equilibrium, in which both $H-$ and $L-$type brand-name firms charge the same price $\hat{p}_B = p_B^{MH}$.

Similar to Proposition 1 in the paper, Proposition E.1 shows that the stable equilibrium is pooling when the gap between b^H and b^L is sufficiently small (i.e., when the types of the brand-name firm are sufficiently similar), whereas the stable equilibrium is separating when the gap between b^H and b^L is sufficiently large (i.e., when the types of the brand-name firm differentiate significantly). Note that Proposition E.1 reduces to Proposition 1 in the paper for $N = 1$, and thus, follows from the same intuition.

Next, equipped with the stable equilibrium in Proposition E.1, we characterize the cases where the GCP can occur. In preparation, we define the threshold values $b^{NH(2)}(b^L)$ and $b^{NL(4)}$, respectively, as follows:

$$b^{NH(2)}(b^L) = \frac{\alpha_B b^L(1+N-b^L\gamma^2)}{\alpha_B(1+N-b^L\gamma^2) - Nb^L\gamma\alpha_G}, \tag{E.8}$$

$$b^{NL(4)} = \frac{N\gamma\alpha_G + \alpha_B(1+N+\gamma^2) - \sqrt{\left(N\gamma\alpha_G + \alpha_B(1+N+\gamma^2)\right)^2 - 4(1+N)\gamma^2\alpha_B^2}}{2\gamma^2\alpha_B}. \tag{E.9}$$

Theorem E.1. *Suppose that there are N identical generic firms considering to enter the market. In the stable equilibrium in Proposition E.1, the GCP occurs if, and only if, the brand-name firm is $L-$type, and $b^L \in (0, b^{NL(4)})$ and $b^H \in (b^{NH(2)}(b^L), \min\{b^{NH(1)}(b^L), 1\})$.*

Akin to Theorem 1 in the paper, Theorem E.1 shows that, when there are N identical generic firms, the GCP will occur only when the brand-name firm is $L-$type and the gap between b^H and b^L is sufficiently low, but not too low (i.e., the two types of brand-name firms are not extremely similar). The intuition behind Theorem 1 in the paper and Theorem E.1 above is the same.

E.2. Welfare Implications

Now, through a similar analysis in Section 5 of the paper, we study the impact of information asymmetry on consumers and the society when there are N identical generic firms. We summarize our results in Proposition E.2. In preparation, we define $\mathcal{M}_1$ and $\mathcal{M}_2$, respectively, as follows:

$$\mathcal{M}_1 = \frac{b^L N^2 \alpha_G^2}{(1+N-b^L\gamma^2)^2} + \frac{2b^L N\alpha_G(N\alpha_G+\tilde{\alpha}_B^L\gamma)}{(1+N)(1+N-b^L\gamma^2)} + \frac{(\tilde{\alpha}_B^L)^2+b^L\alpha_G^2-2b^L\tilde{\alpha}_B^L\alpha_G\gamma}{(1+N)^2(1-b^L\gamma^2)/N^2} + (\tilde{\alpha}_B^L)^2\frac{5+2N(5+2N)}{(1+N)^2}, \tag{E.10}$$

$$\mathcal{M}_2 = \frac{N^2\alpha_G^2}{(1+N-b^L\gamma^2)^2} + \frac{2\alpha_G\left(\gamma\tilde{\alpha}_B^L-(2+N)\alpha_G\right)}{(1+N)(1+N-b^L\gamma^2)/N} + \frac{N\left((\tilde{\alpha}_B^L)^2+b^L\alpha_G^2-2b^L\gamma\tilde{\alpha}_B^L\alpha_G\right)}{b^L(1+N)^2(b^L\gamma^2-1)/(4+3N)} + \frac{1+6N+4N^2}{b^L(1+N)^2/(\tilde{\alpha}_B^L)^2}, \tag{E.11}$$

where $\tilde{\alpha}_B^L := \alpha_B - b^L c$ is the absolute advantage of consumer valuation for the brand-name drug. Also we define the thresholds $b^{NH(3)}(b^L)$ and $b^{NH(4)}(b^L)$, respectively, as follows:

$$b^{NH(3)}(b^L) = \frac{\alpha_B b^L}{2\alpha_B - b^L c - \sqrt{\mathcal{M}_1 - 4(\tilde{\alpha}_B^L)^2}}, \tag{E.12}$$

$$b^{NH(4)}(b^L) = \frac{\alpha_B b^L}{b^L c + \sqrt{b^L}\sqrt{8N\rho K + \mathcal{M}_2}}, \tag{E.13}$$

and we let $b^{NL(5)}$ and $b^{NL(6)}$ be unique b^L values that, respectively, satisfy $b^{NH(3)}(b^L) = 1$ and $b^{NH(4)}(b^L) = 1$.

Proposition E.2. *Suppose that there are N identical generic firms considering to enter the market and that $b^L \in (0,1)$ and $b^H \in (b^L, \min\{b^{NH(1)}(b^L), 1\})$ (i.e., the stable equilibrium in Proposition E.1 is pooling) and the brand-name firm is $L-$type.*

(i) The consumer surplus in the signaling period under information asymmetry increases relative to that under complete information if, and only if, $b^L \in (0, b^{NL(5)})$ and $b^H \in (b^{NH(3)}(b^L), \min\{b^{NH(1)}(b^L), 1\})$.

(ii) The social welfare in the signaling period under information asymmetry increases relative to that under complete information if, and only if, $b^L \in (0, b^{NL(6)})$ and $b^H \in (b^{NH(4)}(b^L), \min\{b^{NH(1)}(b^L), 1\})$.

Proposition E.2 is akin to Proposition 2 in the paper and indicates that the welfare implications of the information asymmetry with a single generic firm extend to cases with multiple generic firms.

E.3. Proofs of the Results in Appendix E.

Proof of Lemma E.1. We use the backward induction to solve the brand-name firm's and N identical generic firms' optimization problem. First, given the prices p_B and p_G of the brand-name and the generic drugs, the representative consumer maximizes his/her utility given in (1). We then obtain the total demand for each type of drugs below (note that we firstly assume that the demands both are strictly positive, and finally will identify the sufficient and necessary conditions to guarantee this):

$$q_B^i(p_B, p_G) = \frac{(\alpha_B - b^i p_B) - b^i\gamma(\alpha_G - p_G)}{1 - b^i\gamma^2}, \tag{E.14}$$

$$q_G^i(p_B, p_G) = \frac{(\alpha_G - p_G) - \gamma(\alpha_B - b^i p_B)}{1 - b^i\gamma^2} = \sum_{n=1}^{N} q_G^{ni}. \tag{E.15}$$

Second, we analyze each generic firm's best response. By (E.15), the price of the generic drug is

$$p_G = \alpha_G - (1 - b^i\gamma^2)\sum_{n=1}^{N} q_G^{ni} - \gamma(\alpha_B - b^i p_B). \tag{E.16}$$

For the generic firm with index n, by substituting the price p_G in (E.16) into the profit function, his profit per unit time is given by

$$\Pi_G^{ni}(q_G^{ni}) = p_G q_G^{ni} = \Big(\alpha_G - (1-b^i\gamma^2)\sum_{n=1}^{N} q_G^{ni} - \gamma(\alpha_B - b^i p_B)\Big) q_G^{ni}.$$

Then solving the first-order condition of $\Pi_G^{ni}(q_G^{ni})$ with respect to q_G^{ni} gives

$$q_G^{ni} = \frac{\alpha_G - (1-b^i\gamma^2)\sum_{n'\neq n}^{N} q_G^{n'i} - \gamma(\alpha_B - b^i p_B)}{2(1-b^i\gamma^2)}. \tag{E.17}$$

Since generic firms are identical, we have $q_G^{ni} = q_G^{n'i}$ for $\forall n \neq n'$, and hence by solving (E.17), we obtain that for each generic firm with index n, $n = 1, \cdots, N$,

$$q_G^{ni} = q_G^{Ni} := \frac{\alpha_G - (\alpha_B - b^i p_B)\gamma}{(1+N)(1-b^i\gamma^2)}. \tag{E.18}$$

As a result, by plugging (E.18) into (E.16), we obtain that the price of the generic drug in equilibrium is a function of the price of the brand-name drug, i.e.,

$$p_G = \frac{\alpha_G - (\alpha_B - b^i p_B)\gamma}{1+N}. \tag{E.19}$$

Third, by plugging p_G in (E.19) into the brand-name firm's profit, we obtain

$$\Pi_B^{Ni}(p_B) = (p_B - c)\frac{(1+N)(\alpha_B - b^i p_B) - b^i\gamma^2(\alpha_B - b^i p_B) - N b^i \gamma \alpha_G}{(1+N)(1-b^i\gamma^2)}. \tag{E.20}$$

Then solving the first-order condition of $\Pi_B^{Ni}(p_B)$ with respect to p_B yields the optimal price of the brand-name drug, which is given by

$$p_B^{Ni} = \frac{1}{2}\Big(c + \frac{\alpha_B}{b^i} - \frac{N\alpha_G\gamma}{1+N-b^i\gamma^2}\Big).$$

Thus, by plugging p_B^{Ni} into (E.19), we obtain the price of the generic drug, which is given by

$$p_G^{Ni} = \frac{1}{2}\Big(\frac{(2+N)\alpha_G}{1+N} - \frac{(\alpha_B - b^i c)\gamma}{1+N} - \frac{N\alpha_G}{1+N-b^i\gamma^2}\Big).$$

Therefore, by considering the condition on α_B such that $p_B^{Ni} > c$, we obtain the lower bound of α_B in (E.3) in Lemma E.1. By further considering the condition on α_B such that $p_G^{Ni} > 0$, we obtain the upper bound of α_B in (E.3) in Lemma E.1, which completes the proof. $\square$

Proof of Lemma E.2. The proof is similar to that of Lemma A.3 in Appendix A.3.

Proof of Proposition E.1. To obtain the stable equilibrium, we firstly identify the $H-$type brand-name firm's dominant strategy in equilibrium, and then use this to obtain the unique equilibrium. For the unique equilibrium, it must survive the Intuitive Criterion and thus is the stable equilibrium. Note that, when the equilibrium is unique, the Pareto dominance criterion is no longer needed.

Firstly, we show that charging the monopoly price p_B^{MH} as given in (E.1) is the $H-$type brand-name firm's dominant strategy. Suppose that the $H-$type brand-name firm charges its monopoly price p_B^{MH}, then there are two possible outcomes based on the response of the $L-$type brand-name firm, i.e., the $L-$type brand-name firm charges the same or a different price from p_B^{MH}. If the $L-$type brand-name firm charges the same price as p_B^{MH}, then by (E.4), after observing the price, all generic firms will not enter the market. Thus, the $H-$type brand-name firm will earn its monopoly profit Π_B^{MH} as given in (E.1), which is the best it can earn. On the other hand, if the $L-$type brand-name firm charges a price different from p_B^{MH}, all generic firms can distinguish between $H-$ and $L-$type brand-name firms after observing their prices. Thus, when observing price p_B^{MH}, each generic firm will realize that the brand-name firm is $H-$type and will stay out of the market by (E.4). As a result, by charging the price p_B^{MH}, the $H-$type brand-name firm can still obtain its monopoly profit, which is the best it can earn. Therefore, in both cases, the $H-$type brand-name firm always earns the monopoly/best profit, which is larger than that from charging any other price. This means that, charging price p_B^{MH} is the $H-$type brand-name firm's dominant strategy, and thus is the $H-$type's strategy in equilibrium.

Secondly, based on the $H-$type brand-name firm's dominant strategy of charging its monopoly price p_B^{MH}, there will be a pooling equilibrium in which the $L-$type charges the same price if, and only if,

$$\Pi_B(L, p_B^{MH}, \{H, L\}) \geq \max_{p_B \neq p_B^{MH}} \Pi_B(L, p_B, L). \tag{E.21}$$

Note that by charging the same price p_B^{MH}, according to (E.4), the $L-$type brand-name firm can deter entry of all generic firms. Condition (E.21) ensures that the $L-$type brand-name firm earns more profits when charging the price p_B^{MH} to deter generic entry than the best it can obtain by charging any other price and revealing its type. Then condition (E.21) is equivalent to

$$(p_B^{MH} - c)(\alpha_B - b^L p_B^{MH}) \geq (p_B^{NL} - c)\frac{\alpha_B - b^L p_B^{NL} - b^L\gamma(\alpha_G - p_G^{NL})}{1 - b^L\gamma^2}, \tag{E.22}$$

where for $j \in \{B, G\}$, p_j^{NL} is given by (E.2). By solving (E.22) with respect to b^H, we obtain that $b^H \in (b^L, \min\{b^{NH(1)}, 1\})$, where $b^{NH(1)}$ is defined by (E.6). Furthermore, $b^L < b^{NH(1)} < 1$ if and only if $b^L \in (0, b^{NL(1)})$, where $b^{NL(1)}$ is defined by (E.7).

Therefore, for the parameter space specified by (E.4) and (E.5), the equilibrium is a pooling equilibrium if and only if $b^L \in (0,1)$ and $b^H \in (b^L, \min\{b^{NH(1)}, 1\})$, in which both $H-$ and $L-$type brand-name firms charge the same price p_B^{MH} and all generic firms will not enter the market after observing the pooling price p_B^{MH}; the equilibrium is a separating equilibrium if and only if $b^L \in (0, b^{NL(1)})$ and $b^H \in [b^{NH(1)}, 1)$, in which the $H-$type brand-name firm will charge the price p_B^{MH} and all generic firms will not enter the market after observing the price p_B^{MH}, while the $L-$type brand-name firm will charge the price p_B^{NL} and all generic firms will enter the market after observing the price p_B^{NL}. The pooling and separating equilibrium is, respectively, the unique equilibrium, and hence they are the stable equilibrium. □

Proof of Theorem E.1. According to Proposition E.1, when the brand-name firm is $H-$type, there is no generic entry both in the signaling and full-information periods, and thus the GCP cannot occur. When the brand-name firm is $L-$type and the stable equilibrium is separating, the price of the brand-name drug will decrease from its monopoly level p_B^{ML} to the competition level p_B^{NL} at the beginning of the signaling period and then will remain unchanged, i.e., the GCP does not exist either. Therefore, the GCP could only occur when the stable equilibrium is pooling and the brand-name firm is $L-$type. Based on Proposition E.1, we equivalently focus on the situation where the type of the brand-name firm is L, and $b^L \in (0,1)$ and $b^H \in (b^L, \min\{b^{NH(1)}, 1\})$. Then by (4) and (E.2), we have

$$p_B^{NL} - p_B^{MH} = \frac{1}{2}\Big(\frac{\alpha_B}{b^L} - \frac{\alpha_B}{b^H} - \frac{N\gamma\alpha_G}{1+N-b^L\gamma^2}\Big) > 0 \text{ if and only if } \frac{1}{b^H} < \frac{1}{b^L} - \frac{N\gamma\alpha_G}{\alpha_B(1+N-b^L\gamma^2)} =: \frac{1}{b^{NH(2)}}.$$

The above condition is equivalent to $b^H > b^{NH(2)}$, where $b^{NH(2)}$ is a function of b^L, i.e., $b^{NH(2)} = b^{NH(2)}(b^L)$.

Next, since we focus on the pooling stable equilibrium in Proposition E.1, i.e., $b^H \in (b^L, \min\{b^{NH(1)}, 1\})$, for the GCP to occur, we need to show that $b^{NH(2)} < b^{NH(1)}$. By a few algebra, we can find that $b^{NH(2)} < b^{NH(1)}$ is equivalent to $\mathcal{F}_2(\alpha_B) > 0$, where

$$\mathcal{F}_2(\alpha_B) := (1+N-b^L\gamma^2)\big((\alpha_B - b^L c)(2\alpha_G + b^L c\gamma - \alpha_B\gamma)(1+N-b^L\gamma^2) - b^L N\gamma\alpha_G^2\big) - Nb^L\gamma\alpha_G^2(1+N)(1-b^L\gamma^2).$$

We can check that $\mathcal{F}_2(\alpha_B) > 0$ for all α_B that satisfies

$$\frac{Nb^L\gamma\alpha_G}{1+N-b^L\gamma^2} + b^L c < \alpha_B < \frac{\alpha_G\,[2(1+N) - (2+N)b^L\gamma^2]}{\gamma(1+N-b^L\gamma^2)} + b^L c,$$

of which (E.5) is a subset. Thus, for α_B that satisfies (E.5), we must have $\mathcal{F}_2(\alpha_B) > 0$, i.e., $b^{NH(2)} < b^{NH(1)}$.

Finally, we identify the sufficient and necessary conditions such that $b^{NH(2)} < 1$, when (E.5) is satisfied. By solving $b^{NH(2)} < 1$ with respect to b^L, we obtain that $b^{NH(2)} < 1$ if, and only if, $b^L \in (0, b^{NL(4)})$, where $b^{NL(4)} \in (0,1)$ and its definition is given by (E.9). This completes the proof. □

Proof of Proposition E.2. The results for consumer surplus and social welfare are obtained by following the procedure in the proof of Proposition 2 in Appendix B. □

F. Sequential Generic Entry

In the appendix, we expand our base model by including two generic firms with high and low fixed capacity costs. The fixed capacity cost for the 'low-cost' generic firm is normalized to zero, and for the 'high-cost' generic firm is represented by $K > 0$. At the beginning of the signaling period, both generic firms are equally informed about the market but are unaware of the brand-name firm's actual type. Specifically, λ_b denotes low- and high-cost generic firms' prior probability that consumers' relative price sensitivity is b^H so that the brand-name firm is $H-$type. As in Appendix E, generic firms engage in quantity competition between themselves while they engage in price competition with the brand-name firm (Kong 2009, Ferrara and Missios 2012). Thus, both generic firms will charge the same price once they enter the market and compete with the brand-name firm. We use the superscript "T" to denote results when three firms (the brand-name firm and two generic firms) are in the market and compete against each other. All other aspects of the model setup remain the same as described in Section 3 of the paper.

Triopoly setting: Using Lemma E.1 for $N = 2$ and $i \in \{H, L\}$, the $i-$type brand-name firm's and two generic firms' prices in the triopoly setting are, respectively, given by:

$$p_B^{Ti} = \frac{1}{2}\left(c + \frac{\alpha_B}{b^i} - \frac{2\alpha_G\gamma}{3 - b^i\gamma^2}\right), \text{ and } p_G^{Ti} = \frac{1}{2}\left(\frac{4\alpha_G}{3} - \frac{(\alpha_B - b^i c)\gamma}{3} - \frac{2\alpha_G}{3 - b^i\gamma^2}\right). \tag{F.1}$$

By Lemma E.1 for $N = 2$, $i-$type brand-name firm and both generic firms will exist in the market so that above triopoly prices are valid if, and only if,

$$\max\left\{\alpha_G, \frac{2b^i\gamma\alpha_G}{3 - b^i\gamma^2} + b^i c\right\} < \alpha_B < \frac{\alpha_G\,(6 - 4b^i\gamma^2)}{\gamma(3 - b^i\gamma^2)} + b^i c,\ i \in \{H, L\}. \tag{F.2}$$

Furthermore, when the brand-name firm is $i-$type, the profit of brand-name firm and each generic firm, is given, respectively, by:

$$\Pi_B^{Ti} = \frac{\left[(\alpha_B - b^i c)(3 - b^i\gamma^2) - 2b^i\gamma\alpha_G\right]^2}{12b^i(3 - b^i\gamma^2)(1 - b^i\gamma^2)}, \text{ and } \Pi_G^{Ti} = \frac{\left[\alpha_G(6 - 4b^i\gamma^2) - (\alpha_B - b^i c)(3 - b^i\gamma^2)\gamma\right]^2}{36(3 - b^i\gamma^2)^2(1 - b^i\gamma^2)}. \tag{F.3}$$

A necessary condition for the GCP: In this appendix, to restrict our attention to the cases where the GCP can occur, we assume that the following necessary condition is satisfied:

$$(1-\lambda_b)\Pi_G^{TL} + \lambda_b \Pi_G^{TH} < k < \Pi_G^{TL}. \tag{F.4}$$

Condition (F.4) ensures that market entry is profitable for the high-cost generic firm only when the brand-name firm is $L-$type, while it is unprofitable when the brand-name firm is $H-$type, or the price of the brand-name drug is uninformative so that the generic firm cannot infer the brand-name firm's actual type. Regardless of the brand-name firm's type, the low-cost generic firm enters the market at the beginning of the signaling period since his fixed capacity cost is zero. Moreover, condition (F.4) ensures that the sequential entry can occur. For example, the high-cost generic firm enters the market in the full-information period when he knows the brand-name firm is $L-$type, as a result, sequential generic entry occurs.

Also, condition (F.4) requires that each generic firm earns more profit when facing an $L-$type brand-name firm than when facing an $H-$type one, i.e., $\Pi_G^{TL} > \Pi_G^{TH}$. Lemma F.1 below provides a sufficient condition and demonstrates that there exist cases where $\Pi_G^{TH} < \Pi_G^{TL}$ for all $0 < b^L < b^H < 1$, ensuring the applicability of our results in this appendix.

Lemma F.1. *Suppose that there is a low-cost generic firm with a fixed capacity cost of zero and a high-cost generic firm with a fixed capacity cost of $K > 0$. Each generic firm earns more when facing an $L-$type brand-name firm than when facing an $H-$type one (i.e., $\Pi_G^{TL} > \Pi_G^{TH}$) for all $0 < b^L < b^H < 1$, if*

$$\max\left\{\frac{6(1-\gamma^2)+4\gamma^4}{\gamma(3-\gamma^2)^2/\alpha_G} + c\Big(\frac{2}{\gamma^2}-1\Big), \frac{2\alpha_G}{3\gamma} + \frac{2c}{\gamma^2}\right\} \le \alpha_B \le \frac{\alpha_G\,(6-4\gamma^2)}{\gamma(3-\gamma^2)} + c \text{ and } \alpha_G \ge \frac{c(3-\gamma^2)(2-\gamma^2)}{2\gamma(6-5\gamma^2)/3}. \tag{F.5}$$

F.1. Equilibrium Analysis

We use backward induction to characterize the pure-strategy PBE of the sequential game between the brand-name firm and two generic firms. The brand-name firm and two generic firms' equilibrium strategies in the full-information period are as follows. The low-cost generic firm enters the market at the beginning of the signaling period since his fixed capacity cost is zero. By (F.4), the high-cost generic firm enters the market only when he knows the brand-name firm is $L-$type. Then specifically, if both generic firms entered the market in the signaling period, the brand-name firm and two generic firms continue to compete in the full-information period by, respectively, charging their triopoly prices p_B^{Ti} and p_G^{Ti}, which are given by (F.1). However, if the high-cost generic firm did not enter the market in the signaling period, as per (F.4), in the full-information period: (i) when the brand-name firm is of the $H-$type, the high-cost generic firm stays out, and the brand-name firm and low-cost generic firm compete as duopoly, charging p_B^{DH} and p_G^{DH} respectively; (ii) when the brand-name firm is of the $L-$type, the high-cost generic firm enters the market, creating a triopoly where the brand-name and generic firms charge prices p_B^{TL} and p_G^{TL}, respectively.

We next focus on the equilibrium strategies of firms in the signaling period. As noted above, the low-cost generic firm always enters the market, ensuring that at least two firms compete during this period. In the signaling period, only separating and pooling equilibria are possible. Proposition F.1 characterizes the equilibrium strategies of brand-name and generic firms in the signaling period. (Refer to the proof of Proposition F.1 for the definitions of the thresholds $\bar{b}^{H(0)}(b^L)$ and $\bar{b}^{H(1)}(b^L)$).

Proposition F.1. *Suppose there is a low-cost generic firm with a fixed capacity cost of zero and a high-cost generic firm with a fixed capacity cost of $K > 0$. In the signaling period:*

(i) the stable equilibrium is a pooling equilibrium, in which the low-cost generic firm enters the market, charging price p_G^{DH}, while the high-cost generic firm stays out, and both $H-$ and $L-$type brand-name firms charge the same price p_B^{DH} if, and only if, $b^L < b^H \leq \min\{\bar{b}^{H(1)}(b^L), \bar{b}^{H(0)}(b^L), 1\}$;

(ii) otherwise, the stable equilibrium is a separating equilibrium, in which (a) when the brand-name firm is of the $H-$type, it charges price p_B^{DH}, the low-cost generic firm charges p_G^{DH}, and the high-cost generic firm stays out, and (b) when the brand-name firm is $L-$type, it charges price p_B^{TL}, and both generic firms enter the market and charge price p_G^{TL}.

Similar to Proposition 1 in the paper, Proposition F.1 shows that the stable equilibrium is pooling if, and only if, the gap between b^H and b^L is sufficiently small (i.e., the two types of the brand-name firm are sufficiently similar), whereas the stable equilibrium is separating when the gap between b^H and b^L is sufficiently large (i.e., the two types of the brand-name firm are sufficiently different). In a stable pooling equilibrium, the low-cost generic firm (with zero fixed capacity cost) always enters the market at the beginning of the signaling period, regardless of the brand-name firm's type, and immediately learns the brand-name firm's actual type. Then, by (F.4), as the high-cost generic firm will not enter if it cannot distinguish between H and L types, the $L-$type brand-name firm can pretend to be the $H-$type by charging the $H-$type's (duopoly) price to prevent the entry of the high-cost generic firm. However, this can only happen if the low-cost generic firm tacitly colludes and also prefers to charge a duopoly price as if the brand-name firm is $H-$type, which is higher than the triopoly price p_G^{TL} (see Corollary 1 below). This is profitable for both the $L-$type brand-name firm and the low-cost generic firm if, and only if, the H type's and low-cost generic firms' duopoly prices p_B^{DH} and p_G^{DH} are not too low, i.e., the two types of the brand-name firm are sufficiently similar.

Corollary 1. *Suppose that the stable equilibrium as characterized in Proposition F.1 is pooling, i.e., $b^L < b^H \leq \min\{\bar{b}^{H(1)}(b^L), \bar{b}^{H(0)}(b^L), 1\}$. The low-cost generic firm charges the duopoly price p_G^{DH}, which is always higher than the triopoly price p_G^{TL}.*

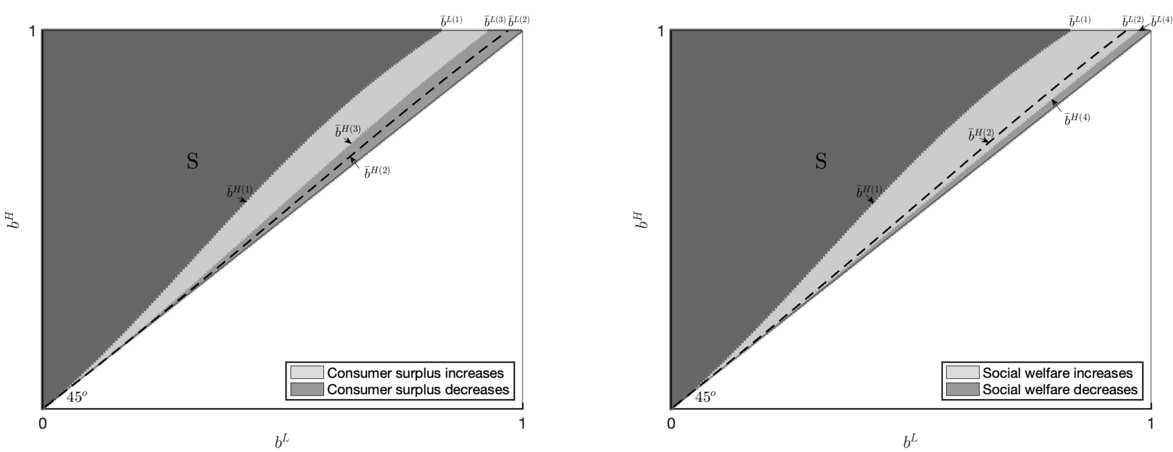
Then using Proposition F.1, Theorem F.1 characterizes cases where the GCP occurs. In preparation, let us define $\bar{b}^{H(2)}(b^L)$ and $\bar{b}^{L(2)}$, respectively, as the unique b^H and b^L values that, respectively, satisfy $p_B^{TL} = p_B^{DH}(b^H)$ and $\bar{b}^{H(2)}(b^L) = 1$.

Theorem F.1. *Suppose that there is a low-cost generic firm with a fixed capacity cost of zero and a high-cost generic firm with a fixed capacity cost of $K > 0$. In the stable equilibrium as characterized in Proposition F.1, the GCP occurs if, and only if, the brand-name firm is $L-$type, and $b^L \in (0, \bar{b}^{L(2)})$ and $b^H \in (\bar{b}^{H(2)}(b^L), \min\{\bar{b}^{H(1)}(b^L), \bar{b}^{H(0)}(b^L), 1\})$.*

Similar to Theorem 1 in the paper, Theorem F.1 demonstrates that the GCP can occur in the case of sequential entry. Note that in this extension, we generalize the definition of GCP to include the phenomenon of price increase of the brand-name drug when an extra generic firm enters the market, not necessarily the entry of the first generic firm, as empirically identified in the literature, such as Regan (2008) and Ching (2010). Specifically, as the low-cost generic firm enters the market at the beginning of the signaling period, whereas the high-cost generic firm only enters the market if he believes the brand-name firm to be $L-$type, the GCP occurs if, and only if, the stable equilibrium is pooling and the gap between b^H and b^L is small, but not too small (i.e., the $H-$ and $L-$type brand-name firms are similar but not extremely similar). The underlying intuition is similar to that presented in Theorem 1 in the paper.

F.2. The Impact of Information Asymmetry

Next, as in Section 5 of the paper, we examine the effects of information asymmetry on consumer surplus and social welfare in this appendix. Given the challenge of analytically characterizing the impact of information asymmetry in this case, we rely on numerical analysis. Figure F.1 depicts the influence of information asymmetry in consumer relative price sensitivity on consumer surplus and social welfare during the signaling period in a numerical instance. As observed in Figure 1(a), the consumer surplus in the signaling period with information asymmetry is higher compared to the scenario without information asymmetry when the two types of brand-name firms are sufficiently, but not significantly, different. Additionally, Figure 1(b) indicates that social welfare in the signaling period with information asymmetry is greater relative to the case without information asymmetry when the two types of brand-name firms are not too similar. All these results corroborate our paper's main conclusion regarding the impact of information asymmetry on consumers and society.



(a) Consumer surplus (b) Social welfare

Figure F.1 The impact of information asymmetry on consumer surplus and social welfare, when $\alpha_{\mathbf{B}} = 1160$, $\alpha_{\mathbf{G}} = 1000$, c = 0.5, and $\gamma = 0.87$

Note. Region S, i.e., the darkest gray region, corresponds to the separating stable equilibrium, while the other gray regions correspond to the pooling stable equilibrium. The GCP occurs in the light gray region above the dashed line.

F.3. Proofs of the Results in Appendix F

Proof of Lemma F.1. Lemma E.2 reduces to Lemma F.1 when $N=2$. □

Proof of Proposition F.1. To obtain the stable equilibrium, we firstly identify the dominant strategies of the $H-$type brand-name firm and the corresponding low-cost generic firm, and then use this to obtain the unique equilibrium. Note that the unique equilibrium must survive the Intuitive Criterion and thus is the stable equilibrium. In addition, when the equilibrium is unique, the Pareto dominance criterion is no longer needed.

Firstly, we show that, charging, respectively, the duopoly prices p_B^{DH} and p_G^{DH} as given by (7) in Section 3.3 of the paper, is the $H-$type brand-name firm's and the low-cost generic firm's (who faces an $H-$type brand-name firm) dominant strategy. Since the low-cost generic firm has zero fixed capacity cost, he will always enter the market. Thus, at best the $H-$type brand-name firm and the low-cost generic firm can, respectively, charge prices p_B^{DH} and p_G^{DH}, and they earn duopoly profits Π_B^{DH} and Π_G^{DH} as respectively given by (9) and (10) in Section 3.3 of the paper.

Now suppose that the $H-$type brand-name firm charges its duopoly price p_B^{DH} and then the low-cost generic firm who faces an $H-$type brand-name firm also charges the duopoly price p_G^{DH}. Then there are two possible outcomes based on the responses of the $L-$type brand-name firm, i.e., the $L-$type brand-name firm charges the same or a different price from p_B^{DH}. Specifically, if the $L-$type brand-name firm charges the same price as p_B^{DH}, then after observing the price, the high-cost generic firm cannot update his belief. But the low-cost generic firm will always enter the market. Then if the high-cost generic firm observes a price p_G^{DH} charged by the low-cost generic firm, the high-cost generic firm will not enter, whether he can confirm this price is from the low-cost generic firm who faces an $H-$type brand-name or cannot distinguish the brand-name firm types, since he expects to earn negative profits by (F.4). Therefore, the $H-$type brand-name firm will earn duopoly profit Π_B^{DH}, and the low-cost generic firm facing an $H-$type brand-name firm will also earn duopoly profit Π_G^{DH}, which are respectively the best they can obtain. On the other hand, if the $L-$type brand-name firm charges a different price from p_B^{DH}, then after observing the price p_B^{DH}, the high-cost generic firm can immediately update his belief and realize that the brand-name firm is $H-$type, and then will not enter. Therefore, the $H-$type brand-name firm will earn duopoly/best profit Π_B^{DH}, and the low-cost generic firm facing an $H-$type brand-name firm will also earn duopoly/best profit Π_G^{DH}. This means, charging the duopoly price is the dominant strategy for both the $H-$type brand-name firm and the low-cost generic firm who faces an $H-$type brand-name firm.

Secondly, based on the dominant strategy of the $H-$type brand-name firm and the low-cost generic firm who faces an $H-$type brand-name firm, there will be a pooling equilibrium in which the $L-$type charges the same price p_B^{DH} as the $H-$type if, and only if, the $L-$type brand-name firm and the low-cost generic firm who faces an $L-$type brand-name firm both prefer to mimic the $H-$type, which is characterized by

$$\Pi_B(L, p_B^{DH}, \{H, L\}) \geq \max_{p_B \neq p_B^{DH}} \Pi_B(L, p_B, L), \tag{F.6}$$

$$\Pi_G(L, p_G^{DH}, \{H, L\}) \geq \max_{p_G \neq p_G^{DH}} \Pi_G(L, p_G, L). \tag{F.7}$$

Condition (F.6) indicates that for the $L-$type brand-name firm, mimicking the $H-$type brand-name firm to deter entry of the high-cost generic firm makes more profits than allowing generic entry. Condition (F.7) shows that the brand-name firm's mimicking should be in line with the low-cost generic firm's interest, otherwise the low-cost generic firm will reveal the brand-name firm's type. Then, with p_j^{TL} and $j \in \{B, G\}$ being given by (F.1), conditions (F.6) and (F.7) are, respectively, equivalent to

$$(p_B^{DH} - c)\frac{\alpha_B - b^L p_B^{DH} - b^L\gamma(\alpha_G - p_G^{DH})}{1 - b^L\gamma^2} \geq (p_B^{TL} - c)\frac{\alpha_B - b^L p_B^{TL} - b^L\gamma(\alpha_G - p_G^{TL})}{1 - b^L\gamma^2}, \tag{F.8}$$

$$p_G^{DH}\frac{\alpha_G - p_G^{DH} - \gamma(\alpha_B - b^L p_B^{DH})}{1 - b^L\gamma^2} \geq p_G^{TL}\frac{\alpha_G - p_G^{TL} - \gamma(\alpha_B - b^L p_B^{TL})}{2(1 - b^L\gamma^2)}, \tag{F.9}$$

It can be verified that (i) $\Pi_B(L, p_B^{DH}, \{H, L\})$ (i.e., left-hand side of (F.8)) firstly increases and then decreases in b^H, and is negative when $b^H = 2/\gamma^2$; (ii) by (F.9), the demand for the generic drug in a pooling equilibrium is convex in b^H, (iii) by (7), $p_G^{DH}(b^H = 1) > 0$, and the demand for the generic drug in a pooling equilibrium is (mathematically) negative when $p_G^{DH}(b^H) = 0$. Further, the inequalities (F.8) and (F.9) are strictly satisfied when $b^H = b^L$, and thus there exists a unique $\bar{b}^{H(0)}(b^L)$ (and $\bar{b}^{H(1)}(b^L)$) such that (F.8) (and (F.9)) holds if, and only if, $b^L < b^H \leq \min\{\bar{b}^{H(0)}(b^L), 1\}$ (and $b^L < b^H \leq \min\{\bar{b}^{H(1)}(b^L), 1\}$), in which $\bar{b}^{H(0)}(b^L)$ and $\bar{b}^{H(1)}(b^L)$ are, respectively, the unique values of b^H such that the equalities in (F.8) and (F.9) are satisfied. Therefore, the condition on b^H derived from (F.6) and (F.7) is $b^L < b^H \leq \min\{\bar{b}^{H(0)}(b^L), \bar{b}^{H(1)}(b^L), 1\}$. $\square$

Proof of Corollary 1. Suppose that the stable equilibrium in Proposition F.1 is pooling, i.e., $b^L < b^H \leq \min\{\bar{b}^{H(0)}(b^L), \bar{b}^{H(1)}(b^L), 1\}$. Note, by the proof of Proposition F.1, that (F.9) is satisfied if, and only if, $b^L < b^H \leq \min\{\bar{b}^{H(1)}(b^L), 1\}$. Hence, given $b^L \in (0, 1)$, if there exists $\bar{b}^H > b^L$ such that inequality (F.9) does not hold when $b^H = \bar{b}^H$, then we must have $\bar{b}^H > \min\{\bar{b}^{H(1)}(b^L), 1\}$.

We firstly show that the inequality (F.9) does not hold when $p_G^{DH} = p_G^{TL}$. Since p_G^{DH} is decreasing in b^H and $p_G^{DH} > p_G^{TL}$ when $b^H = b^L$, there exists a unique $\bar{b}^H > b^L$ such that $p_G^{DH} = p_G^{TL}$ when $b^H = \bar{b}^H$. Next, by (E.19), we obtain that

$$p_B^{DH} = \frac{2p_G^{DH} + \gamma\alpha_B - \alpha_G}{b^H\gamma}, \; p_B^{TL} = \frac{3p_G^{TL} + \gamma\alpha_B - \alpha_G}{b^L\gamma}. \tag{F.10}$$

Then when $p_G^{DH} = p_G^{TL}$, (F.9) being violated is equivalent to

$$b^L\gamma(2p_B^{DH} - p_B^{TL}) - (\gamma\alpha_B - \alpha_G + p_G^{DH}) < 0. \tag{F.11}$$

By substituting p_B^{DH} and p_B^{TL} in (F.10) into (F.12), we obtain that (F.12) is equivalent to

$$-2(b^H - b^L)(\gamma\alpha_B - \alpha_G + 2p_G^{DH})/b^H = -2(b^H - b^L)\gamma p_B^{DH} < 0, \tag{F.12}$$

which must be true since $p_B^{DH} > 0$ and $b^H > b^L$. Thus, when $p_G^{DH} = p_G^{TL}$, (F.9) must be violated, which implies $\bar{b}^H > \min\{\bar{b}^{H(1)}(b^L), 1\}$. Therefore, (F.9) being satisfied implies $b^H < \bar{b}^H$. In addition, since p_G^{DH} is decreasing in b^H, we obtain that $p_G^{DH} > p_G^{TL}$ when (F.9) is satisfied. This proves that when the stable equilibrium in Proposition F.1 is pooling, the price charged by the low-cost generic firm, i.e., p_G^{DH}, is larger than p_G^{TL}. $\square$

Proof of Theorem F.1. According to Proposition F.1, when the brand-name firm is $H-$type, there is no generic entry both in the signaling and full-information periods, and thus the GCP cannot occur. When the brand-name firm type is L and the stable equilibrium is separating, the price of the brand-name drug will decrease from p_B^{ML} to p_B^{TL} at the beginning of the signaling period and then will remain unchanged, i.e., the GCP does not exist either.

Therefore, the GCP could only occur when the brand-name firm is $L-$type and the stable equilibrium is pooling. Based on Proposition F.1, we equivalently focus on the situation where the brand-name firm is $L-$type, and $b^H \in (b^L, \min\{\bar{b}^{H(1)}(b^L), \bar{b}^{H(0)}(b^L), 1\})$. To prove the proposition, we firstly show that when $p_B^{DH} = p_B^{TL}$, inequalities (F.8) and (F.9) are strictly satisfied. The emergence of GCP means $p_B^{DH} \le p_B^{TL}$, i.e.,

$$\frac{\alpha_B}{b^L} - \frac{\alpha_B}{b^H} \ge \frac{2\alpha_G\gamma}{3 - b^L\gamma^2} - \frac{\alpha_G\gamma}{2 - b^H\gamma^2}. \tag{F.13}$$

Then, by (F.13), for $b^H \in (b^L, 2/\gamma^2)$, there exists a unique $\bar{b}^{H(2)}(b^L)$ such that $p_B^{DH} \le p_B^{TL}$ if, and only if, $b^H \in [\bar{b}^{H(2)}(b^L), 2/\gamma^2)$, where $\bar{b}^{H(2)}(b^L)$ is defined by

$$\bar{b}^{H(2)}(b^L) = \left(\frac{\mathcal{M}_5 + \sqrt{\mathcal{M}_4 + \mathcal{M}_5^2}}{4b^L\alpha_B(3 - b^L\gamma^2)}\right)^{-1} = \frac{\mathcal{M}_5 - \sqrt{\mathcal{M}_4 + \mathcal{M}_5^2}}{2\gamma^2\left[\alpha_B(3 - b^L\gamma^2) - 2b^L\alpha_G\gamma\right]}, \tag{F.14}$$

$\mathcal{M}_4 := 8b^L\alpha_B\gamma^2(3 - b^L\gamma^2)\,[2b^L\alpha_G\gamma - \alpha_B(3 - b^L\gamma^2)]$, and $\mathcal{M}_5 := \alpha_B(3 - b^L\gamma^2)(2 + b^L\gamma^2) - b^L\alpha_G\gamma(1 + b^L\gamma^2)$. By (F.14), we obtain that (i) for $b^L \in (0,1]$, $\bar{b}^{H(2)}(b^L) > b^L$ and is increasing in b^L, and (ii) $\bar{b}^{H(2)}(0) = 0$. Thus, there exists a unique $\bar{b}^{L(2)} \in (0,1)$ such that $\bar{b}^{H(2)}(b^L) \le 1$ if, and only if, $b^L \in (0, \bar{b}^{L(2)})$.

Then, to prove the existence of the GCP, we only need to show that inequalities (F.8) and (F.9) strictly hold when $p_B^{DH} = p_B^{TL}$ (i.e., when $b^H = \bar{b}^{H(2)}(b^L)$). Firstly, we directly obtain $p_G^{DH} > p_G^{TL}$ when $p_B^{DH} = p_B^{TL}$, and thus inequality (F.8) strictly holds when $b^H = \bar{b}^{H(2)}(b^L)$. It also implies that inequality (F.9) is strictly satisfied. Therefore, the generic competition paradox occurs if, and only if, the brand-name firm is $L-$type, $b^L \in (0, \bar{b}^{L(2)})$, and $b^H \in (\bar{b}^{H(2)}(b^L), \min\{\bar{b}^{H(0)}(b^L), \bar{b}^{H(1)}(b^L), 1\})$. $\square$

G. Proofs of the Results in Section 6 of the Paper

Proof of Proposition 3. In preparation, we define the following values that will be used in this appendix. Prices and profits of the $b-$type brand-name firm and the generic firm in the monopoly and duopoly setting are, respectively, the same as those in Sections 3.3.1 and 3.3.2 of the paper when b^i is set to b. That is, $p_B^{Mb} = p_B^{Mi}$ and $\Pi_B^{Mb} = \Pi_B^{Mi}$ as given by (4), and $p_j^{Db} = p_j^{Di}$ and $\Pi_j^{Db} = \Pi_j^{Di}$ for $j \in \{B, G\}$ as given by (7), (9) and (10) when $b^i = b$. Also, condition (8) for $b^i = b$ is still sufficient to ensure the competition between firms in the duopoly setting. The threshold value $b^{L(1)} \in (0, b^H)$ is uniquely determined by $b^{H(1)}(b^{L(1)}) = 1$, where $b^{H(1)}(b)$ is given by (14) in the paper when b^L is set to b.

We restrict our attention to the partial-pooling equilibrium, where

$$\frac{\int_{b^{L(1)}}^{1} \Pi_G^{Db} \mathrm{d}b}{1 - b^{L(1)}} < k < \Pi_G^{D0}. \tag{G.1}$$

In addition, $b^{(2)}$ is uniquely determined by

$$\frac{\int_{b^{(2)}}^{b^{H(1)}(b^{(2)})} \Pi_G^{Db} \mathrm{d}b}{b^{H(1)}(b^{(2)}) - b^{(2)}} = k. \tag{G.2}$$

Similarly, we rewrite $b^{H(2)}(b^L)$ and $b^{H(3)}(b^L)$ in Sections 4.4 and 5 of the paper, respectively, as a function of b, i.e., as $b^{H(2)}(b)$ and $b^{H(3)}(b)$, by replacing b^L in $b^{H(2)}(b^L)$ and $b^{H(3)}(b^L)$ with b.

Given the condition (G.1), we formulate the conjecture that there exist $\hat{b}^{(1)}$ and $\hat{b}^{(2)}$ such that in PBE: (i) each type of brand-name firm will charge price $p_B^M(b)$ and the generic firm will not enter, when $b \in (\hat{b}^{(2)}, 1]$; (ii) each type of brand-name firm will charge price $p_B^D(b)$ and there will be generic entry, when $b \in (0, \hat{b}^{(1)})$; (iii) each type of brand-name firm will charge price $p_B^M(\hat{b}^{(2)})$ and there is no generic entry, when $b \in [\hat{b}^{(1)}, \hat{b}^{(2)}]$.

Firstly, we show that the generic firm's expected profit/revenue (per unit time) must be less than k when the pooling price $p_B^M(\hat{b}^{(2)})$ is observed, i.e.,

$$\frac{\int_{\hat{b}^{(1)}}^{\hat{b}^{(2)}} \Pi_G^D(b)\mathrm{d}b}{\hat{b}^{(2)} - \hat{b}^{(1)}} \leq k. \tag{G.3}$$

This must be true, otherwise the pooling part in the partial-pooling equilibrium will collapse since market entry is profitable for the generic firm when observing a pooling price.

Secondly, we show that the pooling price must be $p_B^M(\hat{b}^{(2)})$. Suppose that a pooling price is $p_B^M(\hat{b}^{(2)} - \varepsilon)$ and $\varepsilon > 0$. Then, the brand-name firm with type $b = \hat{b}^{(2)}$ must be better off by deviating from the pooling price $p_B^M(\hat{b}^{(2)} - \varepsilon)$ to the price $p_B^M(\hat{b}^{(2)} + \epsilon)$, for a sufficiently small real number $\epsilon > 0$, which ruins the equilibrium. Thus, it should be indifferent for the brand-name firm with type $b = \hat{b}^{(2)}$ between pooling and separating.

Third, we show that $\hat{b}^{(2)} = b^{H(1)}(\hat{b}^{(1)})$. Based on the proof of Proposition 1, we must have $\hat{b}^{(2)} \leq b^{H(1)}(\hat{b}^{(1)})$. We further show that $\hat{b}^{(2)} = b^{H(1)}(\hat{b}^{(1)}) < 1$. Suppose that $\hat{b}^{(2)} < b^{H(1)}(\hat{b}^{(1)}) < 1$, then there exist $\hat{b}^{(1')} < \hat{b}^{(1)}$ and $\hat{b}^{(1')} = (b^{H(1)})^{-1}(\hat{b}^{(2)})$ such that the types of brand-name firm $b \in (\hat{b}^{(1')}, \hat{b}^{(1)})$ will be better off by deviating to the price $p_B^M(\hat{b}^{(2)})$. Note that $(b^{H(1)})^{-1}(b)$ is an inverse function of $b^{H(1)}(b)$. This breaks the equilibrium, and thus we have $\hat{b}^{(2)} = b^{H(1)}(\hat{b}^{(1)})$. Similarly, if $b^{H(1)}(\hat{b}^{(1)}) \geq 1$, the equilibrium will also be broken.

Next, given that the inequality (G.3) holds, we show $\hat{b}^{(1)} = b^{(2)}$. Based on the analysis above, we obtain that if and only if $b^{(2)} < b^{L(1)}$, i.e.,

$$\frac{\int_{b^{L(1)}}^{1} \Pi_G^D(b)\mathrm{d}b}{1 - b^{L(1)}} < k, \tag{G.4}$$

for $\forall\ \hat{b}^{(1)} \in [b^{(2)}, b^{L(1)})$, the equilibrium specified above is a partial-pooling equilibrium. Moreover, any equilibrium specified above with $\hat{b}^{(1)} \in (b^{(2)}, b^{L(1)})$ is dominated by the equilibrium with $\hat{b}^{(1)} = b^{(2)}$.

Finally, we characterize the generic firm's belief on and off the equilibrium path. Define the generic firm's expected postentry profit (per unit time) after observing the price p_B as $\mathbb{E}[\Pi_G(\cdot)|p_B]$.

For the belief on the equilibrium path, the expected profit $\mathbb{E}[\Pi_G(\cdot)|p_B] = \Pi_G^{Db} > k$ when $p_B \in (p_B^{Db^{(2)}}, p_B^{D0})$. This is because in this partial-pooling equilibrium, when $b \in (0, b^{(2)})$, each type of the brand-name firm reveals its type by charging its duopoly price upon the true type. When $p_B = p_B^M(b^{H(1)}(b^{(2)})) \equiv p_B^{Mb^{H(1)}(b^{(2)})}$, we have $\mathbb{E}[\Pi_G(\cdot)|p_B] = k$ by (G.2), and as a result the generic firm will not enter the market. When $p_B \in (p_B^{M1}, p_B^{Mb^{H(1)}(b^{(2)})})$, we have $\mathbb{E}[\Pi_G(\cdot)|p_B] < k$, and thus the generic firm will not enter the market.

For the belief off the equilibrium path, we specify that the generic firm believes that: (i) $b < b^{(2)}$ with probability 1 when $p_B \geq p_B^{D0}$, and thus $\mathbb{E}[\Pi_G(\cdot)|p_B] > k$, (ii) $b > b^{H(1)}(b^{(2)})$ with probability 1 when $0 < p_B < p_B^{M1}$, and thus $\mathbb{E}[\Pi_G(\cdot)|p_B] < k$, and (iii) $b < b^{H(1)}(b^{(2)})$ with probability 1 when $p_B \in (p_B^{Mb^{H(1)}(b^{(2)})}, p_B^{Db^{(2)}})$, and thus $\mathbb{E}[\Pi_G(\cdot)|p_B] > k$. $\square$

Proof of Theorem 2. By Proposition 3, for $b \in (0, b^{(2)})$, the generic firm enters the market at the beginning of the signaling period and the price of $b-$type brand-name firm will decrease from its monopoly level p_B^{Mb}

to the duopoly level p_B^{Db} (note that $p_B^{Mb} > p_B^{Db}$ by Lemma A.1(i) in Appendix A.1). As such, the GCP cannot happen for $b \in (0, b^{(2)})$. For $b \in (b^{H(1)}(b^{(2)}), 1]$, by Proposition 3, the generic firm stays out of the market in both the signaling and full-information periods, and hence the GCP can never occur.

Thus, the GCP can only occur when $b \in [b^{(2)}, b^{H(1)}(b^{(2)})]$. In such cases, by Proposition 3, in the signaling period, the generic firm stays out of the market and the $b-$type brand-name firm charges price $p_B^{Mb^{H(1)}(b^{(2)})}$, where

$$p_B^{Mb^{H(1)}(b^{(2)})} = \frac{c}{2} + \frac{\alpha_B}{2b^{H(1)}(b^{(2)})}, \tag{G.5}$$

$b^{(2)}$ is uniquely determined by (G.2), and $b^{H(1)}(b)$ is given by (14) in the paper when b^L is set to b. Whereas, in the full-information period, the generic firm will enter the market if, and only if, he can earn positive profits, i.e., $b \in [b^{(2)}, b^{(1)})$, where $b^{(1)}$ is the unique value of b such that $\Pi_G^{Db} = k$. Thus, for $b \in [b^{(2)}, b^{(1)})$, the generic firm will enter the market in the full-information period with the brand-name firm charging price p_B^{Db}, which is given by

$$p_B^{Db} = \frac{c}{2} + \frac{\alpha_B}{2b} - \frac{\alpha_G \gamma}{4 - 2b\gamma^2}. \tag{G.6}$$

Then by (G.5) and (G.6), we obtain that

$$p_B^{Db} - p_B^{Mb} = \frac{\alpha_B}{2}\left(\frac{1}{b} - \frac{\alpha_G\gamma}{(2-b\gamma^2)\alpha_B} - \frac{1}{b^{H(1)}(b^{(2)})}\right) = \frac{\alpha_B}{2}\left(\frac{1}{b^{H(2)}(b)} - \frac{1}{b^{H(1)}(b^{(2)})}\right), \tag{G.7}$$

where $b^{H(2)}(b)$ is given by (18) with b^L being replaced by b. Then by (G.7), $p_B^{Db} > p_B^{Mb}$ if, and only if, $b^{H(2)}(b) < b^{H(1)}(b^{(2)})$. Since $b^{H(2)}(b)$ is strictly increasing in b, $b^{H(2)}(b) < b^{H(1)}(b^{(2)})$ is equivalent to $b^{(2)} < b < b^{(3)} := \left(b^{H(2)}\right)^{-1}(b^{H(1)}(b^{(2)}))$, where $(b^{H(2)})^{-1}(b)$ is the inverse function of $b^{H(2)}(b)$. Note that by Theorem 1 in the paper, $0 < b^{(2)} < b^{(3)}$. Therefore, for $b \in [b^{(2)}, b^{(1)})$, the GCP occurs if, and only if, $b \in [b^{(2)}, \min\{b^{(1)}, b^{(3)}\})$.

Lastly, for $b \in [b^{(1)}, b^{H(1)}(b^{(2)})]$, by Proposition 3 and $\Pi_G^{Db} \leq k$, the generic firm stays out of the market in both the signaling and full-information periods, and hence the GCP does not exist. $\square$

Proof of Proposition 4. Suppose the brand-name firm's type $b \in [b^{(2)}, b^{H(1)}(b^{(2)})]$. For $b \in [b^{(1)}, b^{H(1)}(b^{(2)})]$, the generic firm stays out of the market in the signaling regardless of the presence of information asymmetry, by Proposition 3 and $\Pi_G^{Db} \leq k$. In the signaling period, the brand-name firm of type b charges price $p_B^{Mb^{H(1)}(b^{(2)})}$ as given by (G.5) under information asymmetry; whereas the brand-name firm will charge price p_B^{Mb} under complete information in the signaling period, where $p_B^{Mb} = p_B^{Mi}$ as given by (4) with b^i being replaced by b. Note by $b \in [b^{(2)}, b^{H(1)}(b^{(2)})]$ that $p_B^{Mb} \geq p_B^{Mb^{H(1)}(b^{(2)})} > c$. Therefore, both consumer surplus and social welfare benefit from the information asymmetry in the signaling period.

Next, we consider the cases where $b \in [b^{(2)}, b^{(1)})$, and prove each part of the proposition separately.

Part (i): Following the proof of Proposition 2(i) in Appendix B, to analyse the impact of information asymmetry on consumer surplus in the signaling period when $b \in [b^{(2)}, b^{(1)})$, it is enough to compare the representative consumer's net utility per-unit time, $\mathcal{U}^b(q_B, q_G)$, with and without the information asymmetry, where $\mathcal{U}^b(q_B, q_G)$ is given by (1) with superscript i of b^i being dropped.

By Proposition 3, with information asymmetry, the brand-name firm is a monopoly in the market, and the amount of the brand-name drug that the representative consumer purchases per-unit time at price $p_B^{Mb^{H(1)}(b^{(2)})}$ is equal to $q_B^M = \alpha_B - bp_B^{Mb^{H(1)}(b^{(2)})}$ when $b \in [b^{(2)}, b^{(1)})$. As a result, the consumer surplus per-unit time under information asymmetry is given by $S^b(q_B^M, 0) = \mathcal{U}^b(q_B^M, 0)$.

On the other hand, without information asymmetry, since $\Pi_G^{Db} > k$, the generic firm enters the market and competes with the brand-name firm when $b \in [b^{(2)}, b^{(1)})$. Consequently, in absence of information asymmetry, the amount of brand-name and generic drugs that the representative consumer purchases per-unit time, at prices p_B^{Db} and p_G^{Db}, is respectively equal to q_B^{Db} and q_G^{Db} as given by q_B^{Di} and q_G^{Di} in (B.1) with b^i being replaced by b. The consumer surplus per-unit time without information asymmetry is equal to $S^b(q_B^{Db}, q_G^{Db}) = \mathcal{U}^b(q_B^{Db}, q_G^{Db})$.

Next, to examine the impact of information asymmetry, we compare the consumer surplus per-unit time with and without information asymmetry, i.e., $S^b(q_B^M, 0)$ with $S^b(q_B^{Db}, q_G^{Db})$. To that end, we define $\Delta S := S^b(q_B^{Db}, q_G^{Db}) - S^b(q_B^M, 0)$, and then obtain that

$$32\Delta S = -4b\Big(\frac{\alpha_B}{b^{H(1)}(b^{(2)})} - c\Big)^2 + 3\tilde{\alpha}_B^L\Big(\frac{\alpha_B}{b^{H(1)}(b^{(2)})} - c\Big) + 13\alpha_B\tilde{\alpha}_B^L\Big(\frac{1}{b^{H(1)}(b^{(2)})} - \frac{1}{b}\Big) + \Theta_1(b) - \frac{3(\tilde{\alpha}_B^L)^2}{b}, \tag{G.8}$$

where $\tilde{\alpha}_B^L := \alpha_B - bc$, and $\Theta_1(b)$ is given by (A.16) when b^L is set to b. Following the analysis on (B.4) in the proof of Proposition 2(i) in Appendix B, we obtain that $\Delta S < 0$ so that the consumer surplus increases under information asymmetry if, and only if, $b^{H(3)}(b) < b^{H(1)}(b^{(2)}) < 1$, where $b^{H(3)}(b)$ is given by (A.14) with b^L being replaced by b. Since $b^{H(3)}(b)$ is strictly increasing in $b \in (0,1)$, for $b \in [b^{(2)}, b^{(1)})$, $b^{H(3)}(b) < b^{H(1)}(b^{(2)})$ is equivalent to $b^{(2)} < b < b^{(4)} := (b^{H(3)})^{-1}(b^{H(1)}(b^{(2)}))$, where $(b^{H(3)})^{-1}(b)$ is the inverse function of $b^{H(3)}(b)$. Note that $b^{(4)} \in (b^{(2)}, b^{(1)})$. Thus, for $b \in [b^{(2)}, b^{(1)})$, the consumer surplus increases under information asymmetry if, and only if, $b \in [b^{(2)}, \min\{b^{(4)}, b^{(1)}\})$.

***Part (ii)*:** By Proposition 3, with information asymmetry in the signaling period: the brand-name firm is a monopoly in the market, and the amount of the brand-name drug that the representative consumer purchases per-unit time at price $p_B^{Mb^{H(1)}(b^{(2)})}$ is equal to $q_B^M = \alpha_B - bp_B^{Mb^{H(1)}(b^{(2)})}$ when $b \in [b^{(2)}, b^{(1)})$. As a result, the consumer surplus per-unit time in the signaling period is given by $S^b(q_B^M, 0) = \mathcal{U}^b(q_B^M, 0)$, and the total firm profit per-unit time is given by

$$\Pi_B^{Mb}(p_B^{Mb^{H(1)}(b^{(2)})}) = (p_B^{Mb^{H(1)}(b^{(2)})} - c)(\alpha_B - bp_B^{Mb^{H(1)}(b^{(2)})}).$$

Whereas, in the full-information period, since $\Pi_G^{Db} > k$ when $b \in [b^{(2)}, b^{(1)})$, the generic firm, by incurring the fixed capacity cost K, enters the market and competes with the $b-$type brand-name firm. Hence, there is duopoly in the full-information period, and the amount of brand-name and generic drugs that the representative consumer purchases per-unit time, at prices p_B^{Db} and p_G^{Db} is, respectively, equal to q_B^{Db} and q_G^{Db} as given by q_B^{Di} and q_G^{Di} in (B.1) with b^i being replaced by b. Then the consumer surplus per-unit time in the full-information period is equal to $S^b(q_B^{Db}, q_G^{Db}) = \mathcal{U}^b(q_B^{Db}, q_G^{Db})$, and the total firm profit per-unit time is given by $\Pi_B^{Db} + \Pi_G^{Db}$, where Π_j^{Db} is, respectively, given by (9) and (10) with b^i being replaced by b, for $j \in \{B, G\}$. Therefore, when there is information asymmetry in the signaling period, the total social welfare $\mathcal{W}_S$ over both periods is given by

$$\mathcal{W}_S = \int_0^T e^{-\rho t}\Big(S^b(q_B^M, 0) + \Pi_B^{Mb}(p_B^{Mb^{H(1)}(b^{(2)})})\Big)\mathrm{d}t + \int_T^\infty e^{-\rho t}\Big(S^b(q_B^{Db}, q_G^{Db}) + \Pi_B^{Db} + \Pi_G^{Db}\Big)\mathrm{d}t - Ke^{-\rho T}. \tag{G.9}$$

On the other hand, without information asymmetry in the signaling period, since $\Pi_G^{Db} > k$ when $b \in [b^{(2)}, b^{(1)})$, the generic firm, by incurring the fixed capacity cost K, enters the market and competes with the brand-name firm at the beginning of the signaling period. Then the generic and brand-name firms compete as duopoly throughout both the signaling and full-information periods. Consequently, the amount of brand-name and generic drugs that the representative consumer purchases per-unit time at prices p_B^{Db} and p_G^{Db} is, respectively, equal to q_B^{Db} and q_G^{Db}. Then the consumer surplus per-unit time is equal to $S^b(q_B^{Db}, q_G^{Db}) = \mathcal{U}^b(q_B^{Db}, q_G^{Db})$, and the total firm profit per-unit time is given by $\Pi_B^{Db} + \Pi_G^{Db}$. Therefore, without information asymmetry, the total social welfare $\mathcal{W}_F$ over both periods is given by

$$\mathcal{W}_F = \int_0^\infty e^{-\rho t}\Big(S^b(q_B^{Db}, q_G^{Db}) + \Pi_B^{Db} + \Pi_G^{Db}\Big)\mathrm{d}t - K. \tag{G.10}$$

Then, by using (G.9) and (G.10), we obtain

$$\mathcal{W}_S - \mathcal{W}_F = \frac{1-e^{-\rho T}}{32\rho}\Big(-4b\big(\frac{\alpha_B}{b^{H(1)}(b^{(2)})} - c\big)^2 + \Theta_2(b) + 32k\Big), \tag{G.11}$$

where $k \equiv \rho K$, and $\Theta_2(b)$ is given by (A.17) when b^L is set to b. Following the analysis on (B.9) in the proof of Proposition 2(ii) in Appendix B, we obtain that $\mathcal{W}_S > \mathcal{W}_F$ if, and only if, $b^{H(1)}(b^{(2)}) > b^{H(4)}(b)$, where $b^{H(4)}(b)$ is given by (A.15) with b^L being replaced by b. Since $b^{H(4)}(b)$ is strictly increasing in $b \in (0,1)$, for $b \in [b^{(2)}, b^{(1)})$, $b^{H(4)}(b) < b^{H(1)}(b^{(2)})$ is equivalent to $b^{(2)} < b < b^{(5)} := (b^{H(4)})^{-1}(b^{H(1)}(b^{(2)}))$, where $(b^{H(4)})^{-1}(b)$ is the inverse function of $b^{H(4)}(b)$ and $b^{(5)} \in (b^{(2)}, b^{(1)})$. Thus, for $b \in [b^{(2)}, b^{(1)})$, the social welfare increases under information asymmetry if, and only if, $b \in [b^{(2)}, \min\{b^{(5)}, b^{(1)}\})$. □

Proof of Proposition 5. We compare the dual-source information asymmetry situation with the base model where information asymmetry is only on consumer price sensitivity. To ensure fairness in comparison, we suppose that: (i) in the base model, the unit production cost for the brand-name firm can be either high or low and is known to the generic firm, and (ii) the two situations have the same fixed capacity cost.

Then we identify the existence of the same fixed capacity cost in the two situations. For the condition (11) in Lemma A.2, considering that there are two types of unit production cost, we rewrite the condition as

$$\text{when the unit production cost is } c^H\text{: } (1-\lambda_b)\Pi_G^{DLH} + \lambda_b \Pi_G^{DHH} < k < \Pi_G^{DLH}, \tag{G.12a}$$

$$\text{when the unit production cost is } c^L\text{: } (1-\lambda_b)\Pi_G^{DLL} + \lambda_b \Pi_G^{DHL} < k < \Pi_G^{DLL}. \tag{G.12b}$$

When there are dual sources of information asymmetry, the condition on the (discounted) fixed capacity cost and the prior is given by (D.5) in Appendix D or (23) in the paper. Note that we have $\Pi_G^{DLH} > \Pi_G^{DHH} > \Pi_G^{DHL}$ and $\Pi_G^{DLH} > \Pi_G^{DLL} > \Pi_G^{DHL}$, by (D.4). Clearly, (D.5) is a subset of (G.12b), and the intersection of (D.5) and (G.12a) is empty.

We then analyze the impact of dual sources of information asymmetry on the generic entry, the GCP, the consumer surplus, and social welfare, respectively.

Generic Entry: When the brand-name firm's unit production cost is c^H, for k that satisfies (D.5), it must be smaller than the lower bound of (G.12a). Thus, when the information asymmetry is only on consumers' relative price sensitivity, generic entry must happen at the beginning of the signaling period and the price of the brand-name drug will decrease from its monopoly level to its duopoly level, whether the consumer price sensitivity is b^H or b^L. However, when there are dual sources of information asymmetry, by Proposition D.1, the $HH-$type of brand-name firm can deter generic entry by mimicking the $HL-$type. There are also some cases where the $LH-$type brand-name firm mimics the $HL-$type to deter generic entry. When mimicking the $HL-$type, both the $HH-$type and $LH-$type brand-name firm will charge the $HL-$type's monopoly price, which is lower than their own monopoly price (i.e., *limit pricing*).

When the brand-name firm's unit production cost is c^L, for k that satisfies (D.5), we have shown that it must satisfy (G.12b). Thus, when the information asymmetry is only on consumers' relative price sensitivity, by Proposition 1, the $LL-$type brand-name firm can deter generic entry by mimicking the $HL-$type in some cases in the signaling period. When there are dual sources of information asymmetry, by Proposition D.1, the $LL-$type can also deter generic entry by mimicking the $HL-$type in some cases in the signaling period. Similarly, when mimicking the $HL-$type, the $LL-$type brand-name firm will charge the $HL-$type's monopoly price, which is lower than its own monopoly price (i.e., *limit pricing*).

By comparing the two situations where the brand-name firm's unit production cost is, respectively, c^H and c^L, we obtain that there are more cases of the brand-name firm utilizing limit pricing to deter generic entry in the signaling period when there are dual sources of information asymmetry than when the information asymmetry is only on consumers' relative price sensitivity.

The GCP: Firstly, consider that the brand-name firm's unit production cost is c^H. As we have analyzed above, the GCP cannot occur when the information asymmetry is only on consumers' relative price sensitivity since the generic firm will enter the market at the beginning of the signaling period and the price of the brand-name drug must decrease. Whereas, when there are dual sources of information asymmetry, by Theorem D.1, the GCP can occur in some cases when the brand-name firm type is LH. Secondly, consider that the brand-name firm's unit production cost is c^L. By comparing Theorem 1 and Theorem D.1, we can find that the GCP occurs in the same cases when the information asymmetry is only on consumers' relative price sensitivity or there are dual sources of information asymmetry.

By comparing the two situations where the brand-name firm's unit production cost is, respectively, c^H and c^L, we obtain that there are more cases of the GCP occuring when there are dual sources of information asymmetry than when the information asymmetry is only on consumers' relative price sensitivity.

The Consumer Surplus: Firstly, consider that the brand-name firm's unit production cost is c^H. As we have analyzed above, generic entry must happen at the beginning of the signaling period when the information asymmetry is only on consumers' relative price sensitivity. As such, the information asymmetry has no impact on the consumer surplus. However, when there are dual sources of information asymmetry, by Proposition D.2, consumer surplus in the signaling period increases under information asymmetry (relative to that without information asymmetry) in some cases when the brand-name firm is $HH-$ and/or $LH-$type. Secondly, consider that the brand-name firm's unit production cost is c^L. By comparing Proposition 2 and Proposition D.2, we can find that the consumer surplus increases under information asymmetry (relative to that without information asymmetry) in the same cases when the information asymmetry is only on consumers' relative price sensitivity or there are dual sources of information asymmetry.

By comparing the two situations where the brand-name firm's unit production cost is, respectively, c^H and c^L, we obtain that there are more cases of information asymmetry benefiting consumers when there are dual sources of information asymmetry than when the information asymmetry is only on consumers' relative price sensitivity.

The Social Welfare: The results are obtained by comparing Proposition 2 with Proposition D.2. □

Proof of Proposition 6. As the number of generic firms N increases, that the $L-$type brand-name firm uses limit pricing and deters generic entry in more cases, means that the threshold $b^{NH(1)}(b^L)$ is increasing in N. Similarly, for an increasing N: that the GCP occurs in fewer cases, means that the threshold $b^{NH(2)}(b^L)$ is increasing; and that consumers benefit from information asymmetry/limit pricing in fewer cases, means that $b^{NH(3)}(b^L)$ is increasing. Therefore, to prove Proposition 6, we only need to prove that all $b^{NH(1)}(b^L)$, $b^{NH(2)}(b^L)$, and $b^{NH(3)}(b^L)$ are increasing in N. For ease of exposition, define $\mathcal{M}_3$ as follows:

$$\mathcal{M}_3 \equiv \frac{(\alpha_B - b^L c)(1+N-b^L\gamma^2)(2\alpha_G - \gamma(\alpha_B - b^L c)) - N\gamma b^L \alpha_G^2}{(1+N)(1-b^L\gamma^2)(1+N-b^L\gamma^2)/N}. \tag{G.13}$$

Then based on (E.6), $b^{NH(1)}(b^L)$ is increasing in N if, and only if, $\mathcal{M}_3$ is increasing in N. Without loss of generality, assume that N is continuous. By (G.13) and condition (E.3) in Lemma E.1, then

$$\frac{\mathrm{d}\mathcal{M}_3}{\mathrm{d}N} = \frac{\gamma/(1+N)^2}{b^L\gamma^2 - 1}\left[\alpha_B - \left(\frac{2\alpha_G}{\gamma} - \frac{b^L\alpha_G N\gamma}{1+N-b^L\gamma^2} + b^L c\right)\right]\left[\alpha_B - \left(\frac{b^L\alpha_G N\gamma}{1+N-b^L\gamma^2} + b^L c\right)\right] > 0.$$

Therefore, $\mathcal{M}_3$ is increasing in N, and hence this implies that $b^{NH(1)}(b^L)$ is increasing in N. In addition, it is straightforward that $b^{NH(2)}(b^L)$ is increasing in N.

Finally, by (E.12), $b^{NH(3)}(b^L)$ is increasing in N if, and only if, $\mathcal{M}_1$ is increasing in N. We then, by (E.10) in which $\tilde{\alpha}_B^L := \alpha_B - b^L c$, obtain

$$\begin{aligned}\frac{\mathrm{d}\mathcal{M}_1}{\mathrm{d}N} = &\frac{-2N(\tilde{\alpha}_B^L)^2}{(1+N)^3} + \frac{2N\big((\tilde{\alpha}_B^L)^2 + b^L\alpha_G^2 - 2b^L\tilde{\alpha}_B^L\alpha_G\gamma\big)}{(1+N)^3(1-b^L\gamma^2)} \\ &- \frac{2b^L N^2\alpha_G^2}{(1+N-b^L\gamma^2)^3} + \frac{2b^L N\alpha_G(\alpha_G - \tilde{\alpha}_B^L\gamma)}{(1+N)(1+N-b^L\gamma^2)^2} + \frac{2b^L\alpha_G\big[N(2+N)\alpha_G + \tilde{\alpha}_B^L\gamma\big]}{(1+N)^2(1+N-b^L\gamma^2)}.\end{aligned}$$

As shown above, $\frac{\mathrm{d}\mathcal{M}_1}{\mathrm{d}N}$ is a convex and quadratic function of $\tilde{\alpha}_B^L$, then we obtain that

$$\frac{\mathrm{d}\mathcal{M}_1}{\mathrm{d}N} \geq \min_{\tilde{\alpha}_B^L}\frac{\mathrm{d}\mathcal{M}_1}{\mathrm{d}N} = \frac{7N^4 + (4N-1)(1-b^L\gamma^2)^2 + 2N^2(1-b^L\gamma^2)(9-2b^L\gamma^2) + 4N^3(5-3b^L\gamma^2)}{2N(1+N)(1+N-b^L\gamma^2)^4/\big[b^L\alpha_G^2(1-b^L\gamma^2)\big]} > 0,$$

i.e., $\mathcal{M}_1$ is increasing in N, and hence $b^{NH(3)}(b^L)$ is increasing in N, which completes the proof. □

Proof of Proposition 7. The collusion between the low-cost generic firm and the $L-$type brand-name firm follows from Proposition F.1. □

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