Product Hopping and Innovation Incentives*

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Abstract

We study innovation incentives in the presence of "product hopping," whereby the incumbent patents a minor modification of a drug (e.g., a new delivery method) and invests in marketing to switch demand towards the minor modification. In our setting firms compete sequentially to discover two innovative drugs. The winner of the first R&D race (the incumbent) can alter the market structure that follows the second R&D race through product hopping. This can increase investments during the second R&D race when product hopping softens competition or when the incumbent benefits from becoming a multi-product monopolist. The change in expected continuation values can increase or decrease investments during the first R&D race. Thus, the welfare effect of product hopping is ambiguous. We discuss our results in the context of the current policy debate on product hopping, welfare, and antitrust.

JEL Codes: D2, K2, K4, L4, L13, O3.

Keywords: Innovation, R&D, patents, strategic deterrence, pharmaceuticals, evergreening, marketing, product hopping

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1 Introduction

Pharmaceutical firms rely on patents to recoup R&D investments.[1] A simplistic view of pharmaceutical innovation is the following: an inventor (a "brand" firm) patents a new drug and gets monopoly profits until the patent expires, which is when generic competitors can enter. In reality, the pharmaceutical industry is embedded in a complex regulatory landscape that firms navigate using creative business strategies, some of which have prompted antitrust scrutiny.[2] In particular, "product hopping" is a strategy that consists on switching consumers from one drug to an almost-identical one. In this strategy, a brand firm patents a minor modification of an original drug (e.g., a new delivery method). Then, it invests in marketing to divert demand from the original drug to the minor modification, shortly before the patent of the original drug expires. Finally, when the patent of the original drug expires and generics are allowed to enter the market, demand has switched from the original drug to the minor modification. This paper presents a framework to study the effect of product hopping on R&D investments and on competition, and we assess the welfare consequences of this practice.

Product hopping grants large rewards to marginal improvements, in contrast to the premise that innovators should be rewarded according to the social value of their innovation (e.g, O'donoghue et al., 1998; Hopenhayn et al., 2006). This is enabled by two distinct features of the prescription drug market: the limited discretion of consumers and the generic-substitution laws. First, when buying prescription drugs, consumers rely on a doctor's prescription (Carrier and Shadowen, 2016); doctors, who do not pay for the drugs, are routinely "detailed" by pharmaceutical companies to prescribe their drugs.[3] Second, generic-substitution laws may prevent competition between two almost-identical products. If drug B is a minor modification of drug A, generic-substitution laws do not permit to substitute drug B by a generic version of drug A (Song and Barthold, 2018). Exploiting these frictions, a brand firm can divert demand from drug A (patent soon to expire) to drug B (recently patented) by coaxing physicians through marketing, even when drugs A and B are almost identical.

An example of product hopping is the case of Prilosec and Nexium, two drugs sold by As-

[1] DiMasi et al. (2016) estimates the cost of developing a drug to be above $2 billion.

[2] Strategies include pay-for-delay settlements (e.g., FTC v. Actavis, 2012), or transferring patents to an American Indian tribe to get sovereign immunity (Dyer, 2017). See Jones et al. (2016).

[3] "Detailing" is a marketing effort to persuade physicians by sending company representatives to their offices, giving them free samples, meals, travels, or consultancy fees. On average, pharmaceutical companies expend over $20,000 annually per physician (Datta and Dave, 2017).

traZeneca and used to treat severe stomach-acid-related conditions.[4] In 2001, a few months before Prilosec's patent expired, AstraZeneca introduced Nexium. After intense marketing efforts, a large fraction of Prilosec patients switched to Nexium. AstraZeneca was accused of exclusionary conduct by "introducing Nexium, a drug virtually identical to and no more effective than Prilosec," and by "switching the market from Prilosec, which now has generic competition, to a virtually identical drug, Nexium, which does not [have generic competition.]."[5] U.S. courts argue this was not an antitrust offense—they argued that generics are free to compete with the off-patent product (Prilosec) and it was not an antitrust offense to advertise a new product—whereas the European Union fined AstraZeneca for abusing its dominant position (Vandenborre et al., 2014). Additionally, recent product hopping cases include Abbott reformulating TriCor (a drug used to lower triglyceride) from capsules to tablets;[6] Reckitt switching Suboxone (a drug to treat opiod addiction) from a sublingual tablet to a sublingual film;[7] Warner Chilcott switching Doryx (an acne medication) from tablets to capsules;[8] Actavis and Forest Laboratories switching Nameda (an Alzheimer's drug) from an immediate release to an extended release formulation.[9]

Despite the prominence of the product hopping, the antitrust and welfare implications of this practice remain unclear. Product hopping is troublesome for at least three reasons. First, it may point innovation efforts towards marginal improvements rather than radical innovation. Second, consumers end up paying high prices for a drug almost identical to an old version now off-patent.[10] Third, firms waste resources persuading doctors to prescribe less cost-effective drugs—in 2013, the 10 biggest pharmaceutical companies spent 98.4 billion in marketing and only 65.8 billion in R&D.[11] On the other hand, pharmaceutical firms argue that minor modifications, such as switching from a pill to a capsule, are valuable for consumers.[12]

We present a model to shed light on the welfare effects of product hopping. We show that

[4] For more details, see, e.g., Feldman and Frondorf (2016) or Jain and Conley (2014) (Chapter 8).

[5] Walgreen Co. vs Astrazeneca Pharmaceuticals L.P. 534 F. Supp. 2d 146 (D.D.C. 2008)

[6] Abbott Laboratories v. Teva Pharmaceuticals, 432 F. Supp. 2d 408 (D. Del. 2006).

[7] In Re: Suboxone Antitrust Litigation (201., 64 F. Supp. 3d 665, 681-83 (E.D. Pa. 2014)

[8] Mylan Pharmaceuticals v. Warner Chilcott, No. 12-3824 (E.D. Pa. June 13, 2013).

[9] New York ex rel. Schneiderman v. Actavis PLC (Namenda), 787 F.3d 638 (2d Cir. 2015)

[10] Arcidiacono et al. (2013) show that removing minor modifications reduces insurance payments by over $7 billion annually, and brand firm profits by more than $4 billion. See also Angell (2004).

[11] "Big pharmaceutical companies are spending far more on marketing than research," by Ana Swanson, published by the Washington Post on 2/11/2015, available at: https://wapo.st/2RWkAkY (Visited on 10/18/2018). See also Lexchin (2018). Additionally, switching is persistent: around 15 percent of consumers switched from drug A to drug B switch back to drug A when a generic becomes available. See https://www.cbsnews.com/news/drug-companies-develop-maneuvers-to-hinder-generic-competition/.

[12] Bokhari and Fournier (2013) show that for AHDH drugs minor modifications could benefit consumers.

conditions under which product hopping *increases* equilibrium R&D investments, by increasing the value of incumbency at the expense of an ex post consumer-welfare loss. Similar to Segal and Whinston (2007), we show that policies favoring an incumbent may have ambiguous effects on the rate of innovation. In our model, product hopping allows the incumbent to suppresses generic competition and it affects the entrant's innovation incentives, i.e., product hopping works as form of strategic entry deterrence (Gilbert and Newbery, 1982).[13]

We assume that only the incumbent can engage in product hopping. There are a number of reasons why incumbents have an advantage to introduce minor modifications. First, developing and patenting a minor modification may be more costly for an entrant because of the lack of experience. Second, the incumbent would likely sue for patent infringement an entrant selling a minor modification before the expiration of the first product's patent (Gans and Stern, 2000). This litigation risk may also force the entrant to begin the marketing of the minor modification only *after* the patent for the original drug has expired. At this point, it may be hard to switch consumers from a generic version of the original drug to the minor modification.[14] In contrast, when the incumbent develops the minor modification it benefits from previous experience, no litigation threats, and the freedom to introduce the minor modification before the expiration of the patent of the original product. Thus, product hopping creates an asymmetry between the incumbent and the entrant.

Our setting captures some of the salient features of product hopping. At $t = 1$, several firms compete to discover and patent product $\mathcal{O}$. The winner of this R&D competition becomes the incumbent (the brand firm) and obtains monopoly profits until $\mathcal{O}$'s patent expires. By paying a cost $K \geq 0$, the incumbent can engage in product hopping whereby (1) develops and patent product $\mathcal{H}$; and (2) persuade physicians and consumers through marketing to buy product $\mathcal{H}$ instead of $\mathcal{O}$ or any of $\mathcal{O}$'s generic versions. At $t = 2$, there is a new R&D race between the incumbent and an entrant to develop and patent product $\mathcal{I}$, which is a radical innovation relative to product $\mathcal{O}$ (or product $\mathcal{H}$). Figure 1 summarizes the timing of our model.

Product hopping changes the competition landscape at $t = 2$ by putting product $\mathcal{H}$ in the market and removing product $\mathcal{O}$ and its generic versions. This change in competition

[13] In Gilbert and Newbery (1982), a monopolist that is threatened by an entrant with a new technology has incentives to preempt it by developing the new technology itself, as long as the efficiency industry condition holds—the monopoly profit when the monopolists sells the old and the new product is higher than total industry profits when the entrant sells the new product.

[14] Incumbents usually switch demand *before* the original drug's patent expires by increasing the price of the original drug (or taking it off the market), apart from investing in marketing.

landscape affects R&D incentives at period 2. Without product hopping, the winner of the R&D race will face competition from product $\mathcal{O}$ and $\mathcal{O}$'s generic versions, sold at marginal cost. With product hopping there are two scenarios, depending on the identity of the winner of the second innovation race. If the incumbent is the winner, it becomes a multi-product firm that can sell both $\mathcal{H}$ and $\mathcal{I}$. If the entrant is the winner, then the incumbent offers $\mathcal{H}$ and the entrant offers $\mathcal{I}$. Depending of the strength of competition (substitution) between $\mathcal{I}$ and $\mathcal{H}$ the entrant's (incumbent's) incentives to invest in R&D may increase/decrease relative to the case of no product hopping. Proposition 2 characterizes the conditions under which product hopping increases for total R&D investments at $t = 2$.

The option of product hopping will be exerted by the incumbent when the introduction of product $\mathcal{H}$ gives it a sufficient advantage in the second R&D race. This is, the expected payoff of the incumbent under product hopping must increase by more than cost K of exerting this option. Whether or not the incumbent engages in product hopping will affect the expected continuation value of winning the first R&D race. We show that equilibrium R&D investments can increase or decrease at $t = 1$. In Proposition 4, we characterizes the conditions under which product hopping increases total R&D investments at $t = 1$.

The main message from our results is that banning product hopping without further intervention may reduce welfare. There are several elements to consider when studying the effect of product hopping on consumer welfare. One important aspect is whether product $\mathcal{H}$ offers any therapeutic benefit over product $\mathcal{O}$. If not, there are at least two clear negative aspects of product hopping: (1) the wasteful marketing spending to persuade physician to switch consumers to a less cost-efficient drug; (2) the reduction in consumer surplus from buying a less cost-efficient drug. The only positive aspect of product hopping in this case is the potential boost on equilibrium R&D investments. If this is the only reason why product hopping should be allowed, it is a bad reason. There are other mechanisms more efficient than product hopping to encourage innovation. The literature on the optimal patent length and breadth advocates for a heterogeneous reward system—based on the innovation's incremental social value.[15] Product hopping bypasses the uniformity of the patent system by enabling an endogenous reward to incumbents. A system where product hopping is banned and firms receive subsidies or patent extensions for pioneer drugs, or drugs that sufficiently improve the current state of the art, for example, can mimic the effect of product hopping on innovation incentives but avoids wasteful marketing investments and reduction of consumer

[15] E.g., Gilbert and Shapiro (1990); Denicolo (1996); O'donoghue et al. (1998); Denicolo (1999); Hopenhayn et al. (2006).

surplus in the second period.

Various policies could effectively ban of product hopping. One alternative is to tighten patentability standards, to make minor modifications ineligible for patent protection. For instance, India modified its patent law in 2005 and required firms to provide clinical evidence of an increase in efficacy of the new drug relative to the current available ones.[16] A second alternative is to monitor and limit firms' marketing efforts. The U.S. already monitors financial relationships between the pharmaceutical companies drug and physicians (and hospitals), so a policy could cap marketing spending. A third alternative is to broaden the definition of "generic equivalents," so pharmacists can substitute a minor modification by a generic version of the original drug.[17] Finally, insurers could only reimburse minor modifications with a clear benefit for consumers.

Related Literature. Most of the legal antitrust literature discusses product hopping from an ex post welfare perspective, ignoring ex ante R&D investments. Carlton et al. (2016) suggest that product hopping is a regulatory problem associated to the Hatch-Waxman Act and should not be remedied by antitrust laws. Miller (2016) concludes that product hopping is not anticompetitive under the current U.S. antitrust laws, and argues that banning it would deter innovative reformulations. Noah (2015) argues that antitrust laws did not apply to the product hopping case of OxyContin/OxiContin-OP. In contrast, Carrier and Shadowen (2016) propose an antitrust analysis of product hopping under price disconnection—doctors who prescribe drugs are not paying for them, and consumers who pay for them are not choosing them. Shadowen et al. (2009) evaluate the extent of product hopping empirically finding that some reformulations are not used to block generic entry. Burke (2018) claims that the anticompetitive harm of product hopping outweighs the minor benefit of a reformulation. Fielding (2016) discusses the court's finding of anticompetitive conduct in the product hopping case Nameda-IR/Nameda-XR. Iyengar (2015) also examines this case and proposes a framework to evaluate under what conditions product hopping should be subject to antitrust liability.

Product hopping, and more broadly "evergreenning" practices, have been studied empirically. Huskamp et al. (2008) show that marketing efforts shift sharply from an original drug to a reformulation, for a class of antidepressants. Other articles exploring the effect on marketing

[16]Novartis' patent application for the cancer drug Glivec was rejected under this law (Liu, 2015).

[17]In the U.S. a pharmacist can only substitute "AB-rated" generic versions of the brand drug, i.e., the generic drug must be bio-equivalent (i.e., absorbed into the body at the same rate) and therapeutically equivalent (i.e., it has the same active ingredient, form, dosage, strength, and safety and efficacy profile) to the original brand drug (Carrier and Shadowen, 2016).

on prescription of drugs include Grennan et al. (2018), Shapiro (2018), Chernew et al. (2018), Feldman (2018), Castanheira et al. (2019), Carey et al. (2015), among others. Daidoji et al. (2013) find that an incumbent's effective patent length after considering reformulation patents is beyond the 20 years, especially for oral formulations. Hemphill and Sampat (2012) show that patent validity challenges are more common for higher sales drugs, and for low quality patents for minor modifications. Huckfeldt and Knittel (2011) documents the substitution between a drug and its reformulations after generic entry.

Advertising as barrier to entry has been examined by Salop (1979), Schmalensee (1983), and Fudenberg and Tirole (1984), among others. More recently, and focusing on the pharmaceutical industry, Morton (2000) shows that advertising is not a barrier to entry for generics. Using a different methodology, Ellison and Ellison (2011) do not find strong evidence of entry deterrence. Dave (2013) studies the effect of advertising to consumers versus advertising to physicians and finds that advertising to physicians increases the demand for the brand, but it does not strongly deter entry. Empirical work should define products carefully, because the endogenous demand shift from the original drug to the minor modification, as a consequence of product hopping, could misrepresent the level of advertising on different products.

2 Model

There are two innovators and generic drug manufacturers. There are two stages. At stage $t = 1$, the two innovators are symmetric and compete by invest in R&D to be the first to patent drug $\mathcal{O}$. The winner of this R&D race becomes the incumbent (the brand firm) and obtains monopoly profits π^m until the patent of product $\mathcal{O}$ expires at $t = 2$.[18] Anticipating the expiration of product $\mathcal{O}$'s patent, the incumbent can engage in *product hopping*, whereby the incumbent commit resources ($K \geq 0$) to develop, patent, and promote product $\mathcal{H}$, which is a minor modification of product $\mathcal{O}$. Only the incumbent can develop and promote this marginal improvement. This advantage over the entrant can be justified from learning-by-doing, no-infringement risk, and it is also often the case empirically. When the incumbent engages in product hopping, product $\mathcal{H}$ takes over product $\mathcal{O}$'s market, effectively foreclosing the entry of generic versions of $\mathcal{O}$. Regulatory frictions—marketing, efforts to persuade physicians to prescribe $\mathcal{H}$ rather than $\mathcal{O}$ or one of $\mathcal{O}$'s generic versions, generic substitution laws, and patentability standards—allow the incumbent to engage in product hopping and to divert

[18] For the sake of exposition, we assume the patents are ironclad.

the demand from product $\mathcal{O}$ and its generics towards product $\mathcal{H}$.

At stage $t = 2$, when the patent of the original product $\mathcal{O}$ expires, free entry of generic drug manufacturers drive the profit of product $\mathcal{O}$ to zero. At this point, the incumbent and the entrant compete in a new innovation race to develop and patent product $\mathcal{I}$, which is *radical innovation* relative to product $\mathcal{O}$. The market structure at $t = 2$ depends on whether the incumbent engaged in product hopping right before the expiration of product $\mathcal{O}$'s patent. If the incumbent does not engage in product hopping, then the market consist of product $\mathcal{I}$, sold by the winner of the second R&D race, and product $\mathcal{O}$ and its generics. We denote by π_I^0 the equilibrium profit of a firm that offers product $\mathcal{I}$. If the incumbent engaged in product hopping, then product $\mathcal{O}$ and its generics are excluded from the market. There are two different scenarios. First, if the incumbent wins the innovation race at $t = 2$, then it becomes a multi-product firm offering both products $\mathcal{H}$ and $\mathcal{I}$. Let π be the incumbent's profit when it offers both $\mathcal{H}$ and $\mathcal{I}$, which internalizes the price externalities from offering both products. Second, if the entrant wins the innovation race at $t = 2$, then the incumbent offers $\mathcal{H}$ and competes with the entrant that offers $\mathcal{I}$. Let π_H and π_I be the profit of selling product $\mathcal{H}$ and product $\mathcal{I}$, respectively, when $\mathcal{I}$ is offered by the entrant and $\mathcal{H}$ is offered by the incumbent. As in Gilbert and Newbery (1982), we assume that a multi-product monopolist generates higher profits than competing firms, i.e., $\pi \geq \pi_I + \pi_H$. Figure 1 illustrates the timing of the model, showing how the market structure is affected by the decision of the incumbent to engage in product hopping before the second R&D race.

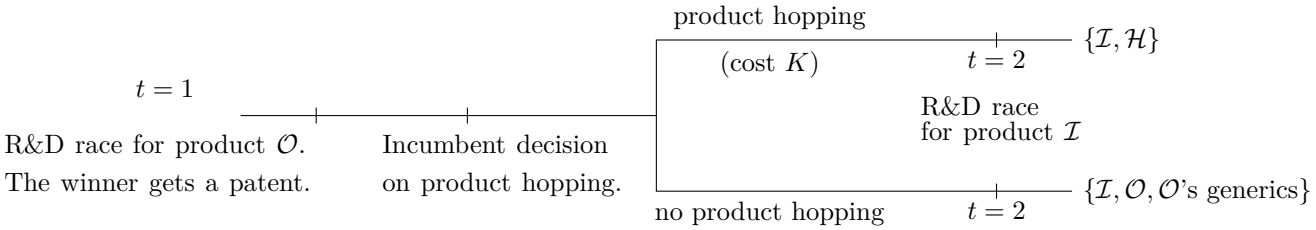


Figure 1: Timing of the events in the model.

Product hopping not only affects the market structure at period 2, but also the incentives to invest in R&D in the competition for product $\mathcal{I}$. Without product hopping, the second innovation race is symmetric, i.e., the incumbent's and the entrant's incentives to invest in R&D are the same. Under product hopping, however, incentives to invest in R&D are asymmetric: product $\mathcal{H}$ is the outside option of the incumbent. Additionally, product hopping distort the incentives of the entrant, because now it will compete against product $\mathcal{H}$ sold at

a positive price, rather than product $\mathcal{O}$ an its generics sold at price of zero.

Note that $\pi_I^0 \leq \pi$ because the incumbent can do better when it sells both $\mathcal{H}$ and $\mathcal{I}$ rather when it sells $\mathcal{I}$ in competition with $\mathcal{O}$ (sold at a price of zero). The comparison between π_I and π_I^0 is ambiguous and depends on the additional therapeutic value of $\mathcal{H}$ relative to $\mathcal{O}$. We have $\pi_I^0 < \pi_I$ when the consumers value products $\mathcal{H}$ and $\mathcal{O}$ equally. In this case, competition between product $\mathcal{I}$ and $\mathcal{O}$ (and $\mathcal{O}$'s generic versions) is stronger than competition between $\mathcal{I}$ and $\mathcal{H}$. We have $\pi_I^0 \geq \pi^I$ when product $\mathcal{H}$ offers higher therapeutic value to consumers than product $\mathcal{O}$, and therefore competition between $\mathcal{H}$ and $\mathcal{I}$ may be stronger than the competition between $\mathcal{I}$ and $\mathcal{O}$ (and $\mathcal{O}$'s generic versions).

We solve the model by backward induction starting from the R&D race at stage $t = 2$, conditional on the incumbent having engaged in product hopping or not. We then determine whether it is optimal for the incumbent to engage in product hopping. Finally, we study the R&D race at stage $t = 1$.

2.1 Stage 2: R&D Race for Product $\mathcal{I}$ (Radical Innovation)

We first consider the case where the incumbent engaged in product hopping. In this case, the demand for product $\mathcal{O}$ and $\mathcal{O}$'s generics is diverted to product $\mathcal{H}$. The incumbent chooses its R&D investment to solve

$$\max_{x \geq 0} \frac{x}{x+y}\pi + \frac{y}{x+y}\pi_H - x, \tag{1}$$

where y is the R&D investment of the entrant. Similarly, the the entrant solves

$$\max_{y \geq 0} \frac{y}{x+y}\pi_I - y. \tag{2}$$

In Equation 1, the incumbent obtains π from winning the R&D race, which happens with probability $\frac{x}{x+y}$, and π_H from losing it. In Equation 2 the entrant gets π_I from winning the innovation race and zero from losing it.

Lemma 1. *The equilibrium level of R&D for the incumbent (x^*) and the entrant (y^*) in the R&D race at $t = 2$ is given by*

$$x^* = \frac{\pi_I}{(1+\gamma)^2}, \quad \textit{and} \quad y^* = \gamma x^*, \quad \textit{where} \quad \gamma = \left(\frac{\pi_I}{\pi - \pi_H}\right).$$

Proof. The first order conditions imply $\frac{(\pi-\pi_H)y^*}{(x^*+y^*)^2}=1$ and $\frac{\pi_I x^*}{(x^*+y^*)^2}=1$. Solving these equations we obtain the result. □

Note that $\gamma \leq 1$ because of the industry efficiency assumption (Gilbert and Newbery, 1982). This implies that the incumbent invests more than the entrant, so the incumbent is more likely to win the second R&D race.

Next, consider the case where the incumbent does not engage in product hopping. Then, the incumbent does not develop product $\mathcal{H}$, and therefore does not have an advantage over the entrant in the R&D race at $t=2$. Thus, incumbent and the entrant have symmetric incentives to invest in R&D and each firm solve

$$\max_{\hat{x}_i \geq 0} \frac{\hat{x}_i}{\hat{x}_i+\hat{x}_{-i}}\pi_I^0 - \hat{x}_i. \tag{3}$$

It is easy to see that the equilibrium level of R&D of both firms is identical and equal to

$$\hat{x}^* = \frac{\pi_I^0}{4}. \tag{4}$$

We now study how equilibrium R&D investments at $t=2$ are affected by product hopping, when product $\mathcal{H}$ eliminates the market for product $\mathcal{O}$ and $\mathcal{O}$'s generic versions. Comparing the incumbent's equilibrium R&D investments x^* and $\hat{x}^*$ we have

$$x^* \geq \hat{x}^* \iff \frac{4\pi_I}{(1+\gamma)^2} \geq \pi_I^0 \tag{5}$$

Proposition 1. *Product hopping increases the incumbent's R&D investment for the radical innovation (product $\mathcal{I}$) at stage $t=2$ when*

$$\bar{\pi}_I^{\text{inc}} \equiv \frac{4\pi_I}{(1+\gamma)^2} \geq \pi_I^0.$$

Furthermore, we have that $\bar{\pi}_I^{\text{inc}} \in [\pi_I, \pi]$.

Proof. When condition (5) holds product hopping increases the incumbent's R&D at $t=2$. Note that $(1+\gamma)^2 \leq 4$ for any $\gamma \in [0,1]$, so $\frac{4\pi_I}{(1+\gamma)^2} \geq \pi_I$. Next, let $D=\pi-\pi^H$ so we have

$$\frac{4\pi_I}{(1+\gamma)^2} \leq \pi \Leftrightarrow 4D^2\pi^I \leq (D+\pi^I)^2\pi \Leftrightarrow -4D\pi^I\pi^H \leq (D-\pi^I)^2\pi.$$

The left-hand side is negative and the right-hand side is positive, so the inequality holds. □

Proposition 1 shows that the whether product hopping increases or reduces the incumbent's R&D investment at $t = 2$ depends on how different is π_I^0 from π. In other words, it depends on the size of the increase in profits for a monopolist that can offer both products $\mathcal{I}$ and $\mathcal{H}$, relative to a firm that offers product $\mathcal{I}$ in competition with $\mathcal{O}$ and $\mathcal{O}$'s generic versions. The reason is that the the incentive to innovate depends on the difference between winning and losing the R&D race. That difference is $\pi - \pi_H$ under product hopping and $\pi_I^0 - 0$ without product hopping. When $\pi_I^0 \geq \bar{\pi}^{\text{inc}}$ the incentive to innovate is larger without product hopping, because the incremental profit from winning the R&D race is larger. Product $\mathcal{H}$ is the incumbent's outside option and creates a replacement effect that decreases the incumbent's incentive to innovate. When $\pi_I^0 < \bar{\pi}^{\text{inc}}$ product hopping increases the incentive to innovate because it softens market competition: the profits of the firm selling product $\mathcal{I}$ are larger when $\mathcal{I}$ competes against $\mathcal{H}$ rather than $\mathcal{O}$ and its generic versions. Without product hopping, the winner of the race competes against $\mathcal{O}$ and its generic versions, and this competition effect can be intense.

We now study whether product hopping increases or decreases the *total* investment in R&D for product $\mathcal{I}$ at stage $t = 2$. When the incumbent engages in product hopping the total R&D investment at the second innovation race is

$$x^* + y^* = x^* + \gamma x^* = (1+\gamma)x^* = \frac{\pi_I}{1+\gamma}.$$

When the incumbent does not engage in product hopping is

$$2\hat{x}^* = \frac{\pi_I^0}{2}.$$

Thus, comparing total R&D investments at the second innovation race we have

$$x^* + y^* \geq 2\hat{x}^* \iff \frac{2\pi_I}{1+\gamma} \geq \pi_I^0. \tag{6}$$

Proposition 2. *Product hopping increases the total R&D investment for product $\mathcal{I}$ at $t = 2$ when*

$$\bar{\pi}_I^{\text{tot}} \equiv \frac{2\pi_I}{1+\gamma} \geq \pi_I^0.$$

Furthermore, we have that $\bar{\pi}_I^{\text{tot}} \in [\pi_I, \pi]$ and $\bar{\pi}_I^{\text{tot}} \leq \bar{\pi}_I^{\text{inc}}$.

Proof. When condition (5) holds product hopping increases total R&D at $t = 2$. Note that $1 + \gamma \leq 2$ for any $\gamma \in [0, 1]$, so $\frac{2\pi_I}{(1+\gamma)^2} \geq \pi_I$. Next, let $D = \pi - \pi^H$ so we have

$$\frac{2\pi_I}{1+\gamma} \leq \pi \Leftrightarrow 2\pi^I D \leq (D + \pi^I)\pi \Leftrightarrow D\pi^I \leq D(\pi - \pi^I) + \pi^\pi \Leftrightarrow \pi^H - \pi^I \leq \pi,$$

which always holds. $\bar{\pi}_I^{tot} \leq \bar{\pi}_I^{inc}$ is direct from the definition of these variables. □

Proposition 2 shows that the total R&D investment for the radical innovation at stage $t = 2$ (product $\mathcal{I}$) decreases when there is a high degree of cannibalization of the profits of product $\mathcal{H}$ by product $\mathcal{I}$. The intuition is similar to that of Proposition 1: the incumbent has less incentives to invest in R&D with an outside option, which reduces the innovation incentives of the entrant; but, the incumbent would like to soften competition and introduce product $\mathcal{H}$ if, under its absence, competition between $\mathcal{I}$ and $\mathcal{O}$ and $\mathcal{O}$'s generics is intense.

Figure 2 illustrate the different regions as a function of the parameters. It shows that R&D incentives increase when π_I^0 is relatively low. This occurs, for instance, when product $\mathcal{H}$ has no therapeutic benefit for consumers relative to $\mathcal{O}$. This case is problematic from a consumer-welfare perspective, because the introduction of product $\mathcal{H}$ and the foreclosure of the market for $\mathcal{O}$ and its generic versions precludes consumers from accessing more cost-efficient drugs. However, as Figure 2 shows, product hopping *increases* total R&D investment at $t = 2$ in this case. The reason is that it softens competition for the innovative product $\mathcal{I}$, and therefore encourages the entrant to invest more in innovation, which raises total equilibrium R&D.

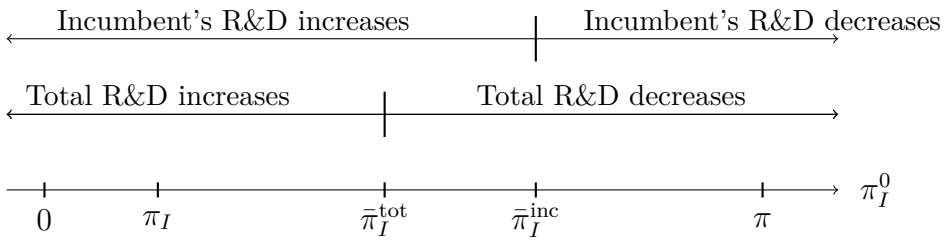


Figure 2: Effect of product hopping on R&D investments at the second innovation race.

Equilibrium continuation value:

The continuation values for the incumbent and the entrant, V^I and V^E, respectively, depend on whether or not the incumbent engaged in product hopping right before the expiration of product $\mathcal{O}$'s patent. When the incumbent engages in product hopping it expects a continu-

ation value of

$$V^I = \frac{\pi + \gamma\pi_H}{1+\gamma} - \frac{\pi_I}{(1+\gamma)^2} = \frac{(\pi + \gamma\pi_H)(1+\gamma) - \pi_I}{(1+\gamma)^2}, \tag{7}$$

The expected continuation value for the entrant under product hopping is

$$V^E = \frac{\gamma}{1+\gamma}\pi_I - \gamma\frac{\pi_I}{(1+\gamma)^2} = \frac{\pi_I\gamma^2}{(1+\gamma)^2}. \tag{8}$$

If the incumbent does not engage in product hopping, then winning the first innovation race does not create an advantage for the incumbent during the second innovation race. Thus, in this case, the continuation value for the incumbent and the entrant are the same and equal to

$$V_0^I = V_0^E = \pi_I^0/4. \tag{9}$$

Engaging in product hopping has a fixed cost $K \geq 0$ for the incumbent. The incumbent decides whether to engage in product hopping comparing this cost to the marginal benefit of entering period 2 with an advantage. Thus, the incumbent engages in product hopping when $V^I - K \geq V_0^I$.

Proposition 3. *The incumbent engages in product hopping when*

$$\pi_H + \frac{\pi_I}{\gamma(1+\gamma)^2} - \pi_I^0/4 \geq K, \tag{10}$$

which holds for any $K \in [0, \bar{K}]$ *when* $\pi^0 \leq \bar{\pi}_I^{inc}$.

Proof. Using the definition of γ, we obtain that $V^I - K \geq V_0^I$ is equivalent to condition (10). When $\pi_I^0 \leq \bar{\pi}_I^{\text{inc}}$, the right-hand side of this condition is strictly positive, because $\gamma \leq 1$. Thus, there exists some strictly positive cutoff $\bar{K}$ such that condition(10) holds for any $K \leq \bar{K}$. □

Proposition 3 shows that a sufficient condition for the incumbent to engage in product hopping is that K is small and that $\pi_I^0 \leq \bar{\pi}_I^{\text{inc}}$. This implies that the incumbent will invest more than the entrant in the race for product $\mathcal{I}$, but total R&D in this race may increase or decrease as a consequence of product hopping. Specifically, when $\pi_I^0 \in [\bar{\pi}_I^{\text{tot}}, \bar{\pi}_I^{\text{inc}}]$ the incumbent wants to engage in product hopping, but the total R&D investment at $t = 2$ decreases; whereas when $\pi_I^0 < \bar{\pi}_I^{\text{tot}}$ the incumbent engages in product hopping and the total

R&D investment at $t = 2$ increases. When $\pi_I^0 > \bar{\pi}_I^{\text{inc}}$ the condition in Proposition 3 may hold, but the total R&D investment at $t = 2$ unequivocally goes down.

2.2 Stage 1: R&D Race for Product $\mathcal{O}$

In the first period, the two innovators race to bring product $\mathcal{O}$ to the market. At this point, the two innovators are symmetric. The winner of the first R&D race obtains a patent, and the monopoly profits π^m associated to selling product $\mathcal{O}$ under patent protection until period 2. Additionally, the winner of the first R&D race becomes the incumbent, which creates the option value of engaging in product hopping at cost $K \geq 0$. We assume that firms do not discount future payoffs.

The incentive to innovate in the first period is driven by the difference between the payoff of winning and the payoff of losing the R&D race for product $\mathcal{O}$. Winning the R&D race guarantees profits π^m from product $\mathcal{O}$'s patent. The continuation value, however, depends on the equilibrium decision of invest in product hopping or not, and on the equilibrium R&D investment in the second period. When it is optimal for the incumbent to engage in product hopping, the difference in the payoff of winning and losing the first R&D race is $\pi^m + V^I - K - V^E$. Given that the firms are symmetric in period 1, it is easy to show that the equilibrium level of investment is

$$x^* = \frac{\pi^m + V^I - K - V^E}{4}.$$

Recall that without product hopping $V_0^I = V_0^E$. Thus, product hopping increases innovation incentives at $t = 1$ if it makes incumbency valuable, i.e., when under product hopping $V^I > V^E + K$. Subtracting Equation 7 and Equation 8, and using the definition of γ, we have that product hopping increases equilibrium R&D investments at $t = 1$ if

$$K^* \equiv \pi_H + \frac{\pi_I(1-\gamma^3)}{\gamma(1+\gamma)^2} \geq K. \tag{11}$$

Note that the condition (11) holds for K sufficiently small, specifically, $K \leq K^*$. Therefore, we have the following result:

Proposition 4. *If the condition in Proposition 3 and $K \leq K^*$, the incumbent engages in product hopping and the total equilibrium R&D investment at $t = 1$ increases. A sufficient*

(but not necessary) condition for R&D to increase is $\pi_I^0 \geq \pi^I$.

Proof. If the condition in Proposition 3 and Equation 11 hold, by definition, the incumbent engages in product hopping and the total equilibrium R&D investment at $t = 1$ increases. For the sufficient condition, note that

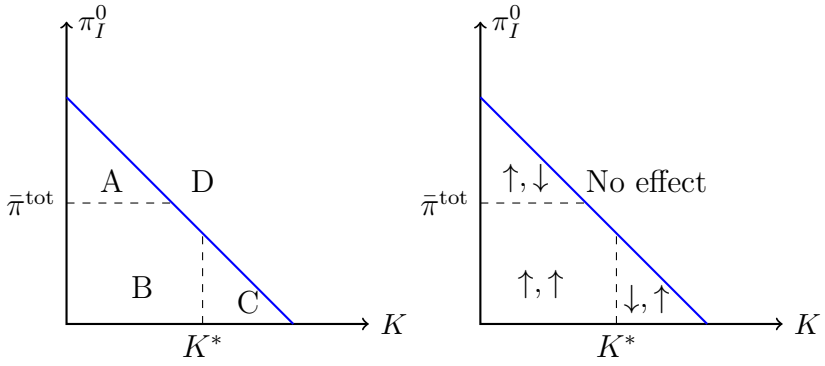
$$\pi_H + \frac{\pi_I(1-\gamma^3)}{\gamma(1+\gamma)^2} - K \geq \frac{\pi_I^0}{4} - \frac{\pi_I \gamma^2}{(1+\gamma)^2} \geq \frac{\pi_I^0 - \pi_I}{4},$$

where the last inequality holds because $\frac{\gamma^2}{(1+\gamma)^2} \leq \frac{1}{4}$ for all $\gamma \leq 1$. □

Proposition 4 shows that banning product hopping may have negative welfare consequences by reducing the R&D investment at $t = 1$. This would only happen when π_I^0 is sufficiently lower than π_I. When $\pi_I^0 > \pi_I$ and it is optimal for the incumbent to engage in product hopping, we have that R&D at $t = 1$ increases. The reason for why R&D decreases at $t = 1$ is because product hopping raises both the incumbent and the entrant's payoff at $t = 2$, but the entrant's payoff increases by more than the incumbent's payoff. To see this, suppose the incumbent engages in product hopping, i.e., $V_I - K > V_I^0$, and R&D investments at $t = 1$ decrease, i.e., $V_I - K - V^E < V_I^0 - V_E^0$. It is easy to see that these two conditions imply $0 < V_I - K - V_I^0 < V^E - V_E^0$. Thus, when product hopping reduces R&D investments at $t = 1$ it increases the entrant's payoff by more than the incumbent's payoff.

Figure 3 (Panel a) shows the four different cases in the model. In region D, the incumbent does not engage in product hopping. In all the remaining regions the incumbent engages in product hopping. In regions A and B, the total R&D's equilibrium level in period 1 increases, whereas in region C it decreases, relative to the case of no product hopping.[19] In regions B and C, product hopping increases total R&D's equilibrium level in period 2, whereas in region A it decreases it, relative to the case of no product hopping. Figure 3 (Panel b) indicates whether product hopping increases or reduces the total equilibrium R&D investment in the first and in the second period.

[19]The maximum K for which the incumbent engages in hopping is $K_{\max} = K^* + \frac{\gamma^2 \pi_I}{(1+\gamma)^2} > K^*$, and the maximum π_I^0 for for which the incumbent engages in hopping is $\pi_{I,\max}^0 = 4\pi_H + \bar{\pi}^{\text{inc}} > \bar{\pi}^{\text{tot}}$.



(a) Different Regions **(b)** R&D under product hopping

Figure 3: Panel (a) shows for regions. In region D, the incumbent does not engage of product hopping. In regions A, B, C the incumbent engages in product hopping. Panel (b) shows an arrow pointing upwards (downwards) when product hopping increases (decreases) R&D in a each period.

2.3 Welfare

Our results, summarized in Figure 3, show that product hopping has ambiguous effect on R&D, depending on the cost for the incumbent of creating an advantage in period 2 (how K compares to K^*) and whether the profit of an innovator that competes with $\mathcal{O}$ and its generic versions is relatively large (how π_I^0 compares to $\bar{\pi}^{\text{tot}}$).

Apart from affecting equilibrium R&D levels, product hopping has other welfare consequences. For instance, when the therapeutic benefit of product $\mathcal{H}$, relative to product $\mathcal{O}$ is small, by engaging in the product hopping cost K the incumbent steers consumers to a less cost-effective drug. Additionally, in this case the incumbent's spending of K is wasteful. It is also plausible that even minor modifications may create value for consumers.

To evaluate the consumer welfare trade-offs that arise from banning product hopping, we consider a consumer-welfare function that increases when innovative products arrive quickly. The speed of arrival of products is determined by the total R&D investment. We assume that firms can start investing in the second product only after the patent of the first product expires.[20] We interpret the contest success function in the R&D contests as the probability that a firm's discovery arrives first. Suppose the incumbent invests x and the entrant y in an R&D race. Let τ_x be the time of arrival of the incumbent's invention, which we assume is distributed according to an exponential distribution of parameter x; let τ_y time of arrival of the entrant's invention, which we assume is distributed according to an exponential

[20]This is a simplification to avoid solving a fully dynamic model, where the flow profit of the incumbent can be interrupted by the arrival of the next product.

distribution of parameter y. Thus, the probability that the incumbent discovers first (and therefore wins the R&D race) is $\frac{x}{x+y}$. Suppose that the social planner discount the future at rate $r > 0$. Then, the expected discount rate for the first product is $E[\exp(-r\tau)]$ where $\tau = \min\{\tau_x, \tau_y\}$. Denote by X_t^* the total equilibrium effort in the period t. Then, the expected consumer surplus is

$$ECS = A_1(X_1)\left[CS_1 + A_2(X_2)CS_2\right]\delta(T, r). \tag{12}$$

In the definition above, CS_t is the consumer surplus in period t, $A_1(X_1) = \frac{X_1}{r+X_1}$ is the expected discounted rate for the first invention and $A_1(X_2) = \frac{e^{-rT}X_2}{r+X_2}$ is the expected discounted rate for the second invention and $\delta(T, r) = \frac{1-\exp(-rT)}{r}$ is the discount rate for a period of length T. Note that $A_t(X_t)$ is increasing in X_t. We denote by X_t and $\hat{X}_t$ the total equilibrium R&D investment in period t with and without product hopping, respectively.

When the incumbent engages in product hopping, $CS_2 = CS^H \equiv \frac{1}{1+\gamma}CS^{I,m} + \frac{\gamma}{1+\gamma}CS^{I,E}$. The term $CS^{I,m}$ is the consumer surplus when the incumbent wins the second innovation race (and, therefore, it is a multi-product monopolist offering $\mathcal{H}$ and $\mathcal{I}$); the term $CS^{I,E}$ is the consumer surplus when the entrant wins the second innovation race and, therefore, products $\mathcal{H}$ and $\mathcal{I}$ are sold under competition. Given that the second R&D race is asymmetric when the incumbent has developed product $\mathcal{H}$ as an outside option, the incumbent wins the R&D with probability $\frac{1}{1+\gamma} > \frac{1}{2}$. When the incumbent does not engage in product hopping, we have $CS_2 = CS^I$, the consumer surplus when $\mathcal{I}$ is offered on the market in competition with $\mathcal{O}$ and $\mathcal{O}$'s generic versions. Finally, CS_1 is the consumer surplus when product $\mathcal{O}$ is sold by the winner of the first R&D race, and product $\mathcal{O}$ is the only product in the market.

When product $\mathcal{H}$ is almost identical to product $\mathcal{O}$, consumers are better off when $\mathcal{O}$ and $\mathcal{O}$'s generic versions are offered at zero price rather than $\mathcal{H}$, i.e., $\max\{CS^{I,m}, CS^{I,E}\} \leq CS^I$ which implies $CS^H \leq CS^I$. In this case, $\pi_I^0 \leq \pi^I$, so product hopping increases total R&D investments in the second period. Suppose that K is small, so in the first period R&D investments also increases. The effect of product hopping on welfare is ambiguous: welfare increases when the incumbent engages in product hopping if $W(x_1, x_2) \geq W(\hat{x}_1, \hat{x}_2)$ or

$$\underbrace{[A_1(X_1) - A_1(\hat{X}_1)]CS^m}_{A} + \underbrace{A_1(X_1)A_2(X_2)CS^H - A_1(\hat{X}_1)A_2(\hat{X}_2)CS^I}_{B} > 0.$$

The first term, A, is positive and correspond to a gain in consumer surplus from a speedier introduction of product $\mathcal{O}$. Product hopping increases the value of incumbency, which pushes

firms to compete more fiercely in the first R&D race. The sign of the second term, B, is ambiguous. First, $A(X_1)A(X_2)$ is larger than $A(\hat{X}_1)A(\hat{X}_2)$ when product hopping accelerates the arrival of both product $\mathcal{O}$ and product $\mathcal{I}$. But product hopping reduces consumer surplus at $t = 2$ relative to the case of no product hopping, $CS^H < CS^I$, and therefore the term B could be negative. This is case is the best-case scenario for supporting product hopping. In any other case, when the incumbent engages in product hopping, there will be a reduction of R&D either in the first or in the second period.

2.4 Banning Product Hopping

Consumers may benefit from product hopping from two channels: (1) product $\mathcal{H}$ is more valuable for consumers than product $\mathcal{O}$; (2) higher R&D investments accelerate the arrival of new products. When products $\mathcal{H}$ and $\mathcal{O}$ are similar, consumers benefit from product hopping only from its potential to increase R&D investments. Thus, a simple consumer-welfare-improving alternative to product hopping is one that deters the incumbent from engaging in product hopping but provides firms with higher innovation incentives.[21] One such mechanism could reward firms that develop the first drug for a given disease (a pioneer drug) or those that dramatically improve the existing drugs. Such a mechanism would generate a payoff of $\pi^m + R + \pi_I^0/4$ for the winner of the first R&D race. Thus, for an appropriate reward R this mechanism mimics the good feature of product hopping, in terms ex ante innovation incentives, and it avoids the negative aspects of product hopping including wasteful marketing investments K as well as higher prices in the second period. Another alternative would be to award longer patents to pioneer drugs, so as to increase π^m, which increases the ex ante innovation investments but decreases consumer welfare (longer length of a monopoly). Finally, another alternative is to give subsidies to firms, which in our model is equivalent to increase the prize in the R&D competition.

In the next section, we present an example with differentiated products to further explain our results.

[21] In the Introduction we discuss a number of regulatory changes that would ban product hopping.

3 Differentiated Products Example

There is a continuum of consumer uniformly distributed along the interval $[0, 1]$. Product $\mathcal{O}$ and any of its generic versions give consumers a utility of v, and they are located at $x = 0$. In period 1, product $\mathcal{O}$ is the only product in the market and it sells at monopoly price p_O. In period 2, product $\mathcal{O}$ and its generic versions sell at price of zero. Product $\mathcal{H}$ gives consumers a utility of v_H, is located at $x = 0$ and it is sold at price p_H. Product $\mathcal{I}$ gives consumers a utility of v_I, is located at $x = 1$, and it is sold at price p_I. The products in the market at $t = 2$ depends on whether the incumbent engaged in product hopping. Without product hopping, the products in the market at $t = 2$ are $\mathcal{O}$, $\mathcal{O}$'s generic versions, and $\mathcal{I}$, whereas with product hopping the products in the market are $\mathcal{H}$ and $\mathcal{I}$. This change in market structure is the friction introduced by product hopping. We assume that the marginal cost of each product is zero and that $v \leq v_H < v_I$. Consumers pay a linear transportation cost κ. Figure 4 describes the location of different products in the market at time t, depending on whether the incumbent engages in product hopping.

	$x = 0$	$x = 1$
$t = 1$	$\mathcal{O}$	None
$t = 2$, no hopping	$\mathcal{O}$, $\mathcal{O}$'s generics	$\mathcal{I}$
$t = 2$, hopping	$\mathcal{H}$	$\mathcal{I}$

Figure 4: Products in the market with and without product hopping.

We assume that the market is fully covered and the solutions are interior.

Assumption 1. *$v_I + v_H \geq 3\kappa$, $v_I - v_H \leq 2\kappa$, and $v_I - v \leq 2\kappa$.*

3.1 Market Equilibrium at $t = 2$

Product Hopping. In this case there are two scenarios depending on which firm wins the R&D race at $t = 2$.

Competition: First, suppose the entrant wins the R&D race at $t = 2$. Product $\mathcal{I}$ is offered by the entrant and product $\mathcal{H}$ by the incumbent.

Lemma 2. *The equilibrium profits under competition for products $\mathcal{H}$ and $\mathcal{I}$ are, respectively,*

$$\pi_H = \frac{(3\kappa - \Delta v)^2}{18\kappa}, \quad \pi_I = \frac{(3\kappa + \Delta v)^2}{18\kappa},$$

where $\Delta v = v_I - v_H > 0$. *The consumer surplus is* $CS^{I,E} = \dfrac{(v_I - v_H)^2 + 18\kappa(v_I + v_H) - 45\kappa^2}{36\kappa}$.

Multiproduct monopolist: Second, consider the case where the incumbent wins the R&D at $t = 2$. In this case, the incumbent can sell both products $\mathcal{H}$ and $\mathcal{I}$ at prices p_H and p_I. Under Assumption 1, the multi-product monopolist that does not exclude any consumer.

Lemma 3. *The equilibrium profit for the multi-product monopolist is*

$$\pi = \frac{(v_I - v_H)^2 + 4\kappa(v_I + v_H) - 4\kappa^2}{8\kappa}.$$

The consumer surplus in multi-product monopolist case is $CS^{I,m} = \dfrac{(v_I - v_H)^2 + 4\kappa^2}{16\kappa}$.

No Product Hopping. In this case, the innovator, which is either the incumbent or the entrant, competes with product $\mathcal{O}$ and its generic versions located at $x = 0$ and sold at price equal to zero (marginal cost).

Lemma 4. *If the incumbent does not engage in product hopping, the innovator's profit is* $\pi_I^0 = \dfrac{(\kappa + v_I - v)^2}{8\kappa}$, *and the consumer surplus is* $CS^I = \dfrac{(v_I - v)^2 + 2\kappa(v_I + v) + 12\kappa v - 7\kappa^2}{16\kappa}$.

3.2 Market Equilibrium at $t = 1$

In period 1, the winner of the R&D race sells product $\mathcal{O}$ under no competition until the patent of product $\mathcal{O}$ expires.

Lemma 5. *The winner of the first R&D race receives a profit of* $\pi_m = \dfrac{v^2}{4\kappa}$ *during the first period. The consumer surplus in this period is* $CS^m = \dfrac{3v^2}{8\kappa}$.

Expected Consumer Surplus. We use Equation 12 to compute the expected consumer surplus with and without product hopping for different parameters. Table 1 show for different cases to illustrate how product hopping affects R&D incentives, competition, and welfare. We set $v_I = 4$, $v = 2$, $\kappa = 1$. With these parameters, we have $\pi_I^0 = 1.13$ and $\pi_m = 1$. The equilibrium investment without product hopping in the first and in the second stage are, respectively, $\hat{X}_1 = 0.5$ and $\hat{X}_2 = 0.56$.

In the first row of Table 1, product $\mathcal{H}$ is more valuable than product $\mathcal{O}$, but less valuable than product $\mathcal{I}$. These parameter values imply that we are in Region A in Figure 3. Product

v_H	K	r	π_H	π_I	π	$\bar{\pi}_I^{tot}$	K^*	X_1	X_2	ECS_H	ECS_{NH}
3.5	0	0.1	0.35	0.68	3.28	1.10	2.26	1.63	0.55	1.82	2.46
3.5	0	0.4	0.35	0.68	3.28	1.10	2.26	1.63	0.55	1.17	1.06
2.0	0	0.1	0.06	1.39	3.00	1.89	1.27	1.14	0.94	1.98	2.45
2.0	1.3	0.1	0.06	1.39	3.00	1.89	1.27	0.49	0.94	1.79	2.45

Table 1: Value of profits under different market structures and other relevant parameters.

hopping changes the market structure that follows the second R&D race. The direct effect encourages the incumbent it is invest more ($\pi - \pi^H > \pi_I^0$) and the entrant to invest less ($\pi_I < \pi_I^0$). But because the entrant invests less, the strategic effect of the incumbent is to reduce its investment. The overall effect is a reduction in total R&D at stage 2 ($X_2 < \hat{X}_2$). Product hopping increases the value of incumbency and it is costless ($K = 0$), which boosts R&D investments in the first period ($X_1 > \hat{X}_1$). Consumers pay higher prices in the second period, but they get higher value from product $\mathcal{H}$ relative to product $\mathcal{O}$. The price effect dominates and consumer surplus decreases in the second period. All these effects combined imply that product hopping reduces the expected consumer surplus overall ($ECS_H < ECS_{NH}$).

The second row in Table 1 is identical to the first row except for the value of r, which measures how much consumers value a quick arrival of new products. A larger value of r implies that consumers are more impatient, and therefore the value more faster arrival of new products. When $r = 0.4$ instead of $r = 0.1$, product hopping increases expected consumer surplus because product hopping increases R&D at the stage 1, accelerating product arrivals.

In the third row of Table 1, consumers value products $\mathcal{H}$ and $\mathcal{O}$ the same (i.e., $v_H = v = 2$). Product $\mathcal{H}$ prevents consumers to access $\mathcal{O}$ or $\mathcal{O}$'s generics, located at zero and sold at marginal cost, so it softens competition in the stage 2. The direct effect for both the incumbent and the entrant encourages R&D in the second period $\pi_I > \pi_I^0$ and $\pi - \pi^H > \pi_I^0$. This direct effect is larger than the strategic effect or R&D competition which increase total R&D in the second period. The increase in value for the incumbent (and the entrant) imply that R&D also increases in the first period. In other words, this case correspond to a point in Region B in Figure 3. Expected consumer welfare decrease because consumers care more about paying lower prices than having access to new products sooner ($r = 0.1$).

The third row of Table 1 is identical to the third row except that $K > 0$. Increasing K decreases the value of incumbency, but it is sub-game perfect to engage in product hopping. Thus, R&D investments decrease in the first period under product hopping, i.e., we are in Region C in Figure 3.

4 Discussion and Concluding Remarks

Pharmaceutical firms often patent minor modifications of a pioneer drug and invest in marketing to switch consumers from the original drug to the minor modification. This switch often happens just before the patent of the pioneer drug expires. This strategy, called product hopping, reduces consumer welfare by preempting the entry of generic drugs, which would have lowered the price of the original drug after patent expiration. We show that product hopping may increase the value of incumbency and, therefore, increase ex-ante innovation incentives. In some cases, product hopping unambiguously reduces ex-post welfare, i.e. it reduces both consumer welfare and innovation incentives for follow-on (radical) innovation. We characterize conditions under which product hopping increases or decreases consumer welfare, as a function of the cost of engaging in product hopping, and the degree of competition between a follow-on innovative product and the original drug sold at marginal cost.

Product hopping affects firms' incentives in two ways. First, it changes the competition landscape in the second period: without product hopping, product $\mathcal{O}$, generic versions of $\mathcal{O}$, and product $\mathcal{I}$ are offered in the market; with product hopping products $\mathcal{H}$ and $\mathcal{I}$ are offered in the market. Thus, product hopping prevents generic manufacturers to enter the market and reduce the price of product $\mathcal{O}$. This change in the competition landscape is the main complaint raised by generic manufacturers in antitrust lawsuits they have filed against incumbents that have engaged in product hopping.[22] The second effect of product hopping is to change innovation incentives. Under product hopping, in the second period, the incumbent's incentive to innovate is driven by the difference of profits of a multi-product firm (offering both products $\mathcal{H}$ and $\mathcal{I}$) and the profits of offering product $\mathcal{H}$ in competition with product $\mathcal{I}$. The entrants incentive to innovate is driven by the profit of selling product $\mathcal{I}$ in competition with product $\mathcal{H}$. Without product hopping, firm's incentives to invest in R&D are symmetric and driven by the profit of selling product $\mathcal{I}$ in competition with $\mathcal{O}$ and $\mathcal{O}$'s generic versions. Proposition 2 analyzes how these trade-off resolve, and it characterizes when total R&D in the second stage increases. The incumbent will engage in product hopping only when the increase expected profits in the second period are larger than the cost of engaging in product hopping. Product hopping changes equilibrium continuation values and, therefore, affect ex-ante innovation incentives. Ex-ante R&D incentives can increase or decrease under product hopping. Proposition 4 characterizes when product hopping increases R&D investments in the first period.

[22] See examples in footnotes 5 to 9.

The main policy implication from our analysis is that simply banning product hopping may be detrimental for innovation and consumer welfare. A situation of particular interest is one where product $\mathcal{H}$ is identical to product $\mathcal{O}$, i.e., product $\mathcal{H}$ does not offer any therapeutic benefit over product $\mathcal{O}$. In this case, the only positive aspect of product hopping is that it can increase R&D investments. Thus, an argument in favor of product hopping is that it encourages innovation. However, providing innovation incentives via product hopping is inefficient. A more efficient mechanism would mimics the positive effects of product hopping on innovation incentives, but it would avoid wasteful marketing investments and reduction in competition in the second period. Such a policy must assure that firms cannot engage in product hopping, which would require regulatory changes in the current system such as tightening patentability standards, capping marketing investments, or modifying generic substitution laws. Alternative mechanisms to encourage innovation include prizes or subsides for pioneer drugs.

At the core of the problem of product hopping is the fact that the current patent system is not optimally crafted. Such a system would reward innovators differentially depending on the incremental contribution of their inventions (e.g, O'donoghue et al., 1998; Hopenhayn et al., 2006). Product hopping arises from giving large rewards to marginal improvements, which counteract other defects of the system like rewarding too little pioneer drugs. Our results suggest that, taken the current patent system as given, we can improve welfare by regulating product hopping to preserve its positive aspects (enhanced innovation incentives) and to remove negative ones (e.g., wasteful marketing spending to steer demand to less cost-efficient drugs).

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A Appendix: Additional Proofs

Proof of Lemma 2

Proof. A consumer located at $x \in [0,1]$ is indifferent between product $\mathcal{I}$ and product $\mathcal{H}$ iff

$$v_H - xt - p_H = v_I - (1-x)t - p_I \Rightarrow x = \frac{1}{2} + \frac{p_I - p_H}{2t} - \frac{\Delta v}{2t},$$

where $\Delta v = v_I - v_H > 0$. The equilibrium prices are $p_H^* = t - \frac{\Delta v}{3}$, $p_I^* = t + \frac{\Delta v}{3}$. The equilibrium profits are $\pi_H = \frac{(3t - \Delta v)^2}{18t}$, $\pi_I = \frac{(3t + \Delta v)^2}{18t}$.

We require $v_H - x^* t - p_H^* \geq 0$, equivalently, $v_I + v_H \geq 3t$, for the market to be fully covered and $\Delta v \leq 3t$ for prices to be positive. The consumer surplus is given by

$$CS^{I,E} = \int_0^{x^*} (v - p_H^* - ty)dy + \int_{x^*}^1 (v_I - p_I^* - t(1-y))dy = \frac{(v_I - v_H)^2 + 18t(v_I + v_H) - 45t^2}{36t}$$

□

Proof of Lemma 3

Proof. The monopolist will extract the entire surplus from the indifferent consumer, located at x. Then, it must be the case that $v_H - p_H - tx = v_I - p_I - t(1-x) = 0$, which implies $p_H = v_H - tx$ and $p_I = v_I - (1-t)x$. Thus, the problem is to choose the location of the indifferent consumer

$$\max_{0 \leq x \leq 1} (v_H - tx)x + (v_I - t(1-x))(1-x).$$

The objective function is concave, so the first order condition results in

$$x^* = \frac{2t - \Delta v}{4t}.$$

Note that x^* is always less than 1 and $x^* \geq 0$ if $\Delta v \leq 2t$. The equilibrium prices are

$$p_H^* = \frac{v_I + 3v_H - 2t}{4}, \quad p_I^* = \frac{3v_I + v_H - 2t}{4}$$

which are positive then $3v_H + v_I \geq 2t$. The equilibrium profit for the multi-product monopolist is

$$\pi = \frac{(v_I - v_H)^2 + 4t(v_I + v_H) - 4t^2}{8t}$$

The consumer surplus in multi-product monopolist case is $CS^{I,m} = \frac{(v_I - v_H)^2 + 4t^2}{16t}$. □

Proof of Lemma 4

Proof. The consumer that is indifferent between these products is located at

$$x = \frac{1}{2} + \frac{p_I}{2t} - \frac{v_I - v}{2t}.$$

Thus, the optimal price of product $\mathcal{I}$ is $p_I^* = \dfrac{t + v_I - v}{2}$, which implies the indifferent consumer locates at $x^* = \frac{3}{4} - \frac{v_I - v}{4t}$ which is always less than 1 and positive when $v_I - v \leq 3t$. The innovator's profit is

$$\pi_I^0 = \frac{(t + v_I - v)^2}{8t}.$$

The consumer surplus when the incumbent does not engage in product hopping is

$$CS^I = \frac{(v_I - v)^2 + 2t(v_I + v) + 12tv - 7t^2}{16t}$$

□

Proof of Lemma 5

Proof. By charging price p_O, the incumbent makes the consumer located at x indifferent between buying $\mathcal{O}$ or not buying it, so $p_O = v - tx$. The monopolist solves

$$\max_{0 \leq x \leq 1} (v - tx)x$$

The solution is $x^* = \frac{v}{2t}$, which is always positive and less than 1 for $v \leq 2t$. The equilibrium price and profit of the monopolist at t=1 are, respectively, $p_O^* = \dfrac{v}{2}$ and $\pi_m = \dfrac{v^2}{4t}$. In this case, consumer surplus is $CS^m = \frac{3v^2}{8t}$. □