IDIOSYNCRATIC MATCHING AND THE ROLE OF DETAILING AND SAMPLING IN PHARMACEUTICAL MARKETS

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ABSTRACT. Pharmaceutical firms spend billions of dollars each year on physician detailing and free samples; yet, their roles as promotional tools are not well understood. We develop a model where the two activities serve complementary roles: detailing informs physicians about drug characteristics while samples help mitigate patients' risk from starting treatment with a drug that may not work for them. Consistent with empirical observations in the literature, we find that detailing is most effective early in a drug's life-cycle and tapers over time. We additionally find that the optimal sample quantity and to which patients they are distributed are dependent on their effectiveness relative to alternatives, their cost, and the firm's market share. Given the complementarity of the two practices, higher detailing rates result in higher sampling rates and vice versa. We conclude with a discussion of the model's implications for marketing managers.

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1. INTRODUCTION

In 1919 Mahon Kline of GlaxoSmithKline pioneered the practice of *sampling* by mailing drug samples directly to physicians across the United States. The practice has since become a major promotional channel for pharmaceutical firms, which spent $5.7 billion on it in 2012 (Cegedim Strategic Data, 2013).[1] Samples are also often provided for beauty products, pet food, and magazines where idiosyncratic tastes make finding the most suitable product match to any particular consumer difficult for consumer and firm alike. This is especially true for pharmaceuticals, where a drug's therapeutic value for a new patient cannot be known in advance. Illustrating the degree of idiosyncrasy in patient-to-drug matches, a senior executive at GlaxoSmithKline made headlines when he revealed that the overwhelming majority of drugs only work for about 30 to 50 percent of patients (BBC, 2003).

Though large, the amount spent on sampling is dwarfed by the amount firms spend on physician *detailing*—the practice of meeting one-on-one with physicians to discuss the firm's products. For instance, approximately $15 billion was spent on detailing in 2012 (Cegedim Strategic Data, 2013), which is about two and half times what was spent on sampling. Despite the heavy use of these promotional channels, there is evidence that firms may not be using them in the most effective way. For example, Bhatia, Hansen, and Krishnamurthi (2006) found that firms can secure a higher return on investment (ROI) by targeting those physicians that see more new patients and, due to the substantial learning effect of detailing, Narayanan, Manchanda, and Chintagunta (2005) found that firms can increase their ROI by concentrating their detailing efforts more at the beginning of

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[1]The value reflects the samples' production and distribution costs. The retail value of the samples provided exceeds $16 billion.

a drug's life cycle. Moreover, little is known about how samples impact physician prescription behavior and how they can most effectively be paired with detailing. Some pharmaceutical firms have considered reducing their levels of sampling believing that doing so will ultimately increase profit (Lurker and Caprara, 2005).

As little is known about the relationship between detailing and sampling or how either practice alters demand, we develop a simple model in which, reflecting the findings of the empirical literature (e.g., Narayanan et al., 2005), detailing is used to inform or educate physicians about the general efficacy of a drug, its contraindications, and side-effects profile and sampling is used to reduce consumer/patient risk inherent in a product that has an uncertain *ex post* value due to idiosyncratic matching. By generating predictions consistent with empirical observations, our model provides new insights into the relationship between the two practices, which will help marketing managers identify how to optimally allocate their resources.

Given the prominence of the two practices in pharmaceutical marketing strategies it is surprising that there are so few theoretical studies that examine either detailing or sampling, let alone the combination of the two. In one example of sampling, Moraga-González (2000) analyzes a more general signaling model of advertising which treats sampling for products such as shampoo as a form of quality revealing advertising and not as a means of risk reduction. In contrast Joseph and Mantrala (2009) take a similar approach as this paper by focusing on the use of samples to mitigate risk but in their model the risk is generated by physicians' diagnostic uncertainty. Samples are provided to determine if the physicians' diagnosis is correct before patients incur a cost of traveling to the pharmacy to buy the drug. However, the authors do not consider the price of the drug, the cost of sampling, or when a firm will find it optimal to provide samples. Moreover, because diagnostic uncertainty instead of idiosyncratic matching drives sampling, all drugs within a particular therapeutic class benefit the same from the practice, which is inconsistent with the sampling variation observed within a drug class.

The most closely related study to this is that by Bala, Bhardwaj, and Chen (2012), who similarly develop a model that incorporates both sampling and detailing. As many physicians have a favorable view of detailing and see it as a way of learning more about specific drugs (Chimonas et al., 2007), Bala et al. model detailing as a way of educating physicians about which specific patients will be a certain match with a drug. In this way, physicians can learn about a patient's match with a drug by being detailed, and if the detailing is insufficient to learn about all patients, then a sample can be used to conduct a trial creating a tradeoff between the two practices; i.e., detailing and sampling represent substitute promotional activities. In the current model, detailing represents the means by which some physicians learn of the *population-level* efficacy of a drug but does not inform physicians of any specific patient's *ex post* match value. This informative effect of detailing increases the number of physicians who are willing to prescribe the drug, but does not reduce the matching risk for individual patients as samples do. This important difference makes the two practices complementary and we believe better reflects the empirical evidence. For example, Montoya et al. (2010) find by informing physicians about drug characteristics, detailing has a long term acquisition effect while sampling generates a short term retention effect by encouraging additional subscriptions for individual patients.

In additional to the differences in the role of detailing and sampling, Bala et al. model patient heterogeneity as a horizontal differentiator, take the market price as given, and exogenously fix the quantity of patients who could benefit from a sample (as do Joseph and Mantrala (2009)). In contrast, in the current model patients are vertically differentiated by illness severity making

the quantity of patients who could benefit the firm by receiving a sample dependent on their out-of-pocket costs, which can be endogenous to the sampling decision. Furthermore, in the current model, the optimal quantity of samples is dependent on the number of physicians who would consider prescribing the drug, which is endogenously determined by the level of detailing.

Although there are only a few theoretical contributions analyzing pharmaceutical detailing or sampling, there is a sizable empirical literature examining various aspects of pharmaceutical choice. Most studies concentrate on problems relating to pharmaceutical quality and learning (e.g., Berndt et al., 2003; Coscelli and Shum, 2004; Crawford and Shum, 2005; Ching, 2010; Ching and Ishihara, 2010). Most relevant to the model of the current paper, Mizik and Jacobson (2004) and Venkataraman and Stremersch (2007) seek to quantify the impact detailing and sampling have on the number of prescriptions physicians write for the drug. Both find a positive effect on the quantity of prescriptions written from both practices while Venkataraman and Stremersch additionally find that the benefit of sampling and detailing is dependent on the drug's effectiveness and side-effect profile, indicating that drug-level characteristics are an important part of the sampling decision. These findings are similar to that of a study by Gönül, Carter, Petrova, and Srinivasan (2001) who explore how detailing and sampling influence prescription choice behavior and conclude that the practices have a mostly informative effect on physicians so do not excessively influence their prescription decisions. Lastly, Narayanan, Manchanda, and Chintagunta (2005) examined the optimality of firms' detailing levels and found that they could improve their ROI by more heavily detailing early in a drug's life-cycle followed by a tapering of their detailing intensity.

The remainder of the paper is organized as follows. Section 2 develops a stylized model of prescription choice. The firm's profit is derived in Section 3. The equilibrium pricing, sampling, and detailing strategies are derived in Section 4. Finally, Section 5 concludes with a discussion of the findings and their implications for marketing managers.

2. THE MODEL

Consider a market where every period a continuum of mass 1 new patients enter wanting to receive treatment for a particular illness. Patients are randomly matched with physicians who diagnose the patient and choose to either prescribe the focal drug that is produced by one firm or some alternative to be described later. All physicians are familiar with the alternative treatment, but only a proportion $\lambda \in (0, 1)$ are sufficiently familiar with the focal drug to consider it as a treatment option.[2] We will refer to a physician that is sufficiently familiar with the drug to consider it as a treatment option as being *informed* and the firm can increase the proportion of informed physicians through detailing. Specifically, the proportion of informed physicians, $\lambda(D)$ is an increasing, concave function of D, the amount of detailing provided to the market. Furthermore, $\lambda(0) > 0$, $\lambda' > 0$, $\lambda'' < 0$ and $\lim_{D\to\infty} \lambda(D) = 1$. Once informed there is no reason to detail the physician again so D represents a stock of detailing that carries over into future periods.[3] Additional detailing d in any period is provided at a cost $k(d)$, in which $k' > 0$ and $k'' > 0$, reflecting the time constraints inherent in detailing a number of physicians in a given period.

Patient i's monetary value for treatment is measured by $\theta_i \in [0, 1]$ and is known by the patient and physician but not the firm. As θ captures the heterogeneity that results from differences in patient illness severity we will refer to θ simply as the illness severity. The severities are uniformly distributed and the firm knows the distribution.

[2]Familiarity means that the physician knows the conditions for which the drug is suitable, the appropriate doses, and its potential contraindications and side effects.

[3]The qualitative insights would not change if the stock of informed physicians was permitted to decay over time.

The efficacy of the drug is defined as a Bernoulli-distributed match probability $\phi \in (0, 1)$ where the drug produces therapeutic value θ_i for patient i in the event of a match and 0 otherwise. Informed physicians know the value of ϕ and the firm cannot select ϕ. Reflecting evidence that patients learn whether they are a match to a drug relatively quickly (Crawford and Shum, 2005), a patient learns if he is a match after the first course of treatment and, reflecting the repeated purchase nature of pharmaceuticals, a patient will require two periods of treatment.[4]

Although many patients are insured, their out-of-pocket cost is still important as nearly half of the amount spent on prescription drugs in the U.S. is out-of-pocket compared to 20% for other healthcare expenditures (U.S. Department of Health and Human Services, Medical Expenditure Panel Survey, 2008) and research has shown that demand is very responsive to even small changes in the out-of-pocket costs (Dunn, 2011). To capture how out-of-pocket costs impact treatment selection (and how detailing and sampling impact the optimal price) we assume that the patient must pay $p_t \geq 0$ in each period t.

Physicians can also prescribe an alternative treatment, which may be another drug or lifestyle change. This alternative produces total net present discounted therapeutic value $\overline{u} \geq 0$. With the alternative, an informed physician has several possible treatment plans: prescribe neither treatment, initiate treatment with one or the other, and, if the patient is not a match either, forgo any further treatment or try the remaining option. To identify the physicians' preferred treatment plans, similar to Bala et al. (2012), we assume physicians have a preference for using the treatment with the highest expected therapeutic value. With this assumption the physician will always prefer either treatment option over not treating the patient allowing us to focus on the physician's selection between treatment options.

Lastly, the firm has a constant marginal cost of production $c > 0$ and, reflecting the fact that sampling directly costs pharmaceutical firms' billions of dollars every year, dispensing samples has a unit cost $s \geq 0$, representing the cost of special packaging and instructions as well as an infrastructure from which samples are dispensed. The additional cost to providing samples can also reflect some inefficiency in physicians' use of samples. For example, the proportion of samples used to subsidize some patients' treatment is not insignificant and those samples will not contribute to a firm's profit and may even decrease it if they cannibalize some demand raising the opportunity cost of providing samples. Though s is assumed to be the same for all physicians, it is a straightforward extension to allow the sampling cost to differ across physicians. The firm's profit is defined in the next section.

3. Firm Profit

3.1. **Profit without Sampling.** Physicians are constrained by the patients' net utility since a patient will likely not fill a prescription if he has an insufficient willingness to pay (Fischer et al., 2010). In consequence, a physician will initiate treatment with the focal drug if and only if patient i's expected utility from doing so is at least as high as that from the alternative treatment; i.e., if and only if

$$\phi(\theta_i - p_t - \delta p_{t+1}) + (1 - \phi)(-p_t + \delta\overline{u}) \geq \overline{u}.$$

[4]It is a straightforward extension to allow for a stochastic number of additional periods of treatment but this does not alter the results. We provide this extension in the appendix.

From this, the marginal patient that is just indifferent between treatments, denoted by $\theta_N(p_t, p_{t+1})$, can be expressed as the θ solving

$$\theta_N(p_t, p_{t+1}) = \overline{u}\left[\frac{1-\delta(1-\phi)}{\phi}\right] + \left[\frac{p_t + \phi\delta p_{t+1}}{\phi}\right]. \tag{1}$$

We focus on the case in which some patients have an insufficient willingness to pay by restricting the parameters such that θ_N has an interior value at the optimal price and where the continuation cutoff—the type who, upon matching with the drug, is indifferent between continuing treatment with the drug or switching to the alternative ($\theta_C(p_{t+1}) = \overline{u} + p_{t+1}$)—is satisfied, otherwise no patient would receive treatment. Types greater than θ_N are referred to as no-sample, inframarginal patients.

To see how risk in the focal drug affects the marginal patient, (1) can be expressed as

$$\theta_N(p_t, p_{t+1}) - p_t - \delta p_{t+1} = \overline{u} + \left[\overline{u}\left(\frac{(1-\phi)(1-\delta)}{\phi}\right) + p_t\left(\frac{1-\phi}{\phi}\right)\right]. \tag{2}$$

The first term on the right-hand side (RHS) is the net expected value of the alternative while the large bracketed term on the RHS represents the extra utility that is needed to overcome the risk of not matching. There are two losses that occur if the drug is not a match. The payment for treatment that has no value and a delay in treatment with the alternative. This term is 0 only when $\phi = 1$. The expected profit from a patient that initiates treatment with the drug at time t can be expressed as $\pi_t^N = (p_t - c) + \phi\delta(p_{t+1} - c)$, where $p_t - c$ is the current period profit and $\delta(p_{t+1} - c)$ is the expected discounted profit from the second period.

The firm's expected profit from a patient that initiates treatment with its drug at time t can be expressed as

$$\pi_t^N = (p_t - c) + \phi\delta(p_{t+1} - c), \tag{3}$$

where $p_t - c$ is the profit in the current period and with probability ϕ the patient will be a match with the drug earning the firm discounted profit $\delta(p_{t+1} - c)$ in the second period.

All informed physicians will prescribe the focal drug to all types $\theta \geq \theta_N(p_t, p_{t+1})$. If the firm has invested in a quantity D_t of detailing by period t then $\lambda(D_t)$ physicians are informed and there will be $\lambda(D_t)(1 - \theta_N)$ patients who initiate treatment at time t. The total expected present discounted profit of the firm can therefore be expressed as

$$E\Pi^N = \sum_{t=1}^{\infty} \delta^{t-1}\{\lambda(D_t)\big(1 - \theta_N(p_t, p_{t+1})\big)\pi_t^N - k(d_t)\}, \text{ where } D_t = \sum_{\tau=1}^{t} d_\tau.$$

3.2. **Profit from Sampling.** The firm's profit from sampling is dependent on which patients receive samples. For example, suppose the firm dispenses $Q < [1 - \theta_N]$ samples to an informed physician. If the physician gives them to no-sample, inframarginal patients, then some revenue will be cannibalized as patients who would have initiated treatment with the drug no longer have to pay for their first course. In this case the firm will have no reason to provide any samples. This issue is reflected in the trade literature; for example, in discussing how samples should be managed Tsang and Rudychev (2006) write: "A much less desirable outcome plays out when the oversampling leads to cannibalization. In this instance, had the physician not been sampled, a script would have been written that the patient would have filled." Profit is also lost when samples are distributed to types below the continuation cut-off as the value of the drug is too low and treatment is terminated or samples are provided again. This balancing act of providing just the right

quantity of samples is summarized nicely by the quote, "If you oversample, you kill your sales, if you undersample, you kill your sales (Best Practices, 2007)."

The only types that may increase the firm's profit by receiving a sample, therefore, are the types between $\theta_C(p_{t+1})$ and $\theta_N(p_t, p_{t+1})$. Even if $\theta_i > \theta_C(p_{t+1})$ patient i may still not find it beneficial to initiate treatment with the drug because of an insufficient reduction in risk. The expected utility for patient i from beginning treatment with the drug with a sample is $\phi(\theta_i - \delta p_{t+1}) + (1-\phi)(\delta\overline{u}) \geq \overline{u}$, and the only types that have higher expected utility are all types greater than $\tilde{\theta}_S(p)$ where

$$\tilde{\theta}_S(p_{t+1}) = \overline{u}\left[\frac{1-\delta(1-\phi)}{\phi}\right] + \delta p_{t+1}. \tag{4}$$

The continuation cut-off $\theta_C(p_{t+1})$ is lower than the $\tilde{\theta}_S(p_{t+1})$ whenever the sample fails to eliminate all of the risk.[5] A sample eliminates the risk of paying for a drug that has no therapeutic value, but it also lowers the total expected cost of treatment. If the price of the drug is sufficiently high relative to the therapeutic value of the alternative, then the sample has the potential to completely eliminate the risk of starting treatment with the drug.

Proposition 1. *A starter sample eliminates the risk of initiating treatment with the sampled drug at time t when $p_t > \overline{u}\left[\frac{(1-\delta)(1-\phi)}{\phi}\right]$ or, equivalently, when $\phi \geq \frac{(1-\delta)\overline{u}}{p_t+(1-\delta)\overline{u}}$.*

Proposition 1 indicates that sampling more effectively reduces risk when patients have higher out-of-pocket costs and is less effective when the value of the alternative is fairly high or the match probability fairly low.

Define $\theta_S(p_{t+1}) = \max\{\theta_C(p_{t+1}), \tilde{\theta}_S(p_{t+1})\}$ and observe that $\theta_S(p_{t+1}) < \theta_N(p_t, p_{t+1})$ for all p_t and p_{t+1}. A physician who is given a limited number of samples maximizes her utility by giving samples to the highest types in the interval $[\theta_S(p_{t+1}), \theta_N(p_t, p_{t+1})]$. When a patient in this interval is a match, he will continue treatment without the need of further samples. Additional samples would either cannibalize some purchases or go to patients who will not purchase the drug otherwise. The firm's revenue is therefore maximized by providing exactly $Q = \theta_N(p_t, p_{t+1}) - \theta_S(p_{t+1})$ samples.[6] The preceding discussion is summarized in the following proposition.

Proposition 2. *A firm maximizes revenue by providing $Q_t^*(p_t, p_{t+1}) = \theta_N(p_t, p_{t+1}) - \theta_S(p_{t+1})$ samples to each informed physician, which they distribute to all patients having type $\theta \in \Theta_S = \left[\theta_S(p_{t+1}), \theta_N(p_t, p_{t+1})\right]$ who initiate treatment with the focal drug first.*

In support of Proposition 2 data from the 2008 Medical Expenditure Panel Survey (MEPS) indicate that samples are much more likely to be provided to new prescribers and that sampling rates are association with differences in drug characteristics (e.g., price and efficacy). For example, 22% of new prescribers for Crestor—the newest and most powerful statin at the time— received a sample while only 12% of new prescribers for Lipitor did.

When a patient having type $\theta_i \in \Theta_S$ is provided a starter sample, the firm's expected profit from that patient is $\pi_t^S = -(c+s) + \phi\delta(p_{t+1} - c)$, where $-(c+s)$ is the period t profit and $\delta(p_{t+1} - c)$ is the discounted expected profit from the second period of treatment. All informed physicians will initiate treatment with the focal drug for all types $\theta_i \geq \theta_N(p_t, p_{t+1})$ without dispensing a

[5] A sample further reduces patient risk if there is a cost for traveling to a pharmacy à la Joseph and Mantrala (2009).

[6] Note that in practice a physician may not be completely efficient with how she distributes samples and provide some to types below θ_S. To account for this potential, c can be interpreted as the average cost of each sample distributed to types between $\hat{\theta}_S$ and $\hat{\theta}_N$ given that additional samples are provided to lower types.

sample and for all types $\theta_i \in \Theta_S$ with a sample. If the firm has invested in a quantity D_t of detailing then there will be $\lambda(D_t)\big(1-\theta_S(p_{t+1})\big)$ patients who initiate treatment at time t with $\lambda(D_t)\big(\theta_N(p_t,p_{t+1})-\theta_S(p_{t+1})\big)$ requiring a sample. The total expected present discounted profit of the firm is

$$E\Pi^S=\sum_{t=1}^{\infty}\delta^{t-1}\big\{\lambda(D_t)\big[\big(1-\theta_N(p_t,p_{t+1})\big)\pi_t^N+\big(\theta_N(p_t,p_{t+1})-\theta_S(p_{t+1})\big)\pi_t^S\big]-k(d_t)\big\},$$

where again $D_t=\sum_{\tau=1}^{t}d_\tau$.

4. Optimal Prices, Sample Quantity, and Level of Detailing

In many cases the price insurers pay for a drug is established via negotiations between the pharmaceutical firm and wholesalers, pharmacies, and pharmacy benefit managers. When not covered, patients are responsible for full payment while covered patients typically pay an amount based on which tier the drug resides in their formulary. Nevertheless, it is still appropriate and useful to model pharmaceuticals as a classic posted price market because as Seget (2003) points out, "Drug prices are [...] determined by competition between rival products, the market size of the drug, the number of substitute products, and the costs of R&D of new products." In short, as with any posted-price market, factors that increase the value of the drug to patients also impact the average wholesale price. In support of this point, Lu and Comanor (1998) find that drugs exhibiting large therapeutic gains have prices two to three times higher while a large number of branded substitutes results in lower launch prices as would be the case in any differentiated product market.

The firm's objective is to maximize profit by choosing to dispense samples and their quantity, the level of detailing, and the price conditioned on the detailing level and sampling decision. The optimal price when the firm does not dispense samples is independent of the proportion of physicians who are informed and, consequently, is time independent (see the proof for Prop. 3). In this case the optimal price, p_N^*, is time-independent and can be expressed as:

$$p_N^*=\frac{1}{2}\left[\frac{\phi-\overline{u}(1-\delta(1-\phi))}{(1+\phi\delta)}+c\right]. \tag{5}$$

It is notable that the optimal price is independent of the detailing level. This follows because detailing expands the market by educating physicians about the drug (e.g., appropriate dosage, contraindications, side effects), but does not alter the willingness to pay of any individual patient as drug matches remain idiosyncratic. However, the optimal level of detailing is time-dependent since the cost of detailing is a function of the amount of detailing provided in the current period while the benefit is a function of both the amount of detailing in the current period and the stock of detailing from previous periods. When the firm invests in detailing it incurs the cost in the current period while increasing the share of informed physicians in all subsequent periods. The optimal level of detailing in period t balances the cost of detailing today with all future benefits and is the $d_{N,t}^*$ solving:

$$\frac{1}{1-\delta}\lambda'(D_t)(1-\theta_N(p_N^*))\pi_N=k'(d_{N,t}^*). \tag{6}$$

The LHS of (6) represents the present discounted marginal benefit, which is the larger number of informed physicians in all future periods, while the RHS is the marginal cost of additional detailing at time t.

As with p_N^*, the optimal price when samples are dispensed, p_S^*, is independent of the proportion of informed physicians (see the proof for Prop. 3) so is time-independent and can be expressed as:

$$p_S^* = \frac{1}{2}\left[\frac{\phi - \overline{u}(1-\delta(1-\phi)) - s}{1+\frac{1}{2}\phi\delta}\right] \tag{7}$$

It is interesting that p_S^* is decreasing with the sample cost s and independent of the marginal cost of production c. This first property follows because fewer samples are needed when prices are lower thus, if the cost of sampling is higher, it is optimal to reduce the number of samples provided, which is achieved with a lower price. Furthermore, p_S^* is independent of the marginal cost because the additional cost of producing more output following a decrease in the price is exactly offset by a reduction in the quantity of samples provided. Lastly, p_S^* also increases with the drug's match probability ϕ and the discount factor δ.

Similar to the no-sample regime, the optimal level of detailing in period t when samples are provided is the $d_{S,t}^*$ solving:

$$\frac{1}{1-\delta}\lambda'(D_t)\big\{(1-\theta_N(p_S^*))\pi_N + (\theta_N(p_S^*) - \theta_N(p_S^*))\pi_S\big\} = k'(d_{S,t}^*). \tag{8}$$

The LHS of (8) again represents the present discounted marginal benefit while the RHS represents the marginal cost of additional detailing at time t.

Before comparing the optimal prices and detailing levels it is important to recognize that any comparison is misleading when the conditions are such that the firm would optimally choose *not* to dispense samples (e.g., the cost of providing samples is so high that the firm's profit is lowered). Sampling is optimal only if those patients who receive a sample generate profit since the firm could always do better by not dispensing samples. From patients who receive a sample, the firm incurs a cost from the sample itself as well as any additional cost to making the sample available and the only profit that the firm earns comes from the patient's second period of treatment. In consequence, sampling will only be profitable if the expected margin from the sampled patient's second period of treatment exceeds these costs; i.e., if and only if $\phi\delta(p_S^* - c) \geq c + s$.

With some manipulation (see the proof for Proposition 3 in the appendix) it can be shown that this condition holds if and only if $p_S^* \geq p_N^*$. In other words, the firm earns a profit on sampled patients if and only if the optimal sampling price is at least as high as the optimal no-sample price. But when $p_S^* > p_N^*$ the total profit from sampling must be higher than that from not sampling since the firm could always set $p_S^* = p_N^*$ and do at least as well as when it does not dispense samples if this were not the case. Sampling allows the firm to optimally charge a higher price and, because it earns more profit in every period, it is optimal to increase the amount of detailing provided in every period as well; i.e., $d_{S,t}^* > d_{N,t}^*$ for all $t \in \{1, 2, \ldots\}$. Furthermore, independent of the sampling decision, the optimal rate of detailing is highest in the early periods and decreases with time as the ability to reach new physicians diminishes; i.e., $d_{k,t}^* > d_{k,t+1}^*$ for $k \in \{S, N\}$ and $t \in \{1, 2, \ldots\}$.

As the firm earns higher profit in every period when dispensing samples the marginal benefit of detailing is higher thus increasing the optimal rate of detailing; i.e., $d_{S,t}^* > d_{N,t}^*$ for all $t \in \{1, 2, \ldots\}$. Both of these effects have been documented in the medical literature. For example, Venkataraman and Stremersch (2007) observe higher detailing levels for more effective drugs, which have higher margins, while Hartung et al. (2010) find sampling increases patient out-of-pocket costs and Boltri, Gordon, and Vogel (2002) find that physicians prescribe a more expensive treatment for hypertension when samples are available. Furthermore, regardless of whether the firm provides samples or not, the optimal rate of detailing is highest in the early periods, as that is

when the marginal benefit of detailing is highest, and decreases with time as the ability to reach new physicians diminishes; i.e., $d^*_{k,t} > d^*_{k,t+1}$ for $k \in \{S, N\}$ and $t \in \{1, 2, \ldots\}$.

Higher profit is the desired outcome for any promotional activity, of course; but what effect does sampling have on the firm's market share? With samples the optimal price is higher, which increases the gap in the quantity demanded between patients given and not given a sample requiring a greater quantity of samples. In balancing this trade-off, the number of patients provided a starter pack of samples exceeds the decrease in the quantity demanded resulting from a higher price for those not provided a sample. That is, the optimal price is not only higher with samples, but so is the firm's market share. The following proposition summarizes all of the findings of this section and represents the main results of this study.

Proposition 3. *The optimal prices when the sampling and no-sampling regimes are respectively defined by (7) and (5) while the optimal levels of detailing in each period are respectively defined by (8) and (6). Dispensing free starter samples is optimal whenever* $p^*_S \geq \frac{1}{\phi\delta}\big[(1+\phi\delta)c + s\big]$ *and when sampling is optimal the optimal price, level of detailing, and market share is higher compared to the no-sampling regime; i.e.,*

(i) $p^*_S > p^*_N$,
(ii) $d^*_{S,t} > d^*_{N,t}$ *for all* $t \in \{1, 2, \ldots\}$,
(iii) $d^*_{k,t} > d^*_{k,t+1}$ *for* $k \in \{S, N\}$ *and* $t \in \{1, 2, \ldots\}$, *and*
(iv) $1 - \theta_S(p^*_S) > 1 - \theta_N(p^*_N)$.

These results highlight the effectiveness of samples as a marketing tool in an industry in which the value of the product to consumers is idiosyncratic and unknown before consumption. Samples allow a firm to increase profit by both expanding its market share and charging a higher price. Although it will want to charge a higher price to maximize profit, it is important to observe that the effectiveness of samples is not dependent on the ability to do so. Even when a firm cannot adjust the price paid by consumers, however, samples allow a firm to increase its market share as long as $\phi\delta(p - c) \geq c + s$, where p is the payment it receives for the drug. Furthermore, because sampling increases a firm's profit by increasing its market share, it remains optimal to conduct a higher level of physician detailing in every period. This follows as a direct corollary to Proposition 3.

Corollary 1. *If the firm cannot adjust patients' out-of-pocket cost* p*, then providing samples allows the firm to cover more of the market,* $1 - \hat{\theta}_S(p) > 1 - \hat{\theta}_N(p)$*, and increase profit when* $p > \frac{1}{\phi\delta}\big[(1+\phi\delta)c + s\big]$*. When samples are optimal, the firm also provides a higher level of detailing in every period; i.e.,* $d^*_{S,t} > d^*_{N,t}$ *for all* $t \geq 1$.

Intuitively, the optimal quantity of samples is increasing with the price consumers must pay but decreasing with the value of the alternative since these directly affect a patient's risk of starting treatment with a drug having an unknown match value. In contrast, the impact of an increase in the match probability ϕ is more nuanced as the match probability has both a direct and indirect effect on the optimal quantity of samples. Holding the price constant, less samples are needed for higher values of ϕ as there is less risk; however, the optimal price is also higher, which increases the risk, requiring more samples. When the optimal price is sufficiently low (e.g., because the value of the alternative treatment is high) the impact of the price increase exceeds that of the reduction in risk resulting in a higher quantity of samples. The following proposition summarizes these comparative statics.

Proposition 4. *The optimal quantity of samples is increasing with the price,* p*, and decreasing with the value of the outside option,* $\overline{u}$*. Furthermore, the optimal quantity of samples is increasing*

with the match probability ϕ when $p_S^* < \frac{1}{2}\left[\frac{1-\delta\overline{u}}{1+\phi\delta}\right]$; otherwise, the optimal quantity of samples are decreasing with the match probability.

These statics results are complementary to the empirical evidence uncovered by Venkataraman and Stremersch (2007) who found that marketing efforts are optimized by considering the characteristics of the drug such as its effectiveness and side-effect profile and not just by considering the market size. The current model indicates that larger markets require more samples, *ceteris paribus*, but it also indicates that marketing managers must consider the drug's characteristics, as well as characteristics of the market, such as the availability of close substitutes and generosity of insurance benefits, when identifying the quantity of samples to provide to physicians.

5. Discussion and Final Remarks

We argue that detailing and sampling serve complementary roles as the promotional benefit of detailing lies with physicians and the promotional benefit of sampling lies with patients. In order to select a particular drug for treatment, physicians must be familiar with a drug's effectiveness, when it is suitable for a particular patient given his personal and illness characteristics, what are the contraindications, and what are the potential side effects. Physicians can gain familiarity with a drug through medical journals and from colleagues, but detailing allows a firm to actively inform and educate a physician about its products, accelerating the rate at which that knowledge is disseminated among physicians. For their part, physicians recognize the educational value of detailing and generally welcome the practice (Chimonas et al., 2007).

In contrast, sampling benefits patients because samples at treatment initiation mitigates some, if not all, of the risk that comes from the uncertain effectiveness of a drug on any specific individual. As a consequence of reducing this risk, samples increase patients' *ex ante* willingness to pay, allowing the firm to increase market share and, when it has the ability to adjust the price paid by patients, set a higher price. Importantly, the model indicates that samples are only effective at increasing profit when given to those marginal patients who would otherwise receive treatment from an alternative because the risk is too high. Consistent with these implications, the majority of samples are provided at the initiation of treatment and only a relatively small proportion of patients initiating treatment are in fact provided samples. We show that sampling rates are directly dependent on the drug's efficacy and the patients' out-of-pocket costs. That the price of the drug matters implies that the optimal sampling rate is also dependent on the availability of a suitable substitute. Because detailing increases the proportion of informed physicians who will prescribe the drug, the overall quantity of samples dispensed rises with the level of detailing. Similarly, when it is optimal to provide samples the firm's profit is also higher, increasing the benefit to additional detailing.

There are several additional implications of these findings for pharmaceutical managers to consider. First, consistent with the simulations performed by Narayanan et al. (2005), the highest ROI on detailing is achieved by concentrating their detailing efforts at product initiation. Similarly, targeting those physicians with the largest number of patients, as is commonly done, will generate the highest returns, but the focus should be on targeting those physicians that are not yet observed to be active prescribers as this suggests they may not yet be suitably familiar with the drug (e.g., have insufficient knowledge about its indications or incorrect beliefs about its effectiveness).

Second, the benefit of samples critically depends on how physicians use them. Though we observe that most samples are given at treatment initiation, the proportion given to those patients to subsidize treatment is not insignificant. This increases the total cost of sampling and has lead some

managers to consider reducing the quantity of samples dispensed (Lurker and Caprara, 2005). However, though physicians may not dispense samples in a manner that is optimal for the pharmaceutical firm, what is important is that the samples generate more revenue from new prescriptions than the cost of the samples given to subsidize treatment. Reducing the number of samples provided to these physicians may negatively impact profit by reducing the number of new prescriptions while the quantity of patients subsidized remains constant. Nevertheless, if the firm has a fixed budget allocated to sampling, it should focus on giving samples to those physicians that use them to generate the most new prescriptions. As Bhatia et al. (2006) argue, those physicians that see more new patients who have not ever been treated for the relevant illness will likely generate the highest returns. Similarly, physicians that see more insured patients may generate the largest returns to sampling since these physicians will likely utilize fewer samples as a means to subsidize some patients' treatment.

Related to the argument above, a third implication of the model is that a physician's patient insurance status should be considered when leaving samples. As the out-of-pocket costs for a patient with more generous insurance benefits will be lower, the optimal quantity of samples is also lower. Likewise, if the drug lies in a higher formulary for many patients or many patients have no prescription drug benefits, then proportionally more samples are optimal; not because more patients need to have their treatment subsidized, but because the risk of initiating treatment with the drug is higher.

Though the model generates many important insights on the roles of detailing and sampling, there are additional avenues of research that would enrich our understanding of the two promotional channels. For instance, it would be beneficial to identify how willing physicians are to try new treatments. For example, there is evidence that less experienced physicians are more likely to alter their treatment choice when samples are provided (Boltri et al., 2002; Rabin, 2007). Does this reflect a status quo bias by older physicians who may have a higher relative opportunity cost for prescribing a new treatment when they have years of experience with a different treatment? Examining sampling differences between physicians of varying experience levels within and across medical disciplines in which there is variation in the rate in which practice standards change will likely provide significant insights into how physician characteristics relate to sampling rates.

REFERENCES

Bala, R., P. Bhardwaj, and Y. Chen (2012). Offering pharmaceutical samples: The role of physician learning and patient payment ability. *Marketing Science 32*(3), 522–527.

BBC (2003, December). Drugs 'don't work on many people'. last accessed Sept. 17th, 2014.

Berndt, E., R. Pindyck, and P. Azoulay (2003). Consumption externalities and diffusion in pharmaceutical markets: Anitulcer drugs. *Journal of Industrial Economics 51*(2), 243–270.

Best Practices (2007). *Best Practices for Pharmaceutical Sales Success*. Best Practices, LLC.

Bhatia, T., K. Hansen, and L. Krishnamurthi (2006). Modeling key drivers of physician's choice of prescription drugs: An integrated view incorporating patient and physician heterogeneity. ISBM Report 5-2006.

Boltri, J. M., E. R. Gordon, and R. L. Vogel (2002). Effect of antihypertensive samples on phyisician prescribing habits. *Family Medicine 34*(10), 729–731.

Cegedim Strategic Data (2013). 2012 u.s. pharmaceutical promotion spending. Technical report, Cegedim.

Chimonas, S., T. A. Brennan, and D. J. Rothman (2007). Physicians and drug representatives: Exploring the dynamics of the relationship. *Journal of General Internal Medicine 22*(2), 184–190.

Ching, A. (2010). Consumer learning and heterogeneity: Dynamics of demand for prescription drugs. *International Journal of Industrial Organization 28*, 619–638.

Ching, A. and M. Ishihara (2010). The effects of detailing on prescribing decisions. *Quantatative Marketing and Economics 8*, 123–165.

Coscelli, A. and M. Shum (2004). An emprical model of learning and patient spillovers in new drug entry. *Journal of Econometrics 122*, 213–246.

Crawford, G. S. and M. Shum (2005). Uncertainty and learning in pharmaceutical demand. *Econometrica 73*(4), 1137–1173.

Dunn, A. (2011). Drug innovations and welfare measures computed from market demand: The case of anti-cholesterol drugs. Bureau of Economic Analysis Working Paper.

Fischer, M. A., M. R. Stedman, C. Vogeli, W. H. Shrank, M. A. Brookhart, and J. S. Weissman (2010). Primary medication non-adherence: Analysis of 195,930 electronic prescriptions. *Journal of General Internal Medicine 25*(4), 284–290.

Gönül, F. F., F. Carter, E. Petrova, and K. Srinivasan (2001). *Journal of Marketing 65*(3), 79–90.

Hartung, D. M., D. Evans, D. G. Haxby, D. F. Kraemer, G. Andeen, and L. J. Fagnan (2010). Effect of drug sample removal on prescribing in a family practice clinic. *Annals of Family Medicine 8*(5), 402–409.

Joseph, K. and M. Mantrala (2009). A model of the role of free drug samples in physicians' prescription decisions. *Marketing Letters 20*, 15–29.

Lu, Z. J. and W. S. Comanor (1998). Strategic pricing of new pharmacueticals. *The Review of Economics and Statistics 80*(1), 108–118.

Lurker, N. and B. Caprara (2005, February 1). The sampling subsidy. *Pharmaceutical Executive*.

Mizik, N. and R. Jacobson (2004). Are physicians "easy marks"? quantifying the effects of detailing and sampling on new prescriptions. *Management Science 50*(12), 1704–1715.

Montoya, R., O. Netzer, and K. Jedidi (2010). Dynamic allocation of pharmaceutical detailing and sampling for long-term profitability. *Marketing Science 29*(5), 909–924.

Moraga-González, J. L. (2000). Quality uncertainty and informative advertising. *International Journal of Industrial Organization 18*, 615–640.

Narayanan, S., P. Manchanda, and P. K. Chintagunta (2005). Temporal differences in the role of marketing communication in new product categories. *Journal of Marketing Research 42*(3), 278–290.

Rabin, R. C. (2007, May). Free drug samples? bad idea, some say. *New York Times*.

Seget, S. (2003). Pharmaceutical pricing strategies: Optimizing returns throughout r&d and marketing. Technical report, Reuters.

Tsang, J.-P. and I. Rudychev (2006). The sample equation. *Medical Marketing and Media February*, 53–58.

Venkataraman, S. and S. Stremersch (2007). The debate on influencing doctor's decisions: Are drug charateristics the missing link? *Management Science 53*(11), 1688–1701.

APPENDIX A. MATHEMATICAL PROOFS

PROOF OF PROPOSITION 1

A sample is equivalent to paying the patient p_t to initiate treatment with the drug. Fraction $(1-\phi)$ of the p_t covers the risk that the patient pays for a treatment with no therapeutic value, leaving ϕp_t to cover the risk from delaying treatment with the alternative, which is $(1-\delta)(1-\phi)\overline{u}$. Finding when ϕp_t exceeds the risk of delayed treatment with the alternative yields the result.

PROOF OF PROPOSITION 2

Most of the proposition is proven in the text preceding it. To complete the proof we just need to verify that $\theta_S(p_{t+1}) < \theta_N(p_t, p_{t+1})$ for all p_t, p_{t+1} and for all $\phi < 1$. When $\theta_S(p_{t+1}) \neq \theta_C(p_{t+1})$ then $\theta_N(p_t, p_{t+1}) - \theta_S(p_{t+1}) = p_t/\phi > 0$. When $\theta_S(p_{t+1}) = \theta_C(p_{t+1})$ then $\theta_N(p_t, p_{t+1}) - \theta_S(p_{t+1}) \geq 0$ is trivially satisfied since $\theta_N(p_t, p_{t+1}) \geq \theta_C(p_{t+1})$ by assumption.

PROOF OF PROPOSITION 3

We start y deriving the optimal prices. Although the period $t-1$ demand is a function of the period t price the period t price is the price that maximizes the present discounted profit in period t only. This is because the firm cannot commit to a period t price in period $t-1$ since once in period t the firm will set the price that optimizes profit in that period. This distinction is important because it means that it is inappropriate to take the first order condition of $E\Pi^N$ and $E\Pi^S$ with respect to p_t to find the optimal period t price as that only represents the optimal price on the condition that the firm commits to that price in advance. With this in mind, the period t first-order conditions for $E\Pi^N$ and $E\Pi^S$ are, respectively:

$$\lambda(D_t)\left[1-\overline{u}\left(\frac{1-\delta(1-\phi)}{\phi}\right)-\frac{2}{\phi}\left(p_t+\phi\delta p_{t+1}\right)+\frac{1}{\phi}(1+\phi\delta)c\right]=0, \tag{A-1}$$

$$\lambda(D_t)\left[1-\overline{u}\left(\frac{1-\delta(1-\phi)}{\phi}\right)-\frac{2}{\phi}\left(p_t+\phi\delta p_{t+1}\right)+\delta p_{t+1}-\frac{1}{\phi}s\right]=0. \tag{A-2}$$

With these first order-conditions the optimal period t prices for all t can be respectively expressed as

$$p_t=\frac{1}{2}\big[\phi-\overline{u}(1-\delta(1-\phi))+(1+\phi\delta)c\big]-\phi\delta p_{t+1}, \tag{A-3}$$

$$p_t=\frac{1}{2}\big[\phi-\overline{u}(1-\delta(1-\phi))-s-\phi\delta p_{t+1}\big]. \tag{A-4}$$

In both cases the period t price is a function of the period $t+1$ price. We can substitute in future prices to yield

$$\begin{aligned} p_t &= \lim_{T\to\infty}\left\{\sum_{\tau=0}^{T}(-\phi\delta)^{\tau}(\frac{1}{2}\big[\phi-\overline{u}(1-\delta(1-\phi))+(1+\phi\delta)c\big]-(\phi\delta)^T p_T\right\} \\ &= \frac{1}{2}\left[\frac{\phi-\overline{u}(1-\delta(1-\phi))}{1+\phi\delta}+c\right], \end{aligned} \tag{A-5}$$

$$\begin{aligned} p_t &= \lim_{T\to\infty}\left\{\sum_{\tau=0}^{T}(-\frac{1}{2}\phi\delta)^{\tau}\frac{1}{2}\big[\phi-\overline{u}(1-\delta(1-\phi))-s\big]-(\frac{1}{2}\phi\delta)^T p_T\big]\right\} \\ &= \frac{1}{2}\left[\frac{\phi-\overline{u}(1-\delta(1-\phi))-s}{1+\frac{1}{2}\phi\delta}\right]. \end{aligned} \tag{A-6}$$

As (A-5) and (A-6) hold for any p_t these are the optimal no-sample and sampling prices in all periods.

Another way to get to achieve this result is to recognize that because each p_t is a function of p_{t+1} and the problem has an infinite horizon it must be the case that $p_t = p_s$ for all $t, s \geq 1$. The optimal prices can then be found by letting $p = p_t = p_{t+1}$ in (A-3) and (A-4) and solving for p. Doing this yields (A-5) and (A-6) as well. Lastly, it is straightforward to show that the second order conditions are strictly negative so that p_N^* and p_S^* are global maximizers.

Next, we show that $p_S^* > p_N^*$ when sampling is optimal. First recall that sampling is optimal if and only if the firm earns positive profit on the sampled patients, which it does whenever $\phi\delta(p_S^* - c) > c + s$.

$$\begin{aligned}
& & \phi\delta(p_S^* - c) &> c + s \\
\iff & & \phi\delta\left(\tfrac{1}{2}\left[\tfrac{\phi - \overline{u}(1-\delta(1-\phi)) - s}{1+\frac{1}{2}\phi\delta}\right] - c\right) &> c + s \\
\iff & & \phi\delta\tfrac{1}{2}\left(\tfrac{\phi - \overline{u}(1-\delta(1-\phi)) - s}{1+\frac{1}{2}\phi\delta}\right) - s &> (1+\phi\delta)c \\
\iff & \phi\delta\tfrac{1}{2}\big(\phi - \overline{u}(1-\delta(1-\phi)) - s\big) - (1+\tfrac{1}{2}\phi\delta)s &> (1+\tfrac{1}{2}\phi\delta)(1+\phi\delta)c \\
\iff & (1+\phi\delta)\big(\phi - \overline{u}(1-\delta(1-\phi)) - s\big) &> (1+\tfrac{1}{2}\phi\delta)\big[\big(\phi - \overline{u}(1-\delta(1-\phi))\big) + (1+\phi\delta)c\big] \\
\iff & & \tfrac{1}{2}\left[\tfrac{\phi - \overline{u}(1-\delta(1-\phi)) - s}{1+\frac{1}{2}\phi\delta}\right] &> \tfrac{1}{2}\left[\tfrac{\phi - \overline{u}(1-\delta(1-\phi))}{1+\phi\delta} + c\right] \\
\iff & & p_S^* &> p_N^*.
\end{aligned}$$

Next we will prove that $d_{S,t}^* \geq d_{N,t}^*$ for all $t \geq 1$ by induction. Start with the first period. The firm's first-order conditions for the no-sample and sampling regimes respectively give

$$k'(d_{N,1}^*) = \frac{1}{1-\delta}\lambda'(d_{N,1}^*)\big(1 - \theta_N(p_N^*)\big)\pi^N, \tag{A-7}$$

$$k'(d_{S,1}^*) = \frac{1}{1-\delta}\lambda'(d_{S,1}^*)\big[(1 - \theta_N(p_S^*))\pi^N + \big(\theta_N(p_S^*) - \theta_S(p_S^*)\big)\pi^S\big]. \tag{A-8}$$

Because $\big[(1 - \theta_N(p_S^*))\pi^N + \big(\theta_N(p_S^*) - \theta_S(p_S^*)\big)\pi^S\big] > \big(1 - \theta_N(p_N^*)\big)\pi^N$ we have $d_{S,1}^* > d_{N,1}^*$.

Next, for arbitrary $t > 1$ we have first-order conditions

$$k'(d_{N,t}^*) = \frac{1}{1-\delta}\lambda'(D_{N,t-1}^* + d_{N,t}^*)\big(1 - \theta_N(p_N^*)\big)\pi^N, \tag{A-9}$$

$$k'(d_{S,t}^*) = \frac{1}{1-\delta}\lambda'(D_{S,t-1}^* + d_{S,t}^*)\big[(1 - \theta_N(p_S^*))\pi^N + \big(\theta_N(p_S^*) - \theta_S(p_S^*)\big)\pi^S\big], \tag{A-10}$$

Suppose $D_{N,t-1}^* < D_{S,t-1}^*$ subject to $\lambda'(D_{N,t-1}^*)\big(1 - \theta_N(p_N^*)\big)\pi^N < \lambda'(D_{S,t-1}^*)\big[(1 - \theta_N(p_S^*))\pi^N + \big(\theta_N(p_S^*) - \theta_S(p_S^*)\big)\pi^S\big]$. Then $d_{S,t}^* > d_{N,t}^*$ because the concavity of λ implies that $\lambda'(D_{N,t-1}^* + d)\big(1 - \theta_N(p_N^*)\big)\pi^N < \lambda'(D_{S,t-1}^*)\big[(1 - \theta_N(p_S^*))\pi^N + \big(\theta_N(p_S^*) - \theta_S(p_S^*)\big)\pi^S\big]$ for all d. Thus $D_{N,t}^* < D_{S,t}^*$ and $\lambda'(D_{N,t}^*)\big(1 - \theta_N(p_N^*)\big)\pi^N < \lambda'(D_{S,t}^*)\big[(1 - \theta_N(p_S^*))\pi^N + \big(\theta_N(p_S^*) - \theta_S(p_S^*)\big)\pi^S\big]$ and $d_{S,t+1}^* > d_{N,t+1}^*$. Finally, as $D_{N,1}^* < D_{S,1}^*$ and $\lambda'(D_{N,1}^*)\big(1 - \theta_N(p_N^*)\big)\pi^N < \lambda'(D_{S,1}^*)\big[(1 - \theta_N(p_S^*))\pi^N + \big(\theta_N(p_S^*) - \theta_S(p_S^*)\big)\pi^S\big]$ it must be the case that $d_{S,t}^* > d_{N,t}^*$ for all t.

The condition $d_{k,t}^* > d_{k,t+1}^*$ for $k \in \{S, N\}$ and $t \in \{1, 2, \ldots\}$ follows from the fact that $\lambda(D_t)$ is concave. As a consequence $\lambda'(D_{k,t-1} + d_{k,t}) > \lambda'(D_{k,t} + d_{k,t+1})$ and $k'(d_{k,t}^*) > k'(d_{k,t+1}^*)$ thus $d_{k,t} > t_{k,t+1}$ for $k \in \{S, N\}$ and $t \in \{1, 2, \ldots\}$.

Finally, we show that $1-\theta_S(p_S^*) > 1-\theta_N(p_N^*)$, or equivalently, that $\theta_N(p_N^*) > \theta_S(p_S^*)$.

$$\begin{aligned}
& \theta_N(p_N^*) && > \theta_S(p_S^*) \\
\iff \quad & \tfrac{1+\phi\delta}{\phi} p_N^* && > \delta p_S^* \\
\iff \quad & (1+\phi\delta)p_N^* && > \phi\delta p_S^* \\
\iff \quad & \phi - \overline{u}(1-\delta(1-\phi)) + (1+\phi\delta)c && > \tfrac{\phi\delta}{1+\frac{1}{2}\phi\delta}\big(\phi - \overline{u}(1-\delta(1-\phi)) - s\big) \\
\iff \quad & (1+\tfrac{1}{2}\phi\delta)\big[\big(\phi - \overline{u}(1-\delta(1-\phi))\big) + (1+\phi\delta)c\big] && > \phi\delta\big(\phi - \overline{u}(1-\delta(1-\phi)) - s\big) \\
\iff \quad & \underbrace{(1-\frac{1}{2}\phi\delta)}_{>0}\underbrace{\big(\phi - \overline{u}(1-\delta(1-\phi))\big)}_{>0} && > -\underbrace{\big[(1+\frac{1}{2}\phi\delta)(1+\phi\delta)c + \phi\delta s\big]}_{>0}.
\end{aligned}$$

PROOF OF COROLLARY 1

If the firm cannot adjust the price then $p_S = p_N = p$ and $\hat{\theta}_N(p) > \hat{\theta}_S$ if and only if $p > 0$. The result that $d_{S,t}^* > d_{N,t}^*$ follows directly from Proposition 3.

PROOF OF PROPOSITION 4

First note that $Q^* = \theta_N(p_S^*) - \theta_S(p_S^*) = p_S^*/\phi$. The first static $\frac{dQ^*}{dp} > 0$ follows immediately and $\frac{dQ^*}{d\overline{u}} = \frac{1}{\phi}\frac{dp_S^*}{d\overline{u}} < 0$. Lastly,

$$\begin{aligned}
\frac{dQ^*}{d\phi} &= \frac{\partial Q^*}{\partial p}\frac{dp_S^*}{d\phi} + \frac{\partial Q^*}{\partial \phi} \\
&= \frac{1}{\phi}\frac{dp_S^*}{d\phi} - \frac{p_S^*}{\phi^2} \\
&= \frac{1}{\phi}\frac{1}{2}\left[\frac{(1-\delta\overline{u})(1+\frac{1}{2}\phi\delta) - \frac{1}{2}\delta(\phi - \overline{u}(1-\delta(1-\phi)))}{(1+\frac{1}{2}\phi\delta)^2}\right] - \frac{p_S^*}{\phi^2} \\
&= \frac{1}{\phi}\frac{1}{2}\left[\frac{(1-\delta\overline{u})(1+\frac{1}{2}\phi\delta)}{(1+\frac{1}{2}\phi\delta)^2}\right] - p_S^*\left[\frac{1}{\phi^2} + \frac{\frac{1}{2}\delta}{\phi(1+\frac{1}{2}\phi\delta)}\right] \\
&= \frac{1}{\phi}\frac{1}{2}\left[\frac{1-\delta\overline{u}}{1+\frac{1}{2}\phi\delta}\right] - p_S^*\left[\frac{1+\phi\delta}{\phi(1+\frac{1}{2}\phi\delta)}\right] \qquad \text{(A-11)}
\end{aligned}$$

From (A-11) $\frac{dQ^*}{d\phi} > 0$ whenever

$$p_S^* < \frac{1}{2}\left[\frac{1-\delta\overline{u}}{1+\phi\delta}\right],$$

and ≤ 0 otherwise.

APPENDIX B. MODEL EXTENSION TO STOCHASTIC LENGTH OF TREATMENT

In this appendix we modify the model so that patients are potentially ill for many periods, not just two and derive the optimal prices to show that the insights of the paper hold. The optimal level of detailing is not affected.

Instead of just two periods of treatment we assume that after every period they are ill and are receiving treatment with probability $\gamma > 0$ they will require an additional period of treatment. In this way the expected number of treatment periods is $1/(1-\gamma)$.

As in the main model, a physician will not initiate treatment with the focal drug if the patient's *ex post* utility is lower than the outside option, so focusing on those types who could benefit from the focal drug, a physician will initiate treatment with the focal drug if patient i's expected utility from doing so is at least as high as that from initiating treatment with the alternative treatment; i.e.,

it is optimal for the physician to initiate treatment with the focal drug at time t if:

$$\phi(\theta_i - Ep_t) + (1-\phi)(-p_t + \delta\overline{u}) \geq \overline{u}, \tag{C-1}$$

where Ep_t is the patient's expected present discounted out-of-pocket costs for the treatment when the patient is a match; i.e., $Ep_t = \sum_{\tau=0}^{\infty}(\gamma\delta)^\tau p_{t+\tau}$.

By rearranging (C-1), the marginal patient can be denoted by $\theta_N(p_t)$, where $\theta_N(p_t)$ is defined as the θ solving

$$\theta_N(p_t) = \overline{u}\left[\frac{1-\delta(1-\phi)}{\phi}\right] + \left[\frac{p_t + \phi\sum_{\tau=1}^{\infty}(\gamma\delta)^\tau p_{t+\tau}}{\phi}\right]. \tag{C-2}$$

We focus on the case in which some patients have an insufficient willingness to pay by restricting the parameters such that θ_N has an interior value at the optimal price. All types greater than θ_N are referred to as no-sample, inframarginal patients as these types will not need a sample to initiate treatment with the drug.

The firm's expected profit from a patient that initiates treatment with its drug at time t without a sample can be expressed as

$$\pi_t^N = (p_t - c) + \phi\sum_{\tau=1}^{\infty}(\gamma\delta)^\tau(p_{t+\tau} - c). \tag{C-3}$$

All informed physicians will prescribe the focal drug to all types $\theta \geq \theta_N(p)$. If the firm invests in a quantity d_t of detailing then $\lambda(d_t)$ physicians are informed and there will be $\lambda(d_t)(1-\theta_N)$ patients who initiate treatment at time t. The total expected present discounted profit of the firm at time t can therefore be expressed as

$$E\Pi^N = \sum_{t=1}^{\infty}\delta^{t-1}\{\lambda(D_t)\big(1-\theta_N(p_t)\big)\pi_t^N - k(d_t; D_{t-1})\}. \tag{C-4}$$

The arguments for which patients increase the firm's profit when given a sample continue to hold and from (**??**), the only types that have a higher expected utility starting treatment with the drug are all types greater than $\tilde{\theta}_S(p)$ where

$$\tilde{\theta}_S(\mathbf{p}_t) = \overline{u}\left[\frac{1-\delta(1-\phi)}{\phi}\right] + \sum_{\tau=1}^{\infty}(\gamma\delta)^\tau p_{t+\tau}. \tag{C-5}$$

The change in model has no impact on Propositions 1 and 2. When a physician provides a starter sample in period t to a patient having type $\theta_i \in [\theta_S(\mathbf{p}_t), \theta_N(\mathbf{p}_t))$, the firm's expected profit off of that patient can be expressed as

$$\pi_t^S = -(c+s) + \phi\sum_{\tau=1}^{\infty}(\gamma\delta)^\tau(p_{t+\tau} - c). \tag{C-6}$$

All informed physicians will initiate treatment with the focal drug for all types $\theta_i \geq \theta_N(\mathbf{p}_t)$ without dispensing a sample and for all types $\theta_i \in [\theta_S(\mathbf{p}_t), \theta_N(\mathbf{p}_t))$ with a sample. If the firm invests in a quantity d_t of detailing then $\lambda(D_t)$ physicians are informed and there will be $\lambda(D_t)\big(1-\theta_S(p_t)\big)$ patients who initiate treatment at time t with $\lambda(D_t)\big(\theta_N(\mathbf{p}_t) - \theta_S(\mathbf{p}_t)\big)$ requiring a sample. The total expected present discounted profit of the firm at time t can therefore be expressed as

$$E\Pi^S = \sum_{t=1}^{\infty}\delta^{t-1}\big\{\lambda(D_t)\big[\big(1-\theta_N(\mathbf{p}_t)\big)\pi_t^N + \big(\theta_N(\mathbf{p}_t) - \theta_S(\mathbf{p}_t)\big)\pi_t^S\big] - k(d_t; D_{t-1})\big\}. \tag{C-7}$$

Given the new expressions for $E\Pi^N$ and $E\Pi^S$ the optimal no-sample and sampling prices in period t are the prices respectively satisfying the following first-order conditions

$$\lambda(D_t)\left[1-\overline{u}\left(\frac{1-\delta(1-\phi)}{\phi}\right)-\frac{2}{\phi}\left(p_t+\phi\sum_{\tau=1}^{\infty}(\gamma\delta)^{\tau}p_{t+\tau}\right)+\frac{1}{\phi}\left(1+\phi\sum_{\tau=0}^{\infty}(\gamma\delta)^{\tau}\right)c\right]=0,$$

$$\lambda(D_t)\left[1-\overline{u}\left(\frac{1-\delta(1-\phi)}{\phi}\right)-\frac{2}{\phi}\left(p_t+\phi\sum_{\tau=1}^{\infty}(\gamma\delta)^{\tau}p_{t+\tau}\right)+\sum_{\tau=1}^{\infty}(\gamma\delta)^{\tau}p_{\tau}-\frac{1}{\phi}s\right]=0.$$

From these first order-conditions the optimal period t prices for all t can be respectively expressed as

$$= \frac{1}{2}\left[\frac{\phi-\overline{u}(1-\delta(1-\phi))}{1+\frac{\phi\gamma\delta}{1-\gamma\delta}}+c\right], \tag{C-8}$$

$$p_S^* = \frac{1}{2}\left[\frac{\phi-\overline{u}(1-\delta(1-\phi))-s}{1+\frac{1}{2}\left[\frac{\phi\gamma\delta}{1-\gamma\delta}\right]}\right]. \tag{C-9}$$

Finally, showing that $p_S^* > p_N^*$ and that $d_{S,t}^* > d_{N,t}^*$ both follow similarly to before.