Vertical Interactions in the U.S. Pharmaceutical Supply Chain in the Presence of a Generic Substitute

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A Thesis
In the Department of
Economics

Presented in Partial Fulfillment of the Requirements
For the Degree of
Master of Arts (Economics)

at Concordia University
Montréal, Québec, Canada

April 2024

CONCORDIA UNIVERSITY
School of Graduate Studies

This is to certify that the thesis prepared

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and submitted in partial fulfillment of the requirements for the degree of

Master of Arts (Economics)

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Abstract

This paper builds upon prior work on vertical interactions in the drug supply chain in the United States. There is limited research to date seeking to model these vertical relationships, particularly in the presence of generic substitute availability. We begin with a model based on Conti et al. (2021), where two branded drug manufacturers compete for preferred formulary placement by offering rebates to a monopolist pharmacy benefit manager (PBM), and add a generic drug whose price is non-negotiable. Additionally, we allow for consumer heterogeneity in terms of willingness to sacrifice perceived quality in exchange for cost savings when deciding between a branded or generic drug. We show that an equilibrium exists whereby the PBM sets the copayment for the generic drug higher than that of the preferred brand in exchange for higher rebates and examine how the incentives produced by the formulary contest may lead PBMs to discourage generic uptake.

Acknowledgements

I would first like to acknowledge and thank my thesis supervisor, Dr. Jan Victor Dee, who encouraged me to trust my judgment while steering me in the right direction and pushing me to improve upon my work to the best of my ability. I am grateful for his patience and guidance whenever I faced challenges and uncertainty. This accomplishment would not be possible without his willingness to share his time and knowledge.

I would also like to acknowledge Dr. Ming Li. I wrote the first iteration of this paper for his Industrial Organization course, and his feedback helped give me the confidence to continue pursuing this research. Additionally, I would like to thank the Department of Economics for giving me the opportunity to deepen my knowledge of and appreciation for economics. I am grateful for the dedication of each professor and TA from whom I have the opportunity to learn, as well as for the administrative staff and Grad Program Director, Dr. Christian Sigouin, who work tirelessly to support the department and ensure that students have the resources they need to succeed.

I would like to thank my partner, Cedric, for being a constant source of encouragement and support, audience for my presentation rehearsals, and occasional economics student during my study sessions. I would also like to thank my parents for supporting my academic pursuits and always encouraging my curiosity from a young age. Finally, I would like to thank the friends I've made at Concordia; all the studying, bouncing ideas off of each other, and celebrating our successes together has made my experience all the more worthwhile and helped motivate me through even the most challenging semesters.

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1 Introduction

The pharmaceutical supply chain in the United States is characterized by complex negotiations between many parties, the results of which are often unknown to policymakers, insurers, and consumers. Figure 1 provides an overview of the pharmaceutical supply chain. At the center of many of these negotiations are pharmacy benefit managers, or PBMs. The main service provided by PBMs is the development of formularies via negotiation with drug manufacturers to obtain discounted prices for branded drugs.

A formulary is a list of drugs covered under an insurance policy, which includes both tiers categorizing different drugs and copayment amounts associated with each tier. Copayments represent the cost-sharing amount of the consumer; the insurer, who contracts with the PBM for access to the formulary, covers the remaining cost. The most common arrangement is a 3- or 4-tiered formulary, where tier 1 contains generic drugs, tier 2 contains "preferred" branded drugs, tier 3 contains "non-preferred" branded drugs, and tier 4 contains specialty drugs. Our model focused on the 3-tiered formulary. Typically, copayments increase with tiers in order to steer consumers toward less expensive, better value treatment, such that generics cost less than all branded drugs and "preferred" branded drugs cost less than "non-preferred" branded drugs. Our model does not assume the generic copayment to be lower than that of the preferred brand, as our primary goal is to explore whether PBMs may be incentivized to adopt a formulary design in which the generic drug is placed on a higher-cost tier than its branded equivalent.

The U.S. healthcare industry as a whole has experienced increased vertical integration in the last several decades, and this has been especially the case for PBMs. The so-called "Big Three" PBMs processed 80% of all equivalent prescription claims in 2021 (Fein 2022). These three major firms are all the result of mergers between various PBMs and major MCOs, or Managed Care Organizations, whose main role is to provide health insurance. While our model does not seek to address vertical integration, this context is important motivation for our research.

Research on these vertical interactions has emerged relatively recently, which has added to the difficulty faced by antitrust authorities such as the Federal Trade Commission and legislators in assessing the potential and actual impacts of mergers and regulations. The complexity and opacity of the pharmaceutical supply chain have remained a source of controversy and a barrier to research. PBMs have maintained that transparency laws requiring disclosure of the rebates they receive or reimbursement prices they charge to insurers and pharmacies will reduce their ability to negotiate lower prices.

A frequent claim by PBMs is that they aim to promote generic substitution. However,

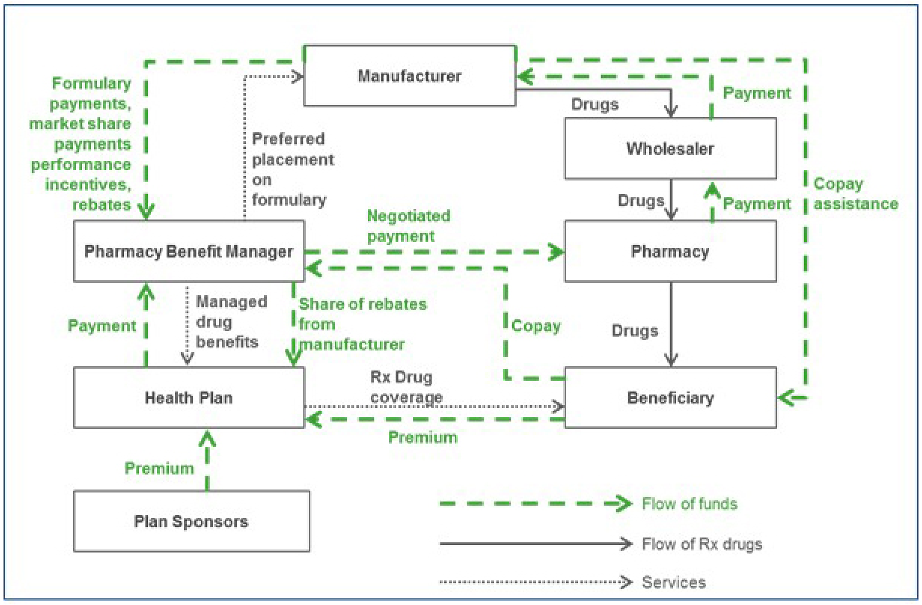

Figure 1: Diagram highlighting the vertical structure of the pharmaceutical supply chain including the flows between each participant (Sood et al. 2017)

studies have observed increases in generic copayment or coinsurance costs for consumers and the exclusion of lower-priced generics from formularies (Egilman et al. 2018). A study by Avalere, a healthcare consulting firm, found that the placement of generic drugs on generic tiers under Medicare Part D plans declined from 65% in 2016 to 43% in 2022, with 57% of covered generic drugs being placed on non-preferred tiers in 2022 (Fix et al. 2022). This paper examines the conditions under which consumers may face higher copayments for generic drugs than for branded drugs.

Our paper does not seek to model every actor in the pharmaceutical supply chain, such as wholesalers and pharmacies. Instead, we focus on a model whereby two branded drug manufacturers who face competition from a generic substitute compete for preferred tier placement on a monopolist PBM's formulary. Upon deciding the drug tier placements and copayment amounts, the PBM then offers its formulary to a monopolist insurance company. Finally, consumers decide whether to purchase insurance and, subsequently, whether to purchase a drug. We build on Conti et al. (2021) to understand several key interactions/decisions in the supply chain in the context of generic substitute availability:

1. **Branded Manufacturer–PBM relationship**: Two branded manufacturers compete for preferred tier placement by choosing discounted prices to offer to the PBM. The PBM selects which of the two drugs is preferred and which is non-preferred and sets copayment prices for each branded drug and the generic drug.

2. **PBM–Insurer relationship**: The PBM offers its formulary to the insurance company, which decides whether to contract with the PBM. The PBM can pass on a portion of the rebate from the branded drug manufacturers to the insurer. The insurer then sets the premium paid by its enrollees.

3. **Consumer Insurance and Drug Demand**: Consumers decide whether to purchase health insurance when they are healthy. They subsequently develop an illness that corresponds to one of the three drugs and choose whether to purchase the drug. Some consumers are able to switch between the drugs without any adverse effects and choose to do so based on not only the cost of the drug but also the ratio of cost savings to perceived quality sacrifice.

Our main contribution is the addition of a generic drug for which consumers have heterogeneous preferences. Whether a consumer opts to purchase the generic drug over a branded drug depends on the relative importance of cost savings versus perceived quality for the individual. The addition of heterogeneity in drug preferences in our model results in an equilibrium in which the copayment of the generic drug is set higher than that of the preferred branded drug. We find that the results of Conti et al. (2021) regarding the tradeoff between the preferred branded copayment and the non-preferred branded copayment hold for our model, such that the preferred tier copayment is always set to zero and the non-preferred tier copayment is always set to the list price for the branded drugs in equilibrium. Our key result is the establishment of an additional tradeoff faced by PBMs between maximizing generic substitution and minimizing net prices offered by the branded drug companies. We find in equilibrium that the PBM sets the generic copayment equal to the generic list price and thus on a more expensive tier than the preferred branded drug.

The remainder of this paper is organized as follows: Section 2 provides an overview of the literature modeling vertical interactions in the drug supply chain; Section 3 introduces the model setup; Section 4 discusses the theoretical results of the model and provides numerical examples and analysis of the effect of various exogenous parameters on the model results; Section 5 concludes by discussing the implications of our results and potential extensions of our model.

2 Literature Review

Brot-Goldberg, Che, and Handel (2022) give an overview of the emerging body of literature on vertical relationships in the pharmaceutical supply chain. Lack of transparency has posed a challenge for both empirical and theoretical research on the role played by PBMs and the impacts of vertical integration on competition and consumer welfare. There is a scarcity of publicly available data on the rebates PBMs receive from drug manufacturers, the pass-through of rebates to insurers, the reimbursement rates for insurers and pharmacies, or the administrative fees charged for PBM services. The PBM industry has long argued that transparency will jeopardize their negotiating power.

Despite these challenges, the authors show that modeling is possible and present the results of a game theoretic model of each interaction within the supply chain. They first solve the model via backward induction given two competing branded drug manufacturers, two competing insurance companies, and one PBM that offers its services to both insurers. Next, they solve the model with the PBM integrated with one of the insurers. They find that compared to the unintegrated case, integration can raise the rival insurer's costs, favoring the merged insurer over its competitor. The unmerged insurer receives fewer rebates from pass-throughs and raises premiums, while the opposite is true for the merged insurer. Drug manufacturer profits increase when the insurers' bargaining power is low, as integration leads to a larger downstream market due to lower premiums.

Several earlier papers have sought to model these vertical relationships. Conti et al. (2021) seeks to explain the role of rebates in the delivery of PBM services, modeling rebates as bids in a contest whereby drug manufacturers seek to obtain favorable formulary positions for their drugs. Again, using a game theoretic model, the authors derive equilibrium rebates, copayments associated with each formulary tier, and profit-maximizing rules used by PBMs to determine which drugs are preferred and non-preferred. They find that formularies are efficiency enhancing compared to direct sales by manufacturers to consumers at list price; however, the PBM captures the surplus generated by the formulary. The authors focus on most favored nation guarantees as a contracting externality. If a PBM designs its formulary "aggressively" by raising copays or restricting the number of branded drugs, it can obtain lower net prices. These prices are guaranteed to other PBMs who have MFN clauses. However, this means an individual PBM's copay choice has less influence on drug prices, so PBMs will set copays in the favored tier above marginal cost, reducing efficiency gains. Finally, they solve the model with endogenous list prices, finding that PBMs may be biased toward higher list prices as they increase the value of participating in the formulary, leading to upward pressure on list prices for branded drugs. Their model suggests that vertical integration between a PBM and an insurer can enhance efficiency and encourage generic usage. The authors do not address potential anticompetitive effects and suggest that this is an area for future research.

The 1990s saw a trend in vertical integration between PBMs and manufacturers, followed by a period of divestiture following the Federal Trade Commission's scrutiny of three mergers in 1993-94 (Burns, Cassak, and Longman 2022).[1] These mergers occurred in response to the rapid rise in the market share of PBM formularies in the early 1990s. Drug manufacturer Merck initially declined to contract with Medco, but changed its strategy after losing significant market share to a competitor willing to offer aggressive price discounts, ultimately determining that acquiring Medco would lead to gains in market share and ensure placement of its drugs on formularies. Lilly and SKB sold their PBMs shortly after the FTC reviewed the Lilly-PCS merger and determined that PCS would have to maintain an open formulary and accept discounts offered by other manufacturers to avoid the formulary favoring Lilly's drugs.

Today, the trend has been toward mergers between PBMs and health insurers or "managed care organizations" (MCOs), which may offer insurance services in addition to their own PBM services. The FTC's controversial approval in 2012 of a merger between Express Scripts, one of the "Big Three" PBMs, and Cigna, an MCO/health insurer, highlights the complexity of the industry and the difficulty of defining the relevant set of competitors pre- and post-merger. For further background on the FTC's investigation of the Express Scripts/Cigna merger, see Lafontaine et al. (2019).

It is worth highlighting that despite the trend of the 1990s, little work has been done to model PBM-manufacturer mergers. However, Kouvelis, Xiao, and Yang (2018) contributed to this area of the literature by modeling the pricing behavior of branded drug manufacturers selling to a common PBM and the vertical integration between a PBM and a drug manufacturer. In their model, the branded drug manufacturers decide the effective wholesale price of a drug in the first stage, while the PBM sets copays for each of the two drugs and the effective resale price, which is the reimbursement price, or the wholesale price minus a portion of the rebate, paid by the insurer. The consumer's decision is characterized by a multinomial logit model in which copay and quality vary for each drug in a class of drugs that includes a generic, preferred branded, and non-preferred branded drug with generic copays lower than branded copays.

Whereas Conti et al. (2021) model rebates offered by manufacturers, Kouvelis, Xiao, and Yang (2018) model wholesale prices and, thus, do not capture the per-unit spread between the wholesale or list price and the net price after rebate. The authors find that the market expansion index, which measures the extent of the PBM's market size expansion with respect to aggregate attraction of all drugs, plays a critical role in pricing decisions and profits of the manufacturers and the PBM. They suggest that unless vertical integration is associated with

1. Merck acquired Medco for $6 billion in 1993. In 1994, SmithKlineBeecham (SKB) acquired Diversified Pharmaceutical Services (DPS) for $2.3 billion and Eli Lilly acquired PCS Health Systems, then the largest PBM in the U.S. in terms of individuals covered, for $4.1 billion.

a sufficient increase in the market size, social welfare decreases due to profit loss from non-integrated manufacturers, assuming sufficiently low price sensitivity of the PBM's market size. Under high price sensitivity, the elimination of double marginalization expands the PBM's market size and leads to higher social welfare. Our paper is similar in that we explore price sensitivity as a contributing factor in the ability of the PBM to obtain higher rebates.

3 Model Setup

Our model is an adaptation of the baseline model developed by Conti et al. (2021). In our model, there are two branded drugs and one generic drug. These drugs are perfect substitutes for a fixed share of the population; however, consumers may perceive quality differences in the drugs. Manufacturers compete for preferential tier assignment by offering rebates off the exogenous list price to a single PBM. The PBM selects the tier assignments and copayment rates for each tier, as well as a reimbursement rate to be paid by the insurer for each drug. The contribution of our paper is the addition of a generic drug to the model and heterogeneous consumer preferences with respect to branded versus generic drugs, which enables us to examine how the PBM's incentives to obtain rebates may influence generic copayments and tier placement and, thus, discourage generic uptake.

We assume that all consumers respond well to at least one drug, such that each drug has a non-overlapping one-third of the population as its base. In other words, one-third of consumers respond well to brand 1, one-third of consumers respond well to brand 2, and the remaining one-third of consumers respond well to the generic drug. To represent drug substitutability, we assume that a fraction $\tau \in [0, 1]$ of the population can substitute between all three drugs, as their condition responds equally well to each drug. The remaining $(1 - \tau)$ cannot substitute, as their condition responds well to only one drug. Thus, $\tau = 1$ indicates the drugs are perfect substitutes for the entire population.

We introduce a variable $\alpha \in [0, 1]$, which represents the drug choice of those who can substitute between the three drugs. This allows us to introduce unobserved heterogeneity in consumer preferences, which corresponds with observed data on generic uptake (Shrank et al. 2009). Without this variable, all patients who can switch to a generic will do so with or without insurance, provided the generic copayment is lower than that of the branded drugs; the results would be identical to those of the case of m drugs as modeled in Conti et al. (2021).

We first define a ratio of cost savings to quality sacrifice as modeled by Rizzo and Zeckhauser (2009):

$$\frac{p_i - p_0}{Q_i - Q_0} = \lambda_i^*, \tag{1}$$

where p_i and p_0 are the prices paid by the consumer for branded drug $i \in \{1, 2\}$ and the generic drug, respectively, and Q_i and Q_0 represent the perceived quality of the branded drug and the generic drug. λ_i^* represents the threshold value where the consumer is indifferent between buying the branded drug and the generic drug. We define λ_j as the consumer type, which allows us to account for heterogeneity in consumer preferences. Thus, if $\lambda_j \geq \lambda_i^*$, consumer j will choose branded drug i over the generic drug and, if $\lambda_j < \lambda_i^*$, the consumer will choose the generic drug.

We define α_i as the fraction of consumers within τ who choose branded drug i over the generic drug. In other words, $\alpha_i = \sum_j Pr(\lambda_j \geq \lambda_i^*)$. Thus, α_i represents the proportion of those for whom the drugs are perfect substitutes who decide not to switch to the generic drug due to the cost savings being too low relative to the perceived quality difference.

We expect that as the price differential, Δp_i, increases, all else equal, the threshold value, λ_i^*, will increase, resulting in a decrease in α_i. Similarly, as the quality differential, ΔQ_i, increases, all else equal, the threshold value will decrease, resulting in an increase in α_i. The magnitude of the change in α_i depends on the distribution of λ_j. This result is intuitive, as one would expect that as the price of a branded drug increases relative to that of a generic drug, more consumers will be willing to switch to the generic drug. On the other hand, if the perceived quality of the branded drug rises relative to that of the generic drug, fewer people will choose the generic.

We assume that consumers are uncertain about the quality of the drugs. In a dynamic setting, one could imagine that consumers would learn by comparing the effectiveness of each drug such that perception of quality would match reality. Factors such as advertising by branded manufacturers may lead to different values of the perceived quality differential. However, our paper does not look at the implications of the quality differential and instead focuses on the cost differential. For example, for a low-income population, one would expect the average λ_j to be lower, such that the cost differential is relatively more important to consumers. In other words, λ_j is more likely to fall below the threshold value, so more generics are purchased.

We assume that $Q_1 = Q_2$ for simplification. Since consumers perceive the two branded drugs to be of equal quality by assumption, and the non-preferred brand will always cost more to the consumer than the preferred brand by the design of the tiered formulary, it follows that no consumer will choose the non-preferred drug over the identical quality, cheaper preferred brand. Thus, the consumer choice for those who are able to substitute is reduced to a choice between the preferred brand and the generic drug. Going forward, we use α to represent those consumers within τ who choose the preferred branded drug and $1-\alpha$ to represent those who choose the generic drug. We also simplify λ_i^* to λ^*. We will use α_0 and λ_0^* to refer to the values of α and λ^* given list prices, i.e., in the absence of the formulary. In other words, all consumers with the ability to substitute will switch from the more expensive non-preferred brand to either the cheaper preferred or generic drug, depending on their individual preferences for quality versus cost-savings. In the absence of the formulary, consumers will either switch to the generic drug or choose the branded drug that corresponds to their condition, as the branded drugs are identical in list price and perceived quality.

Figure 2 below shows the breakdown of the consumer population based on which drug, brand A, brand B, or the generic (G), corresponds to their condition; substitutability between the drugs, where τ represents the fraction for whom all three drugs work equally well; and the drug choice, where α represents the fraction of consumers within τ who choose the preferred branded drug over the generic. As an example, we take drug A to be the preferred branded drug and drug B to be non-preferred. The subsets in red, blue, and violet represent the consumers who choose brand A, brand B, and the generic, respectively. The relative consumer shares of the generic and preferred branded drug depend on α, but the model results in a smaller consumer share for the non-preferred branded drug, irrespective of α.

The term "consumer share" is defined as the share of the population, including those who cannot substitute, that chooses each respective drug, with the total population of consumers normalized to 1. This is distinct from "market share," which is dependent on the functional form of consumer demand. Consumer demand is denoted $q(p)$ and is the cdf of the severity of the consumer's illness, denoted by random variable V, such that $q(p) := Pr(V > p)$. The illness severity is independent of the type of illness, drug substitutability, and preference for cost savings versus quality sacrifice.

3.1 Drug Manufacturers

Two branded drug manufacturers, denoted $i \in \{1, 2\}$, each produce a drug of the same class. Additionally, a generic substitute is available. The list price for a drug is denoted $\bar{p}_i$ for $i \in \{0, 1, 2\}$, where $i = 0$ represents the generic drug. List prices are exogenous and we assume that $\bar{p}_0 = \delta\bar{p}_1 < \bar{p}_1 = \bar{p}_2$ where $\delta \in (0, 1)$. Copayment amounts are set to c_g for the generic drug, c_p for the branded drug on the preferred tier, and c_n for the branded drug on the non-preferred tier, such that $c_p < c_n$ and $c_g < c_n$. We do not restrict c_g to being less than c_p. As we will show, the PBM may, in fact, price the generic drug higher than the preferred brand due to the incentives produced by the formulary contest.

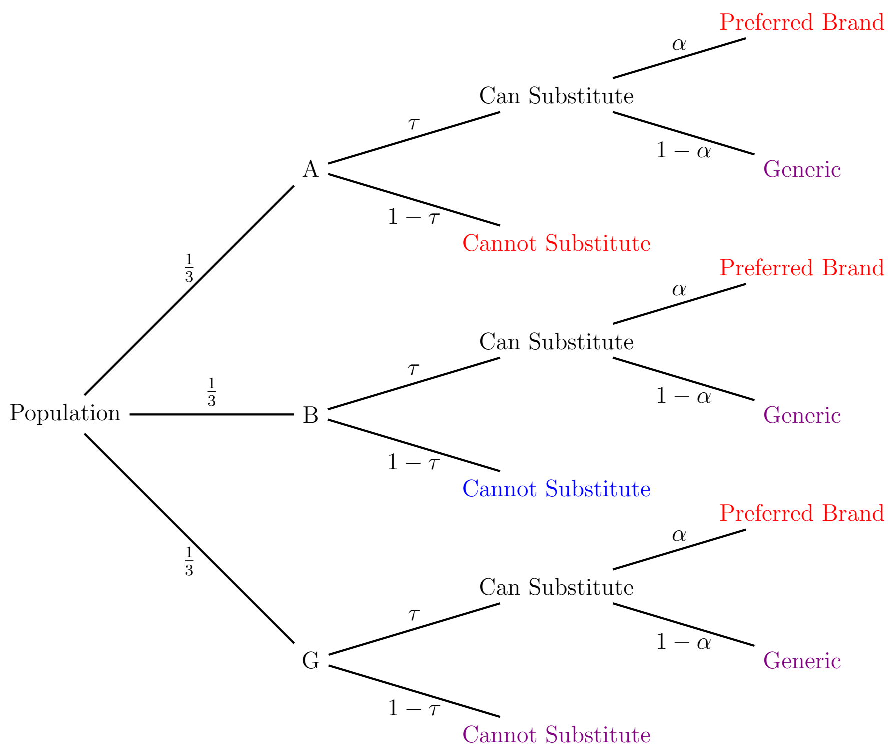

Figure 2: Consumer shares of each drug based on drug compatibility and substitutability

Drug manufacturers compete for placement on the preferred tier by offering a per-unit rebate to the PBM such that the PBM pays the net price $p_i \leq \bar{p}_i$. The PBM does not negotiate with the generic drug manufacturer; thus, we assume the net price of the generic drug is $p_0 = \bar{p}_0$. Drug manufacturers choose net prices to maximize profit, given by

$$\pi_i = \begin{cases} \left(\frac{1}{3}(1-\tau) + \tau\alpha\right) p_i q(c_p) & \text{if } i \text{ is preferred,} \\ \frac{1}{3}(1-\tau) p_i q(c_n) & \text{if } i \text{ is not preferred.} \end{cases}$$

The copayment can affect the demand for branded drugs in two ways. First, a higher copayment, c_i, results in a decrease in $q(c_i)$, as consumers with lower willingness to pay choose not to purchase the drug. Second, a higher preferred brand copayment, c_p, results in a decrease in α, as more consumers switch to the generic drug. Thus, tier placement affects manufacturer profit not only via the direct effect of the copayment on quantity demanded but also via the relative value of the drug as a determinant of drug substitution.

3.2 PBMs

The PBM pays the net price to each drug manufacturer and charges the insurer a reimbursement price, r_i, for drug $i \in \{0, 1, 2\}$. The reimbursement price may exceed the net price. In other words, the rebate may not be fully passed through to the insurer. The consumer and insurer each pay a portion of the reimbursement price. The consumer pays the copayment amount to the PBM, and the insurer pays the difference between the reimbursement rate and the copayment.

The PBM designs the formulary by deciding the tier assignment for each branded drug and the copay amounts for each tier: generic, preferred brand, and non-preferred brand. The copayment amount for branded drug i is denoted c_i. If drug i is assigned to the preferred tier, $c_i = c_p$. Otherwise, $c_i = c_n$.

The PBM chooses copays, tier assignments, and reimbursement rates to maximize profit, given by

$$\pi_{PBM}(a, r_0, r_1, r_2; p_0, p_1, p_2) =$$
$$\begin{cases} \left(\frac{1}{3}(1-\tau) + \tau(1-\alpha)\right) q(c_g)(r_0 - p_0) + \left(\frac{1}{3}(1-\tau) + \tau\alpha\right) q(c_p)(r_1 - p_1) + \frac{1}{3}(1-\tau)q(c_n)(r_2 - p_2) & \text{if } a = 1, \\ \left(\frac{1}{3}(1-\tau) + \tau(1-\alpha)\right) q(c_g)(r_0 - p_0) + \left(\frac{1}{3}(1-\tau) + \tau\alpha\right) q(c_p)(r_2 - p_2) + \frac{1}{3}(1-\tau)q(c_n)(r_1 - p_1) & \text{if } a = 2, \end{cases}$$

where $a \in \{1, 2\}$ denotes which branded drug is placed on the preferred tier.

3.3 Insurers

The insurer sets its premium, P, to maximize its profit, given by:

$$\begin{aligned} \pi_{ins}(P; c_g, c_p, c_n, r_0, r_a, r_{-a}) =& P - \left(\frac{1}{3}(1-\tau) + \tau(1-\alpha)\right) q(c_g)(r_0 - c_g) \\ & - \left(\frac{1}{3}(1-\tau) + \tau\alpha\right) q(c_p)(r_a - c_p) - \frac{1}{3}(1-\tau)q(c_n)(r_{-a} - c_n), \end{aligned}$$

where subscripts a and $-a$ denote which branded drug is preferred and which is not preferred, respectively.

3.4 Consumers

Consumers decide whether to purchase health insurance when they are healthy and may choose to purchase one of the three drugs when sick.

A medical condition $D \in \{0, 1, 2\}$ manifests with $\Pr(D = i) = \frac{1}{3}$ for $i \in \{0, 1, 2\}$. In other words, each consumer's condition corresponds to one of the three drugs, but a fraction of consumers, τ, may switch between all three.

Consumers who choose to enroll in the insurance plan pay a premium P to access the formulary. Consumers can choose to purchase drugs off the formulary at list price $\bar{p}_i$ whether or not they opted to enroll in insurance. If purchasing through the formulary, the consumers for whom the drugs are not substitutable pay the copay for whichever drug corresponds to their condition. Of those consumers who can substitute between drugs, $(1-\alpha)$ of consumers whose condition corresponds to each respective drug will opt to purchase the generic drug at price c_g, and α will purchase the preferred branded drug at price c_p.

In the absence of a formulary, α_i is the fraction of individuals, j, in τ for whom:

$$\lambda_i^* = \frac{\bar{p} - \delta \bar{p}}{Q_i - Q_0} \leq \lambda_j. \tag{2}$$

The assumptions that $Q_1 = Q_2$ and $\bar{p}_1 = \bar{p}_2$ imply that $\alpha_1 = \alpha_2 = \alpha$. When purchasing through the formulary, this condition becomes

$$\lambda_a^* = \frac{c_p - c_g}{Q_a - Q_0} \leq \lambda_j \tag{3}$$

for the drug on the preferred tier and

$$\lambda_{-a}^* = \frac{c_n - c_g}{Q_{-a} - Q_0} \leq \lambda_j \tag{4}$$

for the drug on the non-preferred tier. Taken together with the assumptions that $c_p < c_n$ and $c_g < c_n$, these two conditions imply that $\alpha_a > \alpha_{-a}$, since the cost differential is always higher for the non-preferred drug, while the quality differential is the same for both drugs. Consumers do not consider λ_{-a}, as it never makes sense to purchase the non-preferred drug over the preferred drug. The decision is always between the preferred brand and the generic, as mentioned in the previous section, and we thus use α to refer to α_a.

Depending on the parameter δ and the equilibrium copayments, α may increase or decrease relative to its value in the absence of a formulary. For example, if $\bar{p} = \$50$ and $\delta = 0.5$, the cost differential without insurance is \$25. If the PBM sets $c_p = \$20$ and $c_g = \$0$, the cost differential is now \$20, meaning the threshold value, λ^*, is lower and α increases, resulting in less substitution to the generic drug. In other words, the decision to purchase a drug is not based solely on the price of the drug and its substitutability; rather, consumers also value different drugs based on the cost savings they can obtain relative to the perceived quality sacrifice.

Consumers seek to maximize utility when choosing whether to purchase insurance. Expected utility without insurance is the value, in terms of illness severity, of purchasing the drug at list price:

$$U_0 = \left(\frac{1}{3}(1-\tau) + \tau(1-\alpha_0)\right) E[(V - \bar{p}_0)1(V > \bar{p}_0)] + \left(\frac{2}{3}(1-\tau) + \tau\alpha_0\right) E[(V - \bar{p})1(V > \bar{p})],$$

where $1(\cdot)$ is the indicator function and $\bar{p} = \bar{p}_1 = \bar{p}_2$. Expected utility with insurance is $U_1 - P$, where U_1 is the option value of purchasing a drug through the formulary, which is a weighted average of the respective values of the generic drug, the preferred branded drug, and the non-preferred branded drug:

$$
\begin{aligned}
U_1 = &\left(\frac{1}{3}(1-\tau) + \tau(1-\alpha)\right) E[(V - min\{c_g, \bar{p}_0\})1(V > min\{c_g, \bar{p}_0\})] \\
&+ \left(\frac{1}{3}(1-\tau) + \tau\alpha\right) E[(V - min\{c_p, \bar{p}\})1(V > min\{c_p, \bar{p}\})] \\
&+ \frac{1}{3}(1-\tau)E[(V - min\{c_n, \bar{p}\})1(V > min\{c_n, \bar{p}\})].
\end{aligned}
$$

3.5 Timing

The timing of the model is identical to that of Conti et al. (2021) and is as follows:

1. the PBM offers a contract to the insurer whereby the insurer delegates formulary operation to the PBM in exchange for a payment of π_0 from the PBM; the insurer chooses whether to accept the PBM contract;
2. the PBM chooses the formulary copays, c_g, c_p, and c_n;
3. the branded drug manufacturers set net prices p_1 and p_2; the generic list price, $\bar{p}_0$ is taken as given by the PBM;
4. the PBM assigns the branded drugs to formulary tiers and sets reimbursement prices r_0, r_1, and r_2;
5. the payer sets the premium P;
6. consumers decide whether to purchase insurance;
7. consumers draw their preference parameter, λ_j, and nature chooses the consumer's medical condition, D, its severity, V, and whether the consumer can substitute between the drugs;
8. consumers decide whether to purchase the drug.

3.6 Discussion of Model Assumptions

As in Conti et al. (2021), we assume that each drug manufacturer offers the PBM a price that applies whether or not the drug is assigned to the preferred tier rather than contingent prices based on whether the drug is placed on the preferred or non-preferred tier; hence, in equilibrium, the manufacturers choose a price that will net them the same profit whether or not they are placed on the preferred tier.

We assume all consumers are identical in terms of health status prior to purchasing insurance in order to avoid adverse selection. In Conti et al. (2021), this assumption ensures the PBM fully extracts all consumer surplus by maximizing the value of insurance and capturing the higher premiums set by the insurer.

We assume all consumers are risk neutral. However, we note that an individual's quality preference might be correlated with risk preference. Thus, introducing heterogeneity into the model may imply heterogeneity in risk preferences. For example, a consumer who is extremely sensitive to perceived quality differences between branded and generic drugs, i.e., has a smaller value of λ_j, may be more risk averse. It may be the case that more risk averse individuals are more likely to choose a branded drug for which they have seen advertisements over a generic drug for which they have less information. This does not necessarily affect our model results: for those who are more risk averse, the value of insurance would be higher.

For our simulation of model results in section 5, we assume λ is normally distributed. While the distribution of λ should not affect the theoretical results of the model, the distribution likely varies for different drugs or populations. For example, Rizzo and Zeckhauser (2009) posit that consumers may be more likely to perceive greater quality differences or be more sensitive to quality when treating more serious conditions. Thus, the distribution of λ is likely different for different classes of drugs. The authors also hypothesize that those who purchase more generics would have lower, positive values of λ_j. One could imagine that, for a lower-income group of consumers, λ may not be normally distributed or may be skewed. This suggests that the effectiveness of the PBM in reducing net prices depends on the distribution of λ.

4 Model Results

We solve the model via backward induction. First, consumers decide whether to purchase insurance while healthy, taking list prices, copayments, tier assignments, and the insurance premium as given. Consumers decide whether to purchase a drug, taking list prices, copayments, tier assignments of the branded drugs, their enrollment decision, medication condition D and its intensity V, drug substitutability, and preferences toward branded drugs as given.

Consumers purchase a drug if the cost, either the copay or the list price if paying off the formulary, is less than their willingness to pay for the drug, V. Consumers enrolled in insurance purchase off the formulary only if the list price for their chosen drug is less than the copay. Additionally, consumers who can substitute purchase the preferred brand if the ratio of the price difference to quality difference between the preferred brand and generic, λ^*, is less than their willingness to pay for quality improvement, λ_j. The following proposition formalizes this result:

Proposition 1 (Consumer insurance and drug purchase decisions)**.** *In every sub-game perfect Nash equilibrium, drug purchasing and insurance enrollment decisions are as follows. A consumer, j, purchases the generic drug through the formulary if (1) $V \geq c_g$ and $c_g \leq \bar{p}_0$; and (2) either their illness D corresponds to the generic drug and they cannot substitute, or the drugs are substitutable and $\lambda_j < \lambda^*$. A consumer, j, purchases the preferred branded drug through the formulary if (1) $V \geq c_p$ and $c_p \leq \bar{p}$; and (2) either their illness D corresponds to the preferred branded drug and they cannot substitute, or the drugs are substitutable and $\lambda_j \geq \lambda^*$. A consumer, j, purchases the non-preferred branded drug through the formulary if (1) $V \geq c_n$ and $c_n \leq \bar{p}$ and (2) their illness D corresponds to the non-preferred branded drug and they cannot substitute. Consumers enrolled in insurance who do not purchase through the formulary and consumers not enrolled in insurance purchase drug i out of pocket if and only if $D = i$ and $V \geq \bar{p}$. Of these consumers, those who can substitute purchase the generic drug if $\lambda_j < \lambda_0^*$; otherwise, they purchase the branded drug that corresponds with their condition. Consumers enroll in insurance if and only if*

$$P \leq U_1 - U_0. \tag{5}$$

The insurer then chooses the premium such that its profit is maximized, taking reimbursement prices, copayments, and tier assignments as given. Since the insurer's profit is increasing in the premium, the insurer will set the premium such that the consumer enrollment condition is binding, provided profit is non-negative. Otherwise, it will set a higher premium, resulting in zero profits.

Proposition 2 (Insurer's choice of premium)**.** *In every sub-game perfect Nash equilibrium, the insurer sets premium $P = U_1 - U_0$ if*

$$\pi_{ins}(U_1 - U_0; c_g, c_p, c_n, r_0, r_a, r_{-a}) \geq 0 \tag{6}$$

and $P > U_1 - U_0$ otherwise.

The PBM sets reimbursement prices and assigns the branded drugs to tiers to maximize its profit, subject to the constraint that the insurer's profit is non-negative and taking net prices as given. The PBM's profit is increasing in reimbursement prices. The PBM will set r_0, r_1, and r_2 such that the insurer's profit condition binds. This determines only the weighted average of the reimbursement prices, not the individual prices, as the insurer's profit depends only on the weighted average. The PBM maximizes its profit by assigning the drug with the lower net price, or the larger rebate, to the preferred tier.

Proposition 3 (PBM's choice of reimbursement prices and tier assignment for the branded drugs)**.** *The PBM sets reimbursement prices to satisfy*

$$\begin{aligned}&\left(\frac{1}{3}(1-\tau)+\tau(1-\alpha)\right)q(c_g)(r_0)+\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p)(r_1)+\frac{1}{3}(1-\tau)q(c_n)(r_2)=\\&\quad P+\left(\frac{1}{3}(1-\tau)+\tau(1-\alpha)\right)q(c_g)(c_g)+\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p)(c_p)+\frac{1}{3}(1-\tau)q(c_n)(c_n)\end{aligned}\tag{7}$$

if $p_1 \leq p_2$*, and*

$$\begin{aligned}&\left(\frac{1}{3}(1-\tau)+\tau(1-\alpha)\right)q(c_g)(r_0)+\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p)(r_2)+\frac{1}{3}(1-\tau)q(c_n)(r_1)=\\&\quad P+\left(\frac{1}{3}(1-\tau)+\tau(1-\alpha)\right)q(c_g)(c_g)+\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p)(c_p)+\frac{1}{3}(1-\tau)q(c_n)(c_n)\end{aligned}\tag{8}$$

otherwise. The PBM assigns branded drug 1 to the preferred tier (in other words, sets $c_1 = c_p$ *and* $c_2 = c_n$*) if and only if* $p_1 \leq p_2$*.*

Proof. The PBM's profit function can be rewritten as follows:

$$\begin{aligned}\pi_{PBM}(a,r_0,r_1,r_2;p_0,p_1,p_2)=&\left(\frac{1}{3}(1-\tau)+\tau(1-\alpha)\right)q(c_g)(r_0-p_0)\\&+\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p)(r_a-p_a)+\frac{1}{3}(1-\tau)q(c_n)(r_{-a}-p_{-a}),\end{aligned}$$

where branded drug a is the winning drug and $-a$ is the losing drug. Profit is increasing in reimbursement prices; thus, the PBM will set r_0, r_1, and r_2 such that the insurer's zero profit condition binds. The insurer's profit function can be rewritten as follows:

$$\begin{aligned}\pi_{ins}=&P+\left(\frac{1}{3}(1-\tau)+\tau(1-\alpha)\right)q(c_g)(c_g-r_0)+\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p)(c_p-r_a)\\&+\frac{1}{3}(1-\tau)q(c_n)(c_n-r_{-a}),\end{aligned}$$

where drug a is preferred. Setting $\pi_{ins} = 0$, we can rearrange this equation to obtain the weighted average reimbursement price:

$$\begin{aligned}&\left(\frac{1}{3}(1-\tau)+\tau(1-\alpha)\right)q(c_g)(r_0)+\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p)(r_a)+\frac{1}{3}(1-\tau)q(c_n)(r_{-a})=\\&\quad P+\left(\frac{1}{3}(1-\tau)+\tau(1-\alpha)\right)q(c_g)(c_g)+\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p)(c_p)+\frac{1}{3}(1-\tau)q(c_n)(c_n),\end{aligned}$$

as stated in the proposition.

Rearranging π_{PBM}, we obtain

$$\begin{aligned}\pi_{PBM} = &\left(\frac{1}{3}(1-\tau)+\tau(1-\alpha)\right) q(c_g)(r_0) + \left(\frac{1}{3}(1-\tau)+\tau\alpha\right) q(c_p)(r_a) + \frac{1}{3}(1-\tau)q(c_n)(r_{-a}) \\ &- \left(\frac{1}{3}(1-\tau)+\tau(1-\alpha)\right) q(c_g)(p_0) - \left(\frac{1}{3}(1-\tau)+\tau\alpha\right) q(c_p)(p_a) - \frac{1}{3}(1-\tau)q(c_n)(p_{-a}).\end{aligned}$$

Substituting the previous results into the equation:

$$\begin{aligned}\pi_{PBM} =&P + \left(\frac{1}{3}(1-\tau)+\tau(1-\alpha)\right) q(c_g)(c_g) + \left(\frac{1}{3}(1-\tau)+\tau\alpha\right) q(c_p)(c_p) + \frac{1}{3}(1-\tau)q(c_n)(c_n) \\ &- \left(\frac{1}{3}(1-\tau)+\tau(1-\alpha)\right) q(c_g)(p_0) - \left(\frac{1}{3}(1-\tau)+\tau\alpha\right) q(c_p)(p_a) - \frac{1}{3}(1-\tau)q(c_n)(p_{-a})\end{aligned}$$

Collecting the terms:

$$\begin{aligned}\pi_{PBM} =&P + \left(\frac{1}{3}(1-\tau)+\tau(1-\alpha)\right) q(c_g)(c_g-p_0) + \left(\frac{1}{3}(1-\tau)+\tau\alpha\right) q(c_p)(c_p-p_a) \\ &+ \frac{1}{3}(1-\tau)q(c_n)(c_n-p_{-a})\end{aligned}$$

Finally, we can rewrite the PBM's profit function as follows:

$$\pi_{PBM}(a;p_0,p_1,p_2) = P + \begin{cases} \left(\frac{1}{3}(1-\tau)+\tau(1-\alpha)\right) q(c_g)(c_g-p_0) + \left(\frac{1}{3}(1-\tau)+\tau\alpha\right) q(c_p)(c_p-p_1) + \frac{1}{3}(1-\tau)q(c_n)(c_n-p_2) & \text{if } a=1, \\ \left(\frac{1}{3}(1-\tau)+\tau(1-\alpha)\right) q(c_g)(c_g-p_0) + \left(\frac{1}{3}(1-\tau)+\tau\alpha\right) q(c_p)(c_p-p_2) + \frac{1}{3}(1-\tau)q(c_n)(c_n-p_1) & \text{if } a=2.\end{cases}$$

□

Finally, each branded drug manufacturer takes list prices and copayments as given and sets its net price to maximize expected profit, anticipating the tier assignment. Branded drug manufacturer 1's expected profit is

$$\pi_1(p_1;p_2) = \begin{cases} \left(\frac{1}{3}(1-\tau)+\tau\alpha\right) p_1 q(c_p) & p_1 \le p_2, \\ \frac{1}{3}(1-\tau)p_1 q(c_n) & p_1 > p_2.\end{cases}$$

if the insurer's participation condition is satisfied, i.e., the insurer contracts with the PBM, and $\frac{1}{3}((1-\tau)+\frac{3}{2}\tau\alpha_0)\bar{p}q(\bar{p})$ otherwise. Branded drug manufacturer 2's profit is similarly defined. Note that the consumer shares of the two branded drug manufacturers are identical in the absence of a formulary, as we assume identical list prices and perceived quality. These identical branded drug consumer shares need not be identical to that of the generic drug.[2]

Since $\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p) > \frac{1}{3}(1-\tau)q(c_n)$, the branded drug manufacturer's profit will increase as it undercuts the other's net price. The result is that there is no pure strategy equilibrium. The branded drug manufacturers will play a mixed strategy where net prices are drawn from a distribution where, at the lower end of the support, the profit conditional on being assigned to the preferred tier is equal to the profit from setting a maximum price of $\bar{p}$ and being placed on the non-preferred tier. In other words, the profit for the drug manufacturer is identical whether it wins or loses the formulary contest.

Proposition 4 (Drug net price equilibrium distribution)**.** *There is a unique subgame-perfect Nash equilibrium, which is symmetric and involves a continuously mixed net-price strategy. These net-price strategies are characterized by the following distribution, given copays c_g, c_p, and c_n:*

$$F(p; c_g, c_p, c_n) = \begin{cases} 0 & p < \bar{p}\frac{\frac{1}{3}(1-\tau)q(c_n)}{\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p)} \\ \frac{\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p)-\frac{\bar{p}}{p}\frac{1}{3}(1-\tau)q(c_n)}{\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p)-\frac{1}{3}(1-\tau)q(c_n)} & \bar{p}\frac{\frac{1}{3}(1-\tau)q(c_n)}{\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p)} \leq p < \bar{p}, \\ 1 & p \geq \bar{p}. \end{cases} \tag{9}$$

Proof. We proceed similarly to Conti et al. (2021). Drug manufacturers randomize continuously over a closed interval. Let F be the cdf corresponding to drug manufacturer 2's equilibrium strategy. The upper bound of the support is $\bar{p}$ because when the drug manufacturer sets $p = \bar{p}$, it loses the formulary contest with probability one. Further, a drug manufacturer's profit if it loses the formulary contest is maximized at $\bar{p}$. Drug manufacturer 1's expected profit at support point p is

$$E[\pi_1(p)] = (1-F(p))p\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p) + F(p)p\frac{1}{3}(1-\tau)q(c_n).$$

The upper bound of the support is where $F(\bar{p}) = 1$. The equilibrium condition is such that profit must be equal at all points in the support of F, such that there is no unilateral deviation that may increase profit. This means

$$\bar{p}\frac{1}{3}(1-\tau)q(c_n) = (1-F(p))p\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p) + F(p)p\frac{1}{3}(1-\tau)q(c_n).$$

2. In Conti et al. (2021), manufacturer profit in the absence of insurer participation given two branded drugs and exogenous list prices is $\bar{p}q(\bar{p})/2$, since no consumer will substitute given identical list prices. In our model, no consumers will switch between the branded drugs in the absence of a formulary but can switch to the cheaper generic drug from the branded drug corresponding to their condition. However, some consumers who can do so will not switch to the generic drug, provided the condition in equation 2 holds.

Solving this condition for $F(p)$:

$$\bar{p}\tfrac{1}{3}(1-\tau)q(c_n) = p\left(\tfrac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p) - F(p)p\left(\tfrac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p) + F(p)p\tfrac{1}{3}(1-\tau)q(c_n)$$

$$\tfrac{\bar{p}}{p}\tfrac{1}{3}(1-\tau)q(c_n) = \left(\tfrac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p) - F(p)\left(\tfrac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p) + F(p)\tfrac{1}{3}(1-\tau)q(c_n)$$

$$F(p)\left(\tfrac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p) - F(p)\tfrac{1}{3}(1-\tau)q(c_n) = \left(\tfrac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p) - \tfrac{\bar{p}}{p}\tfrac{1}{3}(1-\tau)q(c_n)$$

$$F(p) = \frac{\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p) - \frac{\bar{p}}{p}\frac{1}{3}(1-\tau)q(c_n)}{\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p) - \frac{1}{3}(1-\tau)q(c_n)} \tag{10}$$

The lower bound of the support occurs where F equals zero. Solving for p, we obtain

$$p = \bar{p}\frac{\frac{1}{3}(1-\tau)q(c_n)}{\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p)}.$$

□

Proposition 5 (Effect of copayments on branded drug net price distribution)**.** *The equilibrium net-price distribution is stochastically increasing in c_p and stochastically decreasing in c_g and c_n. The PBM faces a tradeoff between incentivizing generic substitution and reducing net prices. Thus, the PBM may set $c_g > 0$ in equilibrium while maximizing the spread between c_p and c_n.*

Proof. The derivative of the equilibrium net price cdf (equation 9) with respect to c_g is

$$\frac{\partial F(p;c_g,c_p,c_n)}{\partial c_g} = \frac{\left(\frac{\bar{p}}{p}-1\right)\frac{1}{3}(1-\tau)q(c_n)\tau q(c_p)\frac{\partial\alpha(c_g,c_p)}{\partial c_g}}{\left(\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p)-\frac{1}{3}(1-\tau)q(c_n)\right)^2} > 0.$$

The derivative of the cdf with respect to c_p is

$$\frac{\partial F(p;c_g,c_p,c_n)}{\partial c_p} = \frac{\left(\frac{\bar{p}}{p}-1\right)\frac{1}{3}(1-\tau)q(c_n)\left(\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q'(c_p)+\tau q(c_p)\frac{\partial\alpha(c_g,c_p)}{\partial c_p}\right)}{\left(\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p)-\frac{1}{3}(1-\tau)q(c_n)\right)^2} < 0.$$

The derivative of the cdf with respect to c_n is

$$\frac{\partial F(p;c_g,c_p,c_n)}{\partial c_n} = -\frac{\left(\frac{\bar{p}}{p}-1\right)\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p)\frac{1}{3}(1-\tau)q'(c_n)}{\left(\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)q(c_p)-\frac{1}{3}(1-\tau)q(c_n)\right)^2} > 0.$$

□

Our results for the optimal copayments for the branded drugs are similar to Conti et al. (2021). However, in our model, the PBM must navigate the tradeoff between reducing net prices and encouraging generic demand. Although maximizing c_n and minimizing c_p will minimize the net prices offered in equilibrium, decreasing c_p also raises α, as switching to the preferred brand from the generic offers additional savings. Thus, there is a tradeoff between inducing competition between the branded drug manufacturers and incentivizing consumers to purchase generics.

Proposition 6 (Optimal copayments)**.** *Suppose $\bar{p} \leq q^{-1}(0)$ and $c_p < c_g$. Then the profit-maximizing choices of copays are $c_g = \bar{p}_0$, $c_p = 0$, and $c_n = \bar{p}$.*

Proof. The expected profit of the PBM is given by

$$E[\pi_{PBM}(c_g, c_p, c_n)] = TS(c_g, c_p, c_n) - CS - \text{total drug manufacturer profit.}$$

Total surplus is given by

$$\begin{aligned} TS(c_g, c_p, c_n) =& E\left[\left(\frac{1}{3}(1-\tau) + \tau(1-\alpha)\right) 1(V > c_g)V\right] \\ &+ E\left[\left(\frac{1}{3}(1-\tau) + \tau\alpha\right) 1(V > c_p)V\right] \\ &+ E\left[\frac{1}{3}(1-\tau)1(V > c_n)V\right] \end{aligned}$$

where $\alpha = \alpha(c_p, c_g) = \sum_j Pr(\lambda_j \geq \frac{c_p - c_g}{Q_p - Q_g})$. Consumer surplus is given by

$$\begin{aligned} CS =& E\left[\left(\frac{1}{3}(1-\tau) + \tau(1-\alpha_0)\right) 1(V > \bar{p}_0)(V - \bar{p}_0)\right] \\ &+ E\left[\left(\frac{2}{3}(1-\tau) + \tau\alpha_0\right) 1(V > \bar{p})(V - \bar{p})\right] \end{aligned}$$

where $\alpha_0 = \alpha(\bar{p}, \bar{p}_0) = \sum_j Pr(\lambda_j \geq \frac{\bar{p} - \bar{p}_0}{Q - Q_0})$, or the probability of a consumer purchasing either branded drug in the absence of the formulary. Note that consumer surplus does not depend on the PBM's choice of copays. By the proof of Proposition 4, each branded drug manufacturers' expected profit is $\frac{1}{3}(1-\tau)\bar{p}q(c_n)$. Generic drug manufacturer profit is $\left(\frac{1}{3}(1-\tau) + \tau(1-\alpha)\right) \bar{p}_0 q(c_g)$. Thus, total drug manufacturer profit is given by

$$\frac{2}{3}(1-\tau)\bar{p}q(c_n) + \left(\frac{1}{3}(1-\tau) + \tau(1-\alpha)\right) \bar{p}_0 q(c_g).$$

First, we show that the PBM's expected profit is increasing in c_n. Beginning with the total surplus:

$$\begin{aligned}\frac{\partial E[TS(c_g,c_p,c_n)]}{\partial c_n} &= \frac{1}{3}(1-\tau)\frac{\partial}{\partial c_n}E[1(V>c_n)V] \\ &= \frac{1}{3}(1-\tau)\int \frac{\partial}{\partial c_n}1(V>c_n)Vf(V)dV \\ &= -\frac{1}{3}(1-\tau)c_n(-q'(c_n)) \\ &= \frac{1}{3}(1-\tau)c_n q'(c_n)\end{aligned}$$

where the second line follows from the Leibniz Rule and the third line follows from the proof of Proposition 6 in Conti et al. (2021). Therefore, we have that

$$\begin{aligned}\frac{\partial E[\pi_{PBM}(c_g,c_p,c_n)]}{\partial c_n} &= \frac{1}{3}(1-\tau)c_n q'(c_n) - \frac{2}{3}(1-\tau)\bar{p}q'(c_n) \\ &= -(1-\tau)q'(c_n)\left(\frac{2}{3}\bar{p} - \frac{1}{3}c_n\right) > 0\end{aligned}$$

where the resulting inequality is due to $q'(c_n) < 0$ and $\bar{p} \geq c_n$. As its expected profit is increasing in c_n, the PBM should set c_n to its maximum amount, $c_n = \bar{p}$.

Next, we show that PBM's expected profit is decreasing in c_p. Beginning with the total surplus:

$$\begin{aligned}\frac{\partial E[TS(c_g,c_p,c_n)]}{\partial c_p} &= \frac{1}{3}(1-\tau)\frac{\partial}{\partial c_p}E[1(V>c_p)V] + \tau\frac{\partial}{\partial c_p}(\alpha E[1(V>c_p)V] - \tau\frac{\partial}{\partial c_p}(\alpha E[1(V>c_g)V]) \\ &= \frac{1}{3}(1-\tau)c_p q'(c_p) + \tau\left[\alpha c_p q'(c_p) + E[1(V>c_p)V]\frac{\partial\alpha}{\partial c_p}\right] - \tau E[1(V>c_g)V]\frac{\partial\alpha}{\partial c_p} \\ &= \frac{1}{3}(1-\tau)c_p q'(c_p) + \tau\alpha c_p q'(c_p) + \tau(E[1(V>c_p)V] - E[1(V>c_g)V])\frac{\partial\alpha}{\partial c_p}.\end{aligned}$$

Therefore, we have that

$$\begin{aligned}\frac{\partial E[\pi_{PBM}(c_g,c_p,c_n)]}{\partial c_p} = &\left(\frac{1}{3}(1-\tau)+\tau\alpha\right)c_p q'(c_p) + \tau(E[1(V>c_p)V] - E[1(V>c_g)V])\frac{\partial\alpha}{\partial c_p} \\ &+ \tau\bar{p}_0 q(c_g)\frac{\partial\alpha}{\partial c_p} < 0\end{aligned}$$

where the resulting inequality is due to $q'(c_p) < 0$, $E[1(V>c_p)V] - E[1(V>c_g)V] > 0$, and $\frac{\partial\alpha}{\partial c_p} < 0$. As its expected profit is decreasing in c_p, the PBM should set c_p to its minimum amount, $c_p = 0$.

Finally, we show that the PBM's expected profit is increasing in c_g. Beginning with the total surplus:

$$\begin{aligned}\frac{\partial E[TS(c_g,c_p,c_n)]}{\partial c_g} =&\frac{1}{3}(1-\tau)\frac{\partial}{\partial c_g}E[1(V>c_g)V]+\tau\frac{\partial}{\partial c_g}E[1(V>c_g)V]-\tau\frac{\partial}{\partial c_g}(\alpha E[1(V>c_g)V])\\&+\tau\frac{\partial}{\partial c_g}(\alpha E[1(V>c_p)V])\\=&\frac{1}{3}(1-\tau)c_gq'(c_g)+\tau c_gq'(c_g)-\tau\left[\alpha c_gq'(c_g)+E[1(V>c_g)V]\frac{\partial\alpha}{\partial c_g}\right]\\&+\tau E[1(V>c_p)V]\frac{\partial\alpha}{\partial c_g}\\=&\left(\frac{1}{3}(1-\tau)-\tau(1-\alpha)\right)c_gq'(c_g)+\tau(E[1(V>c_p)V]-E[1(V>c_g)V])\frac{\partial\alpha}{\partial c_g}.\end{aligned}$$

Therefore, we have that

$$\begin{aligned}\frac{\partial E[\pi_{PBM}(c_g,c_p,c_n)]}{\partial c_g}=&\left(\frac{1}{3}(1-\tau)-\tau(1-\alpha)\right)(c_g-\bar{p}_0)q'(c_g)+\tau(E[1(V>c_p)V]-E[1(V>c_g)V])\frac{\partial\alpha}{\partial c_g}\\&+\tau\bar{p}_0q(c_g)\frac{\partial\alpha}{\partial c_g}>0\end{aligned}$$

where the resulting inequality is due to $c_g \leq \bar{p}_0$, $q'(c_g) < 0$, $E[1(V > c_p)V] - E[1(V > c_g)V] > 0$, and $\frac{\partial\alpha}{\partial c_g} > 0$. As its expected profit is increasing in c_g, the PBM should set c_g to its maximum amount, $c_g = \bar{p}_0$. □

Our results for the optimal copayments for the branded drugs are identical to Conti et al. (2021). As we have shown, lowering the copayment for the preferred brand increases the prize for winning the formulary contest. It follows, then, both intuitively and from the results in Proposition 5, that raising the generic copayment leads to additional consumers switching to the preferred brand, further increasing the benefit of being placed on the preferred tier. The resulting overall cost to consumers is lower than the pre-formulary baseline, as those who cannot switch from the generic or non-preferred brands pay the same price with or without the formulary, while those who must use the preferred brand or can switch pay less than in the pre-formulary baseline.

Note that the addition of a third branded drug in Conti et al. (2021) results in a more efficient outcome compared to the two-drug baseline, as all but one branded drug is put on the zero copay tier. Here, the addition of a generic drug does not result in the same efficiency gains, as the PBM cannot negotiate rebates for the drug. Thus, while the outcome is more efficient than without the formulary, there is foregone generic demand in exchange for higher rebates. The magnitude of this tradeoff depends on the form of the demand function.

5 Numerical Examples: Effects of Model Parameters

In the following section, we examine the relationships between several variables and consumer shares. The assumed copayments in these numerical examples differ from the equilibrium copayments; however, the purpose is to illustrate the model mechanisms and factors that may influence the value of the formulary contest and, thus, the PBM's ability to extract higher rebates.

5.1 Effect of the Preferred Brand Copayment on Consumer Shares

Let $\bar{p} = 50$ and $\delta = 0.5$ such that $\bar{p}_0 = 25$ and $\Delta Q = Q - Q_0 = 25$. Thus, in the absence of insurance, $\lambda_0^* = 1$. If we assume $\lambda_j \sim \mathcal{N}(1, 1)$, then $Pr(\lambda_j \geq \lambda_0^*) = \alpha_0 = 0.5$.[3] Recall that the consumer shares for each drug in the absence of a formulary are as follows: $\frac{1}{3}(1-\tau)+\tau(1-\alpha)$ for the generic drug and $\frac{1}{3}((1-\tau)+\frac{3}{2}\tau\alpha)$ for each branded drug. Under the formulary, the consumer share of the generic drug is the same, while the consumer shares for the preferred and non-preferred branded drugs are $\frac{1}{3}(1-\tau)+\tau\alpha$ and $\frac{1}{3}(1-\tau)$, respectively.

We begin with the case where $\tau = 1$ (see Table 1). We assume demand is downward-sloping and inelastic.[4] In the absence of the formulary, the generic consumer share is 0.5 and the identical branded drugs split the remaining share equally. Next, let $c_g = 0$, $c_p = 25$, and $c_n = 50$.

When $c_p = 25$, the consumer share for the generic drug is unchanged at 0.5, as the choice of copays results in the same price differential. Note that the consumer share is equal to α as all consumers are able to substitute; we discuss the impact of substitutability in the following section. When c_p decreases to 0, the consumer share for the generic drug under the formulary decreases from 0.5 to 0.16, while that of the preferred brand increases to 0.84. When c_p increases to 40, the consumer share for the generic drug increases from 0.5 to 0.73, while that of the preferred brand increases from 0.25 to 0.27. This is due to the change in α; as the price differential decreases (increases), fewer (more) consumers wish to purchase the generic drug and these consumers switch between the generic and branded drug accordingly. Thus, the lower c_p, the higher the prize for winning the formulary contest, as demonstrated by Proposition 5.

3. As in the previous section, we use α_0 to indicate the share of consumers in τ who choose either branded drug in the absence of a formulary, noting that this share is equal for both drugs due to the assumptions $\bar{p}_1 = \bar{p}_2 = \bar{p}$ and $Q_1 = Q_2 = Q$. We use α to indicate the share of consumers in τ who choose the preferred brand under the formulary.

4. To simulate the model, we assume $q(p) = 200p^{-0.2}$. The functional form does not affect the relationships discussed in these numerical examples. We will refrain from discussing the effects of the model parameters on market shares, as this is dependent on the functional form of the demand.

Table 1: Effect of the Preferred Brand Copayment on Consumer Shares ($\bar{p} = 50$, $\bar{p}_0 = 25$, $\Delta Q = 25$, $c_g = 0$, $c_n = 50$, $\tau = 1$, $var(\lambda) = 1$)

No Formulary ($\lambda^* = 1$, $\alpha = 0.5$)		Formulary					
Generic	Branded (Each Drug)	c_p	λ^*	α	Generic	Preferred Brand	Non-preferred Brand
0.5	0.25	0	0.0	0.84	0.16	0.84	0
0.5	0.25	25	1.0	0.50	0.50	0.50	0
0.5	0.25	40	1.6	0.27	0.73	0.27	0

Under the formulary, the non-preferred drug obtains no consumer share. Since $\alpha = 0.5$, half of the population that can switch — in this case, all consumers — choose the generic drug and half choose the preferred branded drug under the formulary. When the entire population is able to substitute, all of those who can switch from the more expensive non-preferred branded drug to either the generic or the preferred brand will do so. More generally, the value of c_p has no impact on the consumer share of the non-preferred drug for any value of τ, since only those who cannot substitute will choose the non-preferred drug. Thus, c_p only affects the decision of those consumers who can substitute.

5.2 Effect of Substitutability on Consumer Shares

We begin with the same baseline assumptions as in the previous example. We see in Table 2 that, in the absence of the formulary, as τ increases, the generic drug maintains a higher consumer share than each of the branded drugs, but that this share falls below 0.5. Holding α at 0.5, we see that the generic consumer share is unchanged in the presence of the formulary compared to the pre-formulary share for all levels of τ. Additionally, the consumer share of the preferred branded drug is identical to that of the generic drug for every level of τ, since $\alpha = 0.5$ indicates that half of the population that can switch, τ, will choose the preferred brand.

However, when $\tau < 1$, the non-preferred brand obtains a nonzero share of consumers, with this proportion increasing as τ decreases. The consumer share of the non-preferred drug represents those whose illness corresponds to the drug and who cannot switch, hence the increase in consumer share under the formulary as the proportion of the population who can substitute decreases. The consumer shares of the generic and preferred branded drug under the formulary decrease as τ increases, as the two equally split the consumer share not captured by the non-preferred brand.

Looking at the difference between the consumer shares of the preferred and non-preferred brand, which decreases as fewer consumers can switch, it is clear that the benefit of winning

Table 2: Effect of Substitutability on Consumer Shares, $c_p = 25$ ($\bar{p} = 50$, $\bar{p}_0 = 25$, $\Delta Q = 25$, $c_g = 0$, $c_n = 50$, $var(\lambda) = 1$)

	No Formulary ($\lambda^* = 1$, $\alpha = 0.5$)		Formulary ($\lambda^* = 1$, $\alpha = 0.5$)		
τ	Generic	Branded (Each Drug)	Generic	Preferred Brand	Non-preferred Brand
1.00	0.50	0.25	0.50	0.50	0.00
0.75	0.46	0.27	0.46	0.46	0.08
0.50	0.42	0.29	0.42	0.42	0.17
0.25	0.38	0.31	0.37	0.38	0.25

the formulary contest is increasing in τ. In other words, the more consumers are able to switch to cheaper drugs, the more beneficial it is to a drug manufacturer for its drug to be assigned to the preferred tier.

5.3 Combined Effects of Substitutability and the Preferred Brand Copayment on Consumer Shares

We demonstrate how a change in α via a change in the preferred brand copay interacts with a change in τ using graphical results (Tables 3 and 4 are provided in Appendix B as an additional reference).

Figure 3 shows the consumer share of the generic drug under the formulary for $c_p \in [0, 50]$ and for several levels of τ. We see that for all values of c_p, increasing τ amplifies the effect of c_p on market shares. To understand the intuition behind how τ interacts with α, we must first discuss the threshold value that one can see on the graph where each line intersects at approximately $c_p = 15$. Notice that for any value of c_p above this threshold, increasing τ leads to an increase in the generic consumer share under the formulary (holding c_p constant). Below this threshold, increasing τ leads to a decrease in the generic consumer share.

This threshold value is the point at which consumers are indifferent between the branded drug and the generic drug, as discussed in Section 3 on page 7. When c_p is above the threshold, λ_i^* increases such that λ_j is less likely to be greater than the threshold value. Recall that $\alpha = \sum_j Pr(\lambda_j \geq \lambda_i^*)$. Thus, the share of consumers, α, who wish to purchase the preferred branded drug decreases. The opposite is true when c_p is below this threshold.

When c_p is below this indifference value, more consumers would like to switch to the preferred branded drug from the generic drug. However, $\tau < 1$ indicates that some consumers who would prefer to switch cannot do so. Thus, increasing τ when c_p is below (above) the threshold allows those who would like to switch to the preferred brand (generic drug) who could not otherwise to do so, thereby decreasing (increasing) the consumer share of the

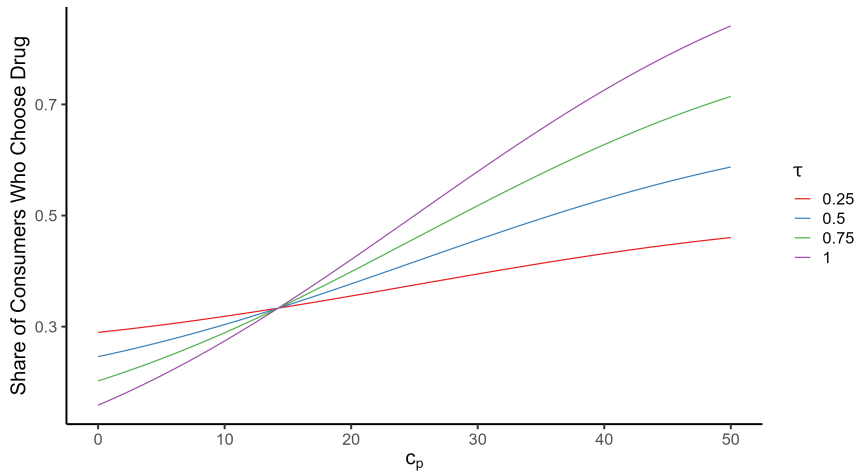

Figure 3: Effect of Substitutability and the Preferred Brand Copayment on Consumer Share of Generic Drug ($\bar{p} = 50, \bar{p}_0 = 25, \Delta Q = 25, c_g = 0, c_n = 50, var(\lambda) = 1$)

generic drug.

Figure 4 shows that the difference in consumer shares between the two drugs increases as c_p decreases for all levels of τ. As confirmed in the previous examples, decreasing c_p increases the consumer share of the preferred branded drug, and increasing τ amplifies this. Recall that τ alone affects the consumer share of the non-preferred drug. This graph also illustrates that the value of winning the formulary contest, measured in terms of the consumer share differential, is highest when c_p is minimized.

5.4 Effect of Consumer Preference Distribution on Consumer Shares

Figure 5 shows the generic consumer shares under the formulary for different levels of τ and $c_p \in [0, 50]$ given the baseline variance ($var(\lambda) = 1$), high variance ($var(\lambda) = 4$), and low variance ($var(\lambda) = 0.25$). Tables 5, 6, and 7 are provided as a supplement in Appendix B.

First, consider the case where $var(\lambda) = 4$. We see that when $c_p > 25$, a smaller share than in the baseline case purchases the generic drug, i.e., α is higher. Recall that since $c_g = 0$, $c_p = 25$ is the point at which $\lambda_i^* = 1$, or $\alpha = 0.5$. Similarly, when $c_p < 25$, a higher share than in the baseline case chooses the generic drug. We might expect that more consumers would switch from the preferred brand to the generic when the latter is more expensive than the former or that more consumers would switch to the preferred brand when it is cheaper than the generic. However, higher variance implies that there exist more consumers whose individual threshold values, λ_j, differ significantly from the average. These consumers are either far more or far less sensitive to cost or perceived quality differences. In other words, a

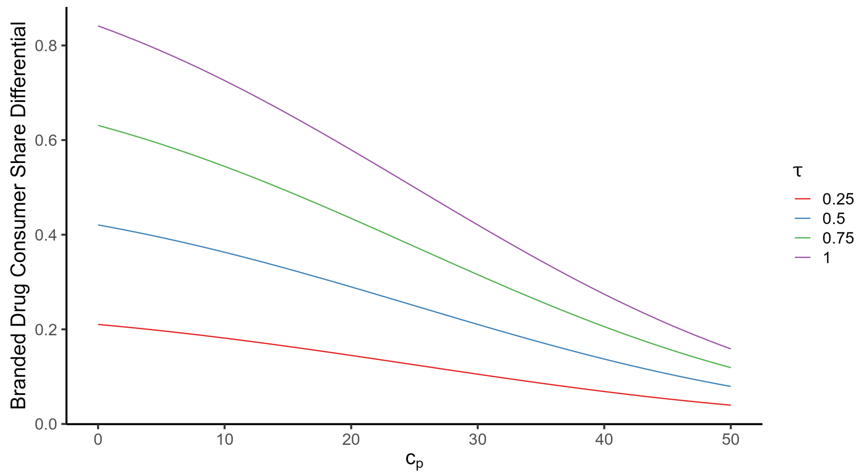

Figure 4: Effect of Substitutability and the Preferred Brand Copayment on Branded Drug Consumer Share Differential ($\bar{p} = 50, \bar{p}_0 = 25, \Delta Q = 25, c_g = 0, c_n = 50, var(\lambda) = 1$)

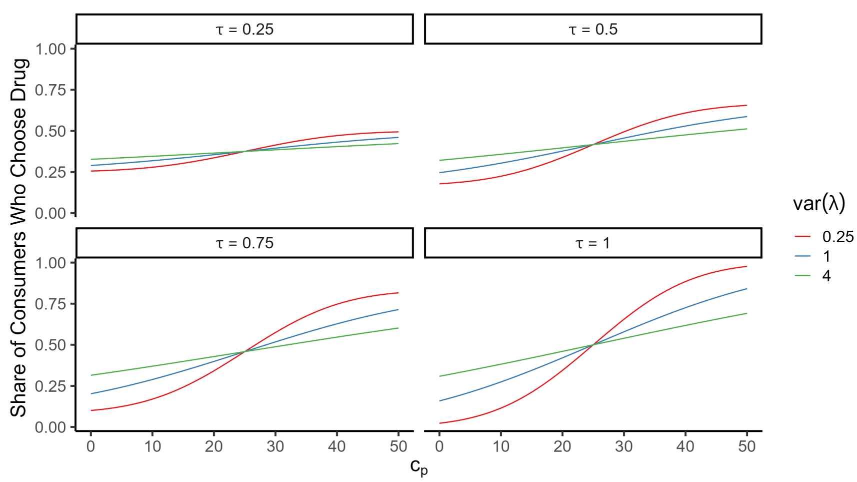

Figure 5: Effect of Consumer Preference Distribution on Consumer Share of Generic Drug ($\bar{p} = 50, \bar{p}_0 = 25, \Delta Q = 25, c_g = 0, c_n = 50, var(\lambda) = 1$)

more extreme λ draw results in different consumer shares than we would expect to see based on the relative drug prices.

A less extreme λ draw ($var(\lambda) = 0.25$) means more consumers tend toward the average value of λ. Thus, we see that more consumers than in the baseline case choose the preferred (generic) drug when $c_p < 25$ ($c_p > 25$). These results imply that if the variance in the population is high, the PBM's choice of copayments for the generic and preferred brand will have a greater impact on both the net prices of the branded drugs and the demand for the generic drug.

Similarly, Figure 6 shows the impact of $var(\lambda)$ on the branded drug consumer share differential under the formulary. The differential between the branded drugs changes due to the change in demand for the preferred brand only. When the generic drug loses consumer share, the preferred brand gains consumer share, increasing the differential between the branded drugs. When variance is low and substitutability is high, the PBM is able to maximize the consumer share differential, thereby minimizing net prices, as the branded drug manufacturers are willing to offer higher rebates in order to win the formulary contest.

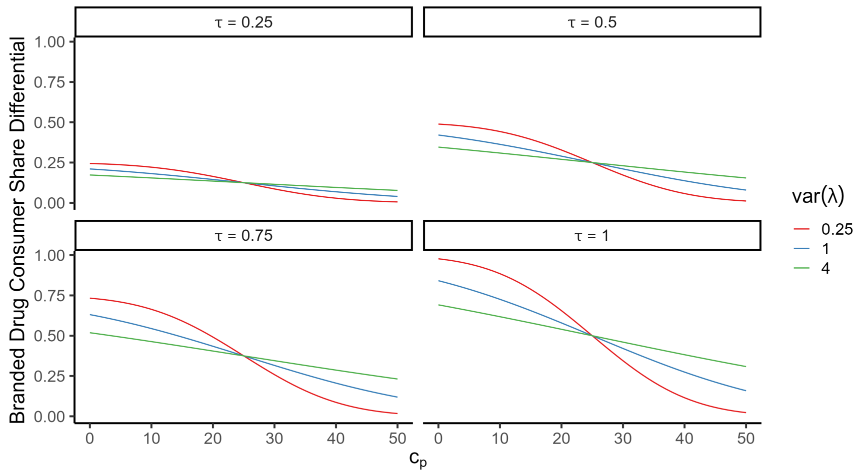

Figure 6: Effect of Consumer Preference Distribution on Branded Drug Consumer Share Differential ($\bar{p} = 50, \bar{p}_0 = 25, \Delta Q = 25, c_g = 0, c_n = 50$)

5.5 Additional Graphical Results

For a visual representation of some of the above examples for the full range of possible values of c_p, additional graphs have been included in Appendix A as a supplement to the tables. For the consumer shares of all drugs at the baseline variance, low variance, and high variance, see Figures 7, 8, 9, respectively. For the same results for branded drugs only, see Figures 10, 11, and 12. For generic consumer shares only, see Figures 13, 14, and 15.

Although the numerical examples assume $c_g = 0$ and $c_n = \bar{p}$, Propositions 5 and 6 show that net prices are minimized and, given the assumption $c_p < c_g$, the PBM's profits are maximized when both c_g and the spread between c_p and c_n are maximized. Therefore, the equilibrium copayments are $c_p = 0$, $c_g = \bar{p}_0$, and $c_n = \bar{p}$. Figure 16 provides a visualization of the result for net prices: we see that, fixing $c_n = \bar{p}$, the lowest net prices are obtained when c_p is minimized and c_g is maximized.

6 Conclusion

Given the lack of publicly available data on PBM contracts, particularly on rebates and pass-through to consumers, and limited existing research on the role and economic impact of PBMs, it is challenging to model the complex U.S. pharmaceutical supply chain. While Conti et al. (2021)'s model opts to exclude generic drugs because PBMs tend to place them on a preferred tier, our model seeks to understand PBMs' incentives with respect to encouraging generic uptake and explain instances of formulary bias toward preferred brands over generics.

Our main result is the demonstration of the existence of a tradeoff faced by the PBM between obtaining higher rebates for branded drugs and encouraging generic uptake. The PBM's incentive to seek higher rebates may lead it to set the copayment for the generic drug higher than that of the preferred brand in order to maximize the value of the formulary contest for branded drug manufacturers. Although raising the generic copayment lowers the value of the formulary, the higher rebates for the branded drugs counter this effect and lead to higher profits for the PBM. Thus, we show that the PBM may, under certain conditions, have a disincentive to encourage generic substitution.

The presence of a generic drug implies, holding list prices fixed, that the PBM is not able to obtain as low net prices as in the two branded drug model, as some portion of consumers will always prefer the generic drug, shrinking the potential gains to the branded manufacturers from winning the formulary contest. Although the potential gains from winning the formulary contest decrease as the number of competing branded drugs increases in Conti et al. (2021), the threat of being placed on the non-preferred tier still allows the PBM to extract the maximum rebates by setting the copays for all but the non-preferred drug to zero, leading to increasing efficiency. By contrast, the PBM's inability to negotiate generic drug rebates results in a less efficient outcome than the case of three branded drugs.

Finally, we examine how different exogenous parameters may affect the PBM's ability to extract lower net prices from the branded drug manufacturers. These results may have implications for examining the impact and effectiveness of PBMs on particular groups of consumers or with respect to certain classes of drugs. For example, a PBM might be more likely to push lower-income, more cost-sensitive consumers away from using generics, as the distribution of lambda may induce stronger formulary competition between the branded drug manufacturers.

Other factors not modeled here, such as competition from other PBMs or spread pricing allowing PBMs to recoup forgone profit from lowering generic copayments, may explain why generics are typically placed on preferred tiers despite the potential incentive to favor discounted branded drugs. It is possible that given certain values of the exogenous parameters in our model, $c_g > c_p$ may not always be profit maximizing for the PBM. In other words, while we show there exists an equilibrium where the PBM sets $c_p = 0$ and $c_g = \bar{p}_0$, there may exist other equilibria where $c_g < c_p$.

It may be useful to apply our model to the case of more than one class of drug in order to analyze the tradeoffs between different types of generic and branded drugs and gain a more realistic understanding of the overall effects on insurance costs and consumer spending. Further, it may also be informative to allow for endogenous list prices or to explore the effects of policies such as mandatory generic substitution.

Our equilibrium results imply that consumers are not worse off due to higher generic copayments, as consumers pay the same price for the generic whether or not they pay through the formulary. Consumers who either cannot switch from the preferred brand or who can switch from the generic to the preferred brand are better off under the formulary. Despite our results of $c_g = \bar{p}_0$, consumers often overpay for generic drugs in reality. We assume that the consumer pays the list price for the drug off the formulary. However, generic drugs are sometimes cheaper for consumers when they pay out-of-pocket at the pharmacy, as pharmacies, unlike PBMs, negotiate generic drug purchase discounts with wholesalers.

Finally, consumers or insurers may overpay for generics due to several strategies used by PBMs to capture generic drug profits. The first strategy, known as spread pricing, occurs when a PBM charges a higher reimbursement price to the insurer than it is willing to reimburse the pharmacy for its costs of filling a prescription. The second strategy is a clawback, whereby the pharmacy must reimburse the PBM if the consumer's copayment is higher than the wholesale price paid by the pharmacy. Thus, while $c_g > c_p$ does not make consumers worse off in our model, we cannot capture the additional costs to the healthcare system that may result from higher generic copays. Our results highlight the conflict between PBMs' stated goal of encouraging generic uptake and the incentives produced by the formulary contest. Further research is needed to understand the complex pharmaceutical supply chain in the U.S. and the potential impacts for consumers of proposed legislation restricting PBMs' ability to obtain rebates or use other strategies to capture profit.

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Appendix A: Figures

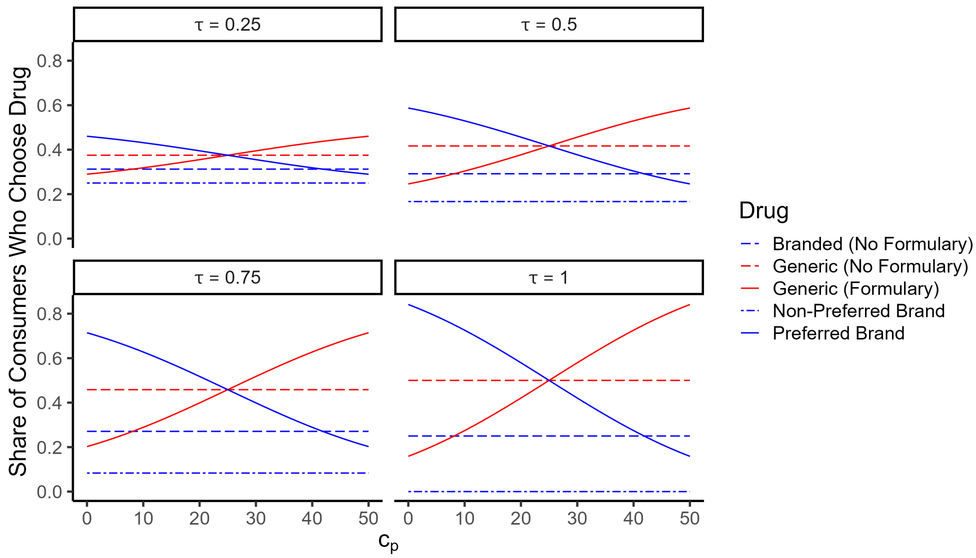

Figure 7: Effect of Substitutability and the Preferred Brand Copayment on Consumer Shares, $var(\lambda) = 1$ ($\bar{p} = 50, \bar{p}_0 = 25, \Delta Q = 25, c_g = 0, c_n = 50$)

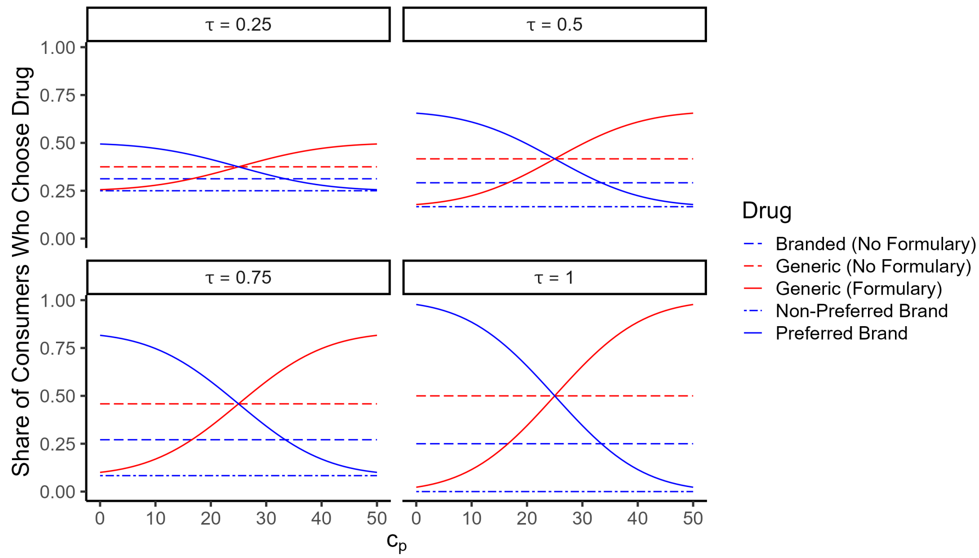

Figure 8: Effect of Substitutability and the Preferred Brand Copayment on Consumer Shares, $var(\lambda) = 0.25$ ($\bar{p} = 50, \bar{p}_0 = 25, \Delta Q = 25, c_g = 0, c_n = 50$)

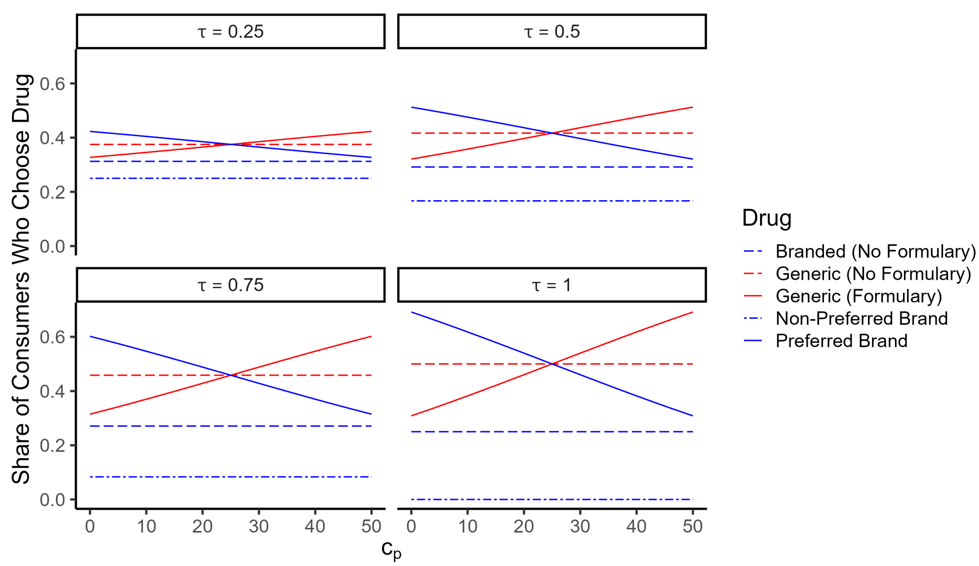

Figure 9: Effect of Substitutability and the Preferred Brand Copayment on Consumer Shares, $var(\lambda) = 4$ ($\bar{p} = 50, \bar{p}_0 = 25, \Delta Q = 25, c_g = 0, c_n = 50$)

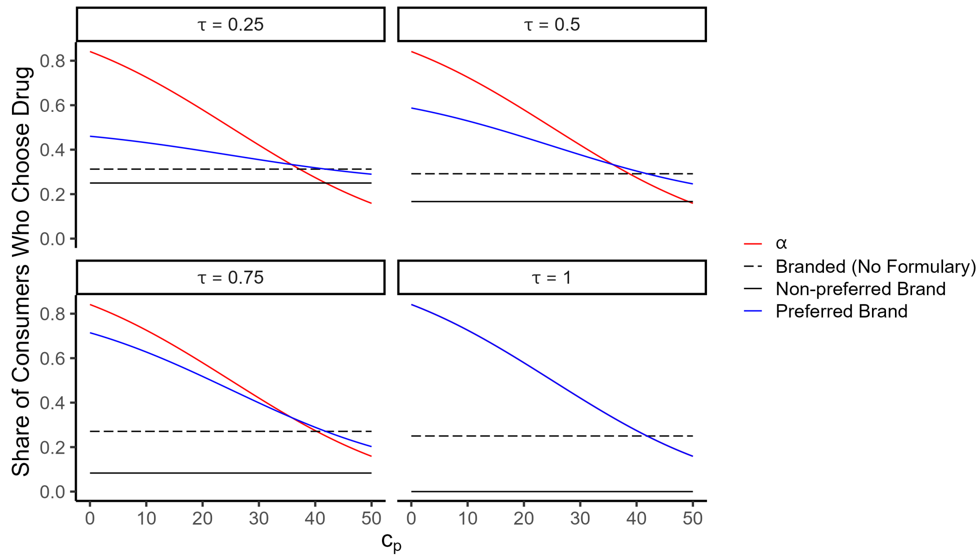

Figure 10: Effect of Substitutability and the Preferred Brand Copayment on Consumer Shares of Branded Drugs, $var(\lambda) = 1$ ($\bar{p} = 50, \Delta Q = 25, \bar{p}_0 = 25, c_g = 0, c_n = 50$)

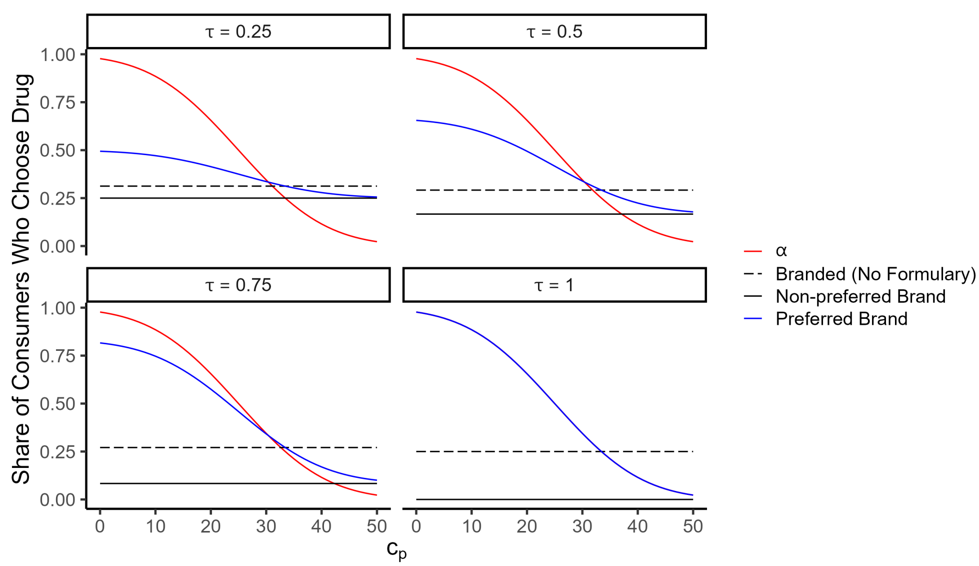

Figure 11: Effect of Substitutability and the Preferred Brand Copayment on Consumer Shares of Branded Drugs, $var(\lambda) = 0.25$ ($\bar{p} = 50, \bar{p}_0 = 25, \Delta Q = 25, c_g = 0, c_n = 50$)

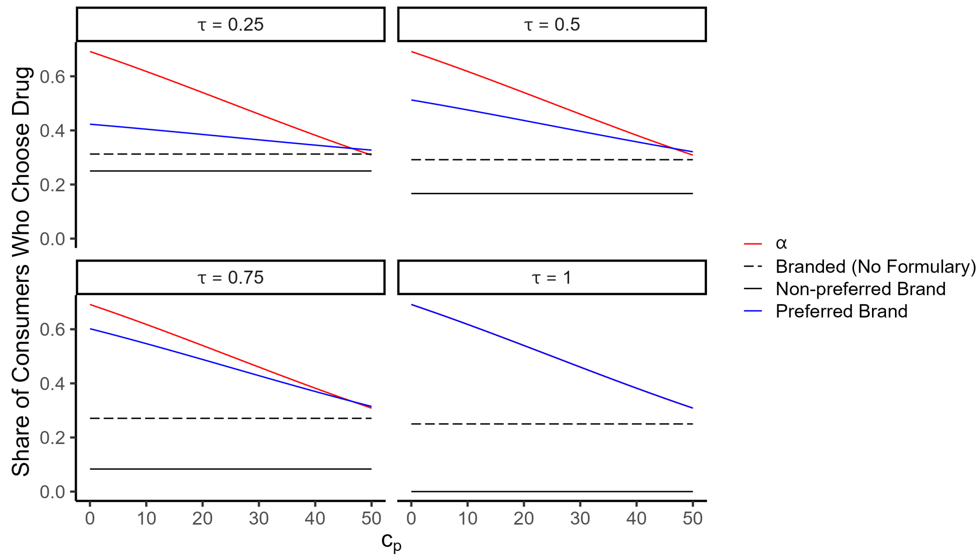

Figure 12: Effect of Substitutability and the Preferred Brand Copayment on Consumer Shares of Branded Drugs, $var(\lambda) = 4$ ($\bar{p} = 50, \bar{p}_0 = 25, \Delta Q = 25, c_g = 0, c_n = 50$)

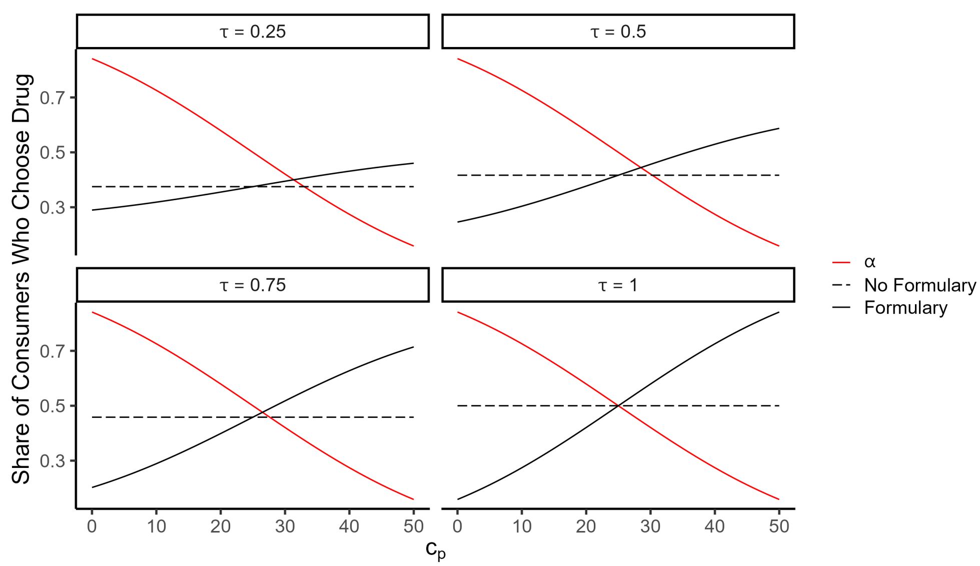

Figure 13: Effect of Substitutability and the Preferred Brand Copayment on Consumer Share of Generic Drug, $var(\lambda) = 1$ ($\bar{p} = 50, \bar{p}_0 = 25, \Delta Q = 25, c_g = 0, c_n = 50$)

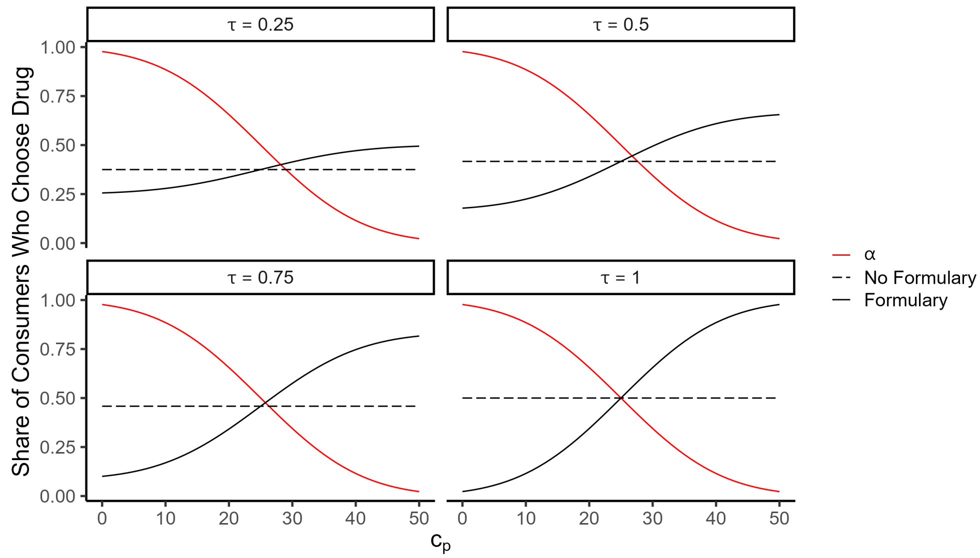

Figure 14: Effect of Substitutability and the Preferred Brand Copayment on Consumer Share of Generic Drug, $var(\lambda) = 0.25$ ($\bar{p} = 50, \bar{p}_0 = 25, \Delta Q = 25, c_g = 0, c_n = 50$)

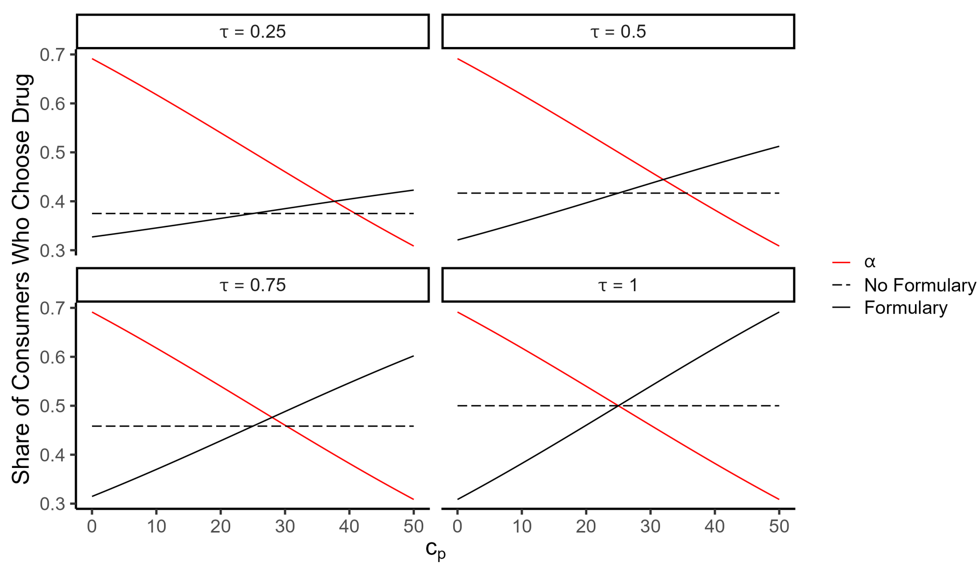

Figure 15: Effect of Substitutability and the Preferred Brand Copayment on Consumer Share of Generic Drug, $var(\lambda) = 4$ ($\bar{p} = 50, \bar{p}_0 = 25, \Delta Q = 25, c_g = 0, c_n = 50$)

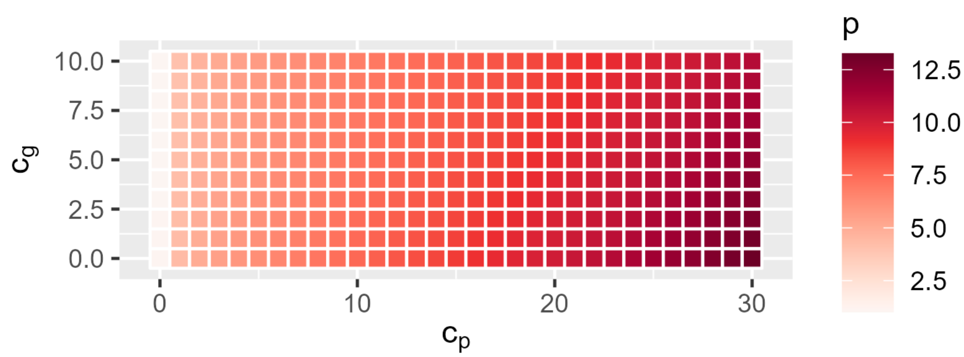

Figure 16: Net Price, p, of Branded Drugs Given $c_g \in \{0, 10\}$ and $c_p \in \{0, 30\}$ ($\bar{p} = 30$, $\bar{p}_0 = 10, c_n = 30$)

Appendix B: Tables

Table 3: Effect of Substitutability on Consumer Shares, $c_p = 0$ ($\bar{p} = 50$, $\bar{p}_0 = 25$, $\Delta Q = 25$, $c_g = 0$, $c_n = 50$, $var(\lambda) = 1$)

	No Formulary ($\lambda^* = 1$, $\alpha = 0.5$)		Formulary ($\lambda^* = 0$, $\alpha = 0.84$)		
τ	Generic	Branded (Each Drug)	Generic	Preferred Brand	Non-preferred Brand
1.00	0.50	0.25	0.16	0.84	0.00
0.75	0.46	0.27	0.20	0.71	0.08
0.50	0.42	0.29	0.25	0.59	0.17
0.25	0.38	0.31	0.29	0.46	0.25

Table 4: Effect of Substitutability on Consumer Shares, $c_p = 40$ ($\bar{p} = 50$, $\bar{p}_0 = 25$, $\Delta Q = 25$, $c_g = 0$, $c_n = 50$, $\alpha = 0.27$, $var(\lambda) = 1$)

	No Formulary ($\lambda^* = 1$, $\alpha = 0.5$)		Formulary ($\lambda^* = 1.6$, $\alpha = 0.27$)		
τ	Generic	Branded (Each Drug)	Generic	Preferred Brand	Non-preferred Brand
1.00	0.50	0.25	0.73	0.27	0.00
0.75	0.46	0.27	0.63	0.29	0.08
0.50	0.42	0.29	0.53	0.30	0.17
0.25	0.38	0.31	0.43	0.32	0.25

Table 5: Effect of Substitutability and the Preferred Brand Copayment on Consumer Shares, $var(\lambda) = 1$ ($\bar{p} = 50$, $\bar{p}_0 = 25$, $\Delta Q = 25$, $c_g = 0$, $c_n = 50$)

No Formulary ($\lambda^* = 1$, $\alpha = 0.5$)		Formulary					
Generic	Branded (Each Drug)	c_p	λ^*	α	Generic	Preferred Brand	Non-preferred Brand
$\tau = 1$							
0.50	0.25	0	0.0	0.84	0.16	0.84	0.00
0.50	0.25	25	1.0	0.50	0.50	0.50	0.00
0.50	0.25	40	1.6	0.27	0.73	0.27	0.00
$\tau = 0.75$							
0.46	0.27	0	0.0	0.84	0.20	0.71	0.08
0.46	0.27	25	1.0	0.50	0.46	0.46	0.08
0.46	0.27	40	1.6	0.27	0.63	0.29	0.08
$\tau = 0.5$							
0.42	0.29	0	0.0	0.84	0.25	0.59	0.17
0.42	0.29	25	1.0	0.50	0.42	0.42	0.17
0.42	0.29	40	1.6	0.27	0.53	0.30	0.17
$\tau = 0.25$							
0.38	0.31	0	0.0	0.84	0.29	0.46	0.25
0.38	0.31	25	1.0	0.50	0.37	0.38	0.25
0.38	0.31	40	1.6	0.27	0.43	0.32	0.25

Table 6: Effect of Substitutability and the Preferred Brand Copayment on Consumer Shares, $var(\lambda) = 0.25$ ($\bar{p} = 50$, $\bar{p}_0 = 25$, $\Delta Q = 25$, $c_g = 0$, $c_n = 50$)

No Formulary ($\lambda^* = 1$, $\alpha = 0.5$)		Formulary					
Generic	Branded (Each Drug)	c_p	λ^*	α	Generic	Preferred Brand	Non-preferred Brand
$\tau = 1$							
0.50	0.25	0	0.0	0.98	0.02	0.98	0.00
0.50	0.25	25	1.0	0.50	0.50	0.50	0.00
0.50	0.25	40	1.6	0.12	0.88	0.12	0.00
$\tau = 0.75$							
0.46	0.27	0	0.0	0.98	0.10	0.82	0.08
0.46	0.27	25	1.0	0.50	0.46	0.46	0.08
0.46	0.27	40	1.6	0.12	0.75	0.17	0.08
$\tau = 0.5$							
0.42	0.29	0	0.0	0.98	0.18	0.66	0.17
0.42	0.29	25	1.0	0.50	0.42	0.42	0.17
0.42	0.29	40	1.6	0.12	0.61	0.22	0.17
$\tau = 0.25$							
0.38	0.31	0	0.0	0.98	0.26	0.49	0.25
0.38	0.31	25	1.0	0.50	0.37	0.38	0.25
0.38	0.31	40	1.6	0.12	0.47	0.28	0.25

Table 7: Effect of Substitutability and the Preferred Brand Copayment on Consumer Shares, $var(\lambda) = 4$ ($\bar{p} = 50$, $\bar{p}_0 = 25$, $\Delta Q = 25$, $c_g = 0$, $c_n = 50$)

No Formulary ($\lambda^* = 1, \alpha = 0.5$)		Formulary					
Generic	Branded (Each Drug)	c_p	λ^*	α	Generic	Preferred Brand	Non-preferred Brand
$\tau = 1$							
0.50	0.25	0	0.0	0.69	0.31	0.69	0.00
0.50	0.25	25	1.0	0.50	0.50	0.50	0.00
0.50	0.25	40	1.6	0.38	0.62	0.38	0.00
$\tau = 0.75$							
0.46	0.27	0	0.0	0.69	0.31	0.60	0.08
0.46	0.27	25	1.0	0.50	0.46	0.46	0.08
0.46	0.27	40	1.6	0.38	0.55	0.37	0.08
$\tau = 0.5$							
0.42	0.29	0	0.0	0.69	0.32	0.51	0.17
0.42	0.29	25	1.0	0.50	0.42	0.42	0.17
0.42	0.29	40	1.6	0.38	0.48	0.36	0.17
$\tau = 0.25$							
0.38	0.31	0	0.0	0.69	0.33	0.42	0.25
0.38	0.31	25	1.0	0.50	0.37	0.38	0.25
0.38	0.31	40	1.6	0.38	0.40	0.35	0.25