Common Agent or Double Agent? Pharmacy Benefit Managers in the Prescription Drug Market

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Abstract

Pharmacy benefit managers (PBMs) are intermediaries that manage prescription drug purchases for health plans and other payers. PBMs play a central, but little analyzed, role in the U.S. market for prescription drugs. Drug makers selling branded pharmaceuticals bid for desirable slots on the PBM's formulary by offering rebates off of a drug's list price. These formularies operate like all-pay contests. We find that PBMs enhance market efficiency, but the efficiency gains do not accrue to consumers or drug makers. Our analysis offers insights into otherwise puzzling questions. Why do drug makers pay rebates to PBMs? Why do payers delegate the critical formulary function to PBMs? Why is the market dominated by a small number of very large PBMs acting as the common agent for many payers? Why are the list prices of branded drugs so high? Why might PBMs vertically integrate with payers? Our framework also offers insights into policy proposals for reforming the market for prescription drugs.

1 Introduction

In 2020, the Food and Drug Administration (FDA) approved fifty-three new drugs—the largest number in more than two decades. The years 2017, 2018 and 2019 were

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also highly productive years in terms of new drug development. While many of these therapies embody novel treatment approaches and offer substantial clinical benefits, their prices can be very high. Launch prices of new drugs are commonly set above $100,000 per course of treatment by drug companies. In May 2019 Novartis launched the "world's most expensive drug," onasemnogene abeparvovec-xioi, a gene therapy for spinal muscular atrophy that costs $2.1M per treated patient. High prices for drugs protected from competition by patents and other types of market exclusivities provide incentives for pharmaceutical companies to conduct research and development, but they also limit access to treatment.

Every national healthcare system relies on a set of policies and institutions to balance the tricky tradeoff between innovation incentives and access to innovative drugs (Scherer, 2000).[1] A peculiar feature of the U.S. system is a set of organizations called pharmacy benefit managers (PBMs). PBMs are for-profit, non-governmental companies that manage pharmacy benefits on behalf of health plans and other payers. Virtually every commercial health insurance plan in the U.S. uses a PBM to manage prescription drug purchases. Medicare, the government insurance program providing medical coverage for the elderly and disabled, relies on PBM services to manage drugs purchased under Medicare Part D drug plans and Medicare Advantage plans. Many states also use PBMs in managing their Medicaid prescription drug program covering vulnerable individuals including children, pregnant women and the poor (Kaiser Family Foundation, 2020; Yost, 2018; Royce et al., 2019).

In this paper, we offer a microeconomic analysis of the role of PBMs in the U.S. market for prescription drugs. Our focus is on PBMs' management of on-patent drugs, which are also known in the industry as branded drugs. While non-patented "generic" drugs make up the bulk of prescriptions sold in the U.S., branded drugs account for nearly three quarters of total drug spending (IQVIA Institute for Human Data Science, 2018).

PBMs are market intermediaries who operate formularies on behalf of their clients, health plans and other payers. In their role as formulary operators, PBMs allocate branded drugs to different formulary tiers. A branded drug assigned to a favorable tier will enjoy lower copays and hence higher demand.[2]

[1]The U.S. healthcare market also faces well known principal-agent challenges: physicians act as agents for patients in their demand for medical care and health insurance plans act a payers for medical services provided by physicians and other medical providers to patients (McGuire, 2000; Pauly, 2000).

[2]Generally, PBMs allocate generic drugs to the most favorable tier. PBMs do more than structure competition between the makers of branded drugs. They also develop generic substitution policies, prior authorization programs, and disease management services. PBMs also strike agreements with pharmacies over the amount and timing of professional fees for dispensing drugs (Feldman,

Branded drug makers compete for favorable formulary placement for their drug by offering PBMs rebates off the drug's list price. Rebates are quite controversial and raise pointed questions. Are drug rebates a kind of side-payment that undermines PBM incentives to negotiate drug prices aggressively on behalf of their clients? If so, then why do payers rely on such potentially compromised representatives? If not, why do branded drug makers pay the rebates at all? Would consumers be better served if rebates were prohibited altogether or, alternatively, directly handed over to insurers or to consumers themselves?

Another set of controversies results from the enormous size of PBMs and the high degree of concentration in the industry. In 2018, three PBMs (Express Scripts, CVS Health/Caremark, and OptumRX) accounted for 80 percent of prescription drug volume and six PBMs account for 95 percent of the prescription drug market (Fein, 2019; Feldman, 2020). The CVS-Health/Caremark PBM alone reports nearly 90 million members in its PBM business—and so negotiates on behalf of a customer population larger than the population of Germany (CVS Health, 2017). Do such large PBMs in a highly concentrated industry obtain lower drug prices on behalf of payers and consumers, or do they leverage their monopsony position to gain at the expense of consumers, health plans and branded drug makers?

We offer a microeconomic model of the role PBMs play in the prescription drug market that sheds light on these questions and controversies. Our model builds on three observations about the operation of PBMs. The first concerns the incentives implicit in formularies. Formularies assign branded drugs to tiers. If a branded drug is assigned to a generous tier, enrollees in the formulary pay little or nothing for the drug. Enrollees using drugs assigned to a less generous tier pay more. Thus branded drug makers who win a spot in a favored tier gain a boost in sales. Drug makers compete for a preferred spot on the formulary by offering per unit rebates off of the list price of the drug. From this perspective, tiered formularies have the same incentive structure as all-pay contests: the per unit rebates constitute the "bid" and the prize for winning the contest is a favored position in the formulary.

Our second observation is that PBMs are market intermediaries who have to offer value to both upstream branded drug manufacturers and downstream health plans or consumers. Branded drug makers will participate in formularies if doing so is at least as profitable as the alternative of selling at list price. Payers and consumers will, similarly, seek out formulary services to the extent that the formulary offers net prices below list. Any account of PBMs as market intermediaries must also explain why payers delegate formulary operation to large PBMs who act as a common agent for many payers.

2020). We do not include these auxiliary functions in our model of PBMs.

Our third observation concerns the high list prices of branded drugs sold on formularies administered by PBMs.[3] In a drug market without rebates, list prices are transaction prices. With rebates, however, few transactions may take place at list price. In an extension to our baseline model, we find that high list prices matter for overall market efficiency and consumer welfare even if very few transactions take place at list price.[4]

Our theoretical framework is stylized and abstract, but it nevertheless helps us understand formulary incentives, the PBM's role as intermediary and the importance of high list prices. As a result of their incentive structure, formularies are far more efficient than the alternative of selling branded drugs at their monopoly prices. Indeed under the simplifying assumptions in our baseline model, formularies are nearly first-best efficient. The surplus generated by these near-efficient contests could, in principle, improve consumer welfare or make more resources available to drug makers for innovation but instead they accrue as rents to PBMs. On this basis, the challenges PBMs pose for economic policy have more to do with distribution than static efficiency.

Our framework also offers insights into why a health plan would delegate the formulary function to very large PBMs who act as a common agent across many commercial and government payers. In an extension to our baseline model, we find efficiency gains when all the payers delegate the operation of the formulary to a single, very large, PBM. These efficiency gains are not the result of economies of scale or scope. Neither do they rely on any relationship between bargaining power and the size of the intermediary. Rather efficiency increases because a very large PBM can better internalize externalities resulting from the widespread use of most favored nation provisions that promise purchasers the lowest net drug price offered anywhere in the market.

Our analysis also clarifies the economic significance of list prices in the market for branded prescription drugs. The central insight is that rebates are available only for drugs sold on the formulary. Otherwise, branded drugs sell at their list price. Thus, when a branded drug maker sets a high list price for their drug they are, all else equal, increasing the value to consumers of purchasing the drug on the

[3] IQVIA Institute for Human Data Science (2020), for example, documents a growing disconnect between the list prices for branded drugs and their net price accounting for rebates.

[4] The term list price often refers to the Average Wholesale Price (AWP). A joke in the industry refers to AWP as "Ain't What's Paid," underscoring the divergence between list and transaction prices. As an empirical matter, previous studies suggest a significant number of insured Americans pay list price for at least some of their drugs because their health plan provides incomplete coverage. In addition, individuals who are uninsured for prescription drugs also pay list prices (Augustine et al., 2018).

formulary at a discount. If participating in the formulary becomes more valuable, the PBM can extract more value from consumers than would be possible with lower list prices. In an extension to our baseline model we find that in equilibrium, some branded drug makers will set list prices very far above monopoly prices, and PBMs will bias their formulary contest to favor such high list price branded drugs. Biased formularies make the pharmaceutical market less efficient and consumers less well off, while increasing the surplus accruing to PBMs and branded drug makers.

Finally our analysis of PBMs as a common agent for many payers sheds some light on the benefits of vertical integration. In the past several years, large PBMs have vertically consolidated with health insurers, including UnitedHealth Plans (health plan) with OptumRx (PBM), Aetna (health plan) with CVS Caremark (PBM), and Blue Cross Blue Shield plans (health plan) with PrimeTherapeutics (PBM). Vertical integration can enhance efficiency or it can be anti-competitive. Understanding which outcome prevails requires an institutionally informed applied theoretical model (Gaynor, 2006). In the case of mergers between an agent (the PBM) and its principal (the payer), the central theoretical issue is what problems a merger solves that aren't solved by a contract between the parties. In a setting where a PBM captures the joint surplus produced by itself and a payer, there is little economic reason to vertically integrate because there is an easy alignment of interests between principal and agent as separate entities. In a richer setting, a payer may want to induce the PBM to take actions that may benefit the payer but not the PBM. A payer may, for example, wish to promote the use of low price generic drugs that offer no rebates to PBMs. In a conventional principal-agent relationship, both parties would realize benefits from enhanced generic use and there would also be little reason to vertically integrate. Common agency, in contrast, can severely limit the use and effectiveness of such contracts. In this setting, vertical integration between a PBM and payers may benefit both parties without making the market less competitive.

We are not the first to observe that auction-like competition can help make markets for patented innovations more efficient. Kremer (1998), for example, proposes that governments offer to purchase patents at their estimated private value as determined by an auction. Selling these products to consumers at a price equal to marginal cost would eliminate monopoly price distortions while still providing innovation incentives. Formularies in our model similarly reduce monopoly price distortions to the extent that they offer copays for drugs that approximate marginal cost. Contrary to Kremer's analysis, however, the bidding for favorable formulary slots aims to generate large rebates rather than to elicit the branded drug maker's private information about the value of their product. Formularies more closely resemble the all-pay contests analyzed in Siegel (2009) in which players make irreversible bids

before the outcome of the competition is known.

Our primary theoretical contribution to the literature on contests is that we derive the equilibrium structure of prizes and rules for selecting winners when the contest is operated by a market intermediary. Creating value for both upstream and downstream players shapes equilibrium contest design for market intermediaries in ways that haven't been previously studied. So too does the contracting externality that causes payers to delegate formulary operations to a single large PBM who acts as a common agent for many payers.[5] We are not aware of any other formal models of contest design by market intermediaries.

The paper proceeds in four sections. In the next section we describe the PBM business model. Section 3 sets up our analytical framework. In Section 4, we present the baseline model in which a single third party payer designs the formulary and drug makers choose rebates for their branded drugs. In Section 5, we show the approximate efficiency of formularies by extending the model to include many branded drugs. In Section 6, we extend the model to allow for multiple payers and contracting externalities. Section 7 modifies the baseline model by allowing branded drug makers to endogenously determine both rebates and list prices. Section 8 discusses how vertical integration results from common agency. We conclude by discussing some broad policy implications of our results as well as directions for further research.

2 Institutional Setting: The PBM Business Model

PBMs are intermediaries between drug makers and payers, and operate formularies for their clients, health plans and other payers. Figure 1 offers a visual depiction of the PBM' s business model. For clarity this depiction is highly stylized and it omits a number of features of real-world markets. For example, we ignore the role played by large wholesale drug distributors such as McKesson. Similarly we omit the interactions between PBMs and pharmacies.

Branded drug manufacturers sell drugs to PBMs at a posted unit list price, but then provide a rebate for each purchase.[6] The list price minus the per unit rebate—what we call the net price—is the effective wholesale price that the PBM pays for each drug sale. When enrollees purchase a branded drug from the PBM, they pay a

[5]For a general analysis of contracting externalities see Segal (1999). For prior analyses of common agency in other aspects of healthcare see Frandsen et al. (2019); Glazer and McGuire (2002); Einav et al. (2020). The foundational analysis of the general theory of common agency is Bernheim and Whinston (1986).

[6]Market participants will sometimes refer to the list price as the Average Wholesale Price (AWP) or alternatively the Wholesale Acquisition Cost (WAC).

copay and also perhaps some coinsurance rate which is not presented in the Figure. The PBM bills the insurer the reimbursement price for the drug minus the amount that the enrollee already paid. In addition to copays, enrollees also pay insurance premiums and the coverage they receive entitles them to participate in the formulary and enjoy the drug subsidies that accompany insurance.

The contracts between health plans and PBMs are closely held trade secrets. We learned about these contracts from a sample of these contracts that we could examine directly, from the release of three government reports on PBM business practices (Grassley and Wyden, 2021; Government Accountability Office, 2019; Yost, 2018), and from some other reports (Feldman, 2019; Ciaccia, 2020). In the contracts and other reports we examined, drugs are assigned to different formulary tiers and the PBM commits to delivering these drugs to the payer at a discount off of the drug's unit list prices. A contract might, for example, commit the PBM to provide all branded drugs in the formulary to the payer at an average reimbursement price that is 11 percent below AWP. Suppose that the PBM's net price for branded drugs averaged 30 percet below list; then the PBM earns a profit equal to 19 percent of the list price on each unit of a branded drug sold.[7] Generics were supplied at prices even further below their unit list price on average—in the neighborhood of 50 percent below list.[8]

In the industry, the difference between the reimbursement price of the drug and the net price accounting for rebates at which the PBM acquires the drug is called the spread. The spread on branded drugs is generally presumed to be an important source of PBM profits. Industry reports estimate that the total value of manufacturer's gross-to-net reductions for brand name drugs was $175 billion in 2019—of which about two-thirds comes from rebates (Fein, 2020).[9]

Finally, the U.S. prescription drug industry features most favored nation rules (MFNs). MFNs are provisions that guarantee purchasers the lowest net price offered to any purchasers of the drug. There are two types of MFNs that are relevant to our work, those that originate from administrative pricing rules and those that

[7]The contracts also specified a different average reimbursement price for generic drugs.

[8]Many contracts also contain commitments to dispense the majority of drugs as generics rather than brands. These contract features are called "generic effective rates" and are calculated in aggregate across all dispensed drugs. The contracts we examined also included per member fees and transaction charges to payers for the handling of drugs. These charges differ depending on whether the drug order was filled by mail order, in house, or other pharmacies. Fees can be paid per unit of drug sold or in aggregate. Industry reports suggest these fees may be a growing source of revenues for PBMs. (Feldman, 2020; Fein, 2017). We do not include these fees in our analysis.

[9]PBMs can also make money on a variety of fees which are not set to reflect any specific drug's list price or sales volume.

originate in contracts between private actors. Administrative pricing rules entitle safety net providers to the lowest prices on prescription drugs. The most important of these sets of rules is the Medicaid Prescription Drug Rebate Program (MDRP) (Scott Morton, 1996; Congressional Budget Office, 2005). In 1990 the Federal Government included a Most Favored Customer (MFC) clause in the contract (OBRA 90) which would govern the prices paid to firms for pharmaceutical products supplied to Medicaid recipients. Under the program, a drug maker who wants its drug covered under Medicaid must enter into a rebate agreement with the Secretary of Health and Human Services stating that it will rebate a specified portion of the Medicaid payment for the drug to the states, who in turn share the rebates with the federal government. Drug makers must also enter into agreements with other federal programs that serve vulnerable populations. In exchange, Medicaid programs cover nearly all of the drug maker's FDA-approved drugs, and the drugs are eligible for federal matching funds.[10] State Medicaid programs provide coverage for prescription drugs for those who qualify. As of August 2020, the Medicaid program enrolled over 75 million individuals—roughly one in five Americans (Centers for Medicare and Medicaid Services, 2020).[11] The Medicaid rebate amount is set in statute and ensures that the program gets the lowest price (with some exceptions).[12]

Medicaid's MDRP influences prices paid by other payers for a branded drug. A

[10]Though the pharmacy benefit is a state option, all states cover it, but, within federal guidelines about pricing and rebates, administer pharmacy benefits in somewhat different ways.

[11]Medicaid enrollees are diverse in their reasons for eligibility and medical needs: Medicaid covers many infants, children, pregnant women, and some parents of Medicaid eligible children, but also many people with disabilities, and elderly people with very low incomes. The ACA expanded Medicaid coverage of low-income, non-disabled, childless adults. The Affordable Care Act (ACA) made significant changes to the MDRP. The law increased the rebate amount for both brand drugs and generic drugs. It also extended rebates to outpatient drugs purchased for beneficiaries covered by Medicaid managed care organizations (MCOs). Previously only drugs purchased through Medicaid fee-for-service were eligible for rebates even though most states contract with MCOs to provide services to Medicaid beneficiaries.

[12]The formula for rebates varies by type of drug: brand or generic. The rebate formula is the same regardless of whether states pay for drugs on a fee-for-service basis or through payments to managed care plans. The specific rebate on a given drug is considered proprietary. For brand name drugs, the rebate is 23.1 percent of average manufacturer price (AMP) or the difference between AMP and "best price," whichever is greater. Certain pediatric and clotting drugs have a lower rebate amount of 17.1 percent. Best price is defined as the lowest available price to any wholesaler, retailer, or provider, excluding certain government programs, such as the health program for veterans. AMP is defined as the average price paid to drug makers by wholesalers and retail pharmacies. For generic drugs, the rebate amount is 13 percent of AMP, and there is no best price provision. Drug makers must report AMP for all covered outpatient drugs to HHS and report their best price for brand name drugs. HHS uses this price data to calculate the unit rebate amount (URA) based on the rebate formula and inflationary component and provides the URA to states. States multiply the

recent Congressional investigation of drug pricing stated "Internal memoranda and correspondence collected for this investigation suggest that manufacturers seek to avoid triggering Medicaid 'best price' when developing their bids for commercial plans (Grassley and Wyden, 2021, p.68)."[13]

The MDRP is the basis of at least one other most favored nation rule governing prescription drugs, 340B drug discounts (Conti et al., 2019). As a condition of participation in the Medicaid Drug Rebate program, drug makers must also participate in the Federal 340B program. The 340B program offers discounted drugs to certain safety net providers that serve vulnerable or underserved populations, including Medicaid beneficiaries. 340B ceiling prices are calculated to match Medicaid prices net of the rebate (Dolan, 2019). Arguably, the 340B drug discount is more important than the Medicaid MFN, because many more drug purchases are entitled to 340B discounts than Medicaid rebates. The U.S. Government Accountability Office estimated that more than 50 percent of total sales of some drugs were 340B eligible (2015).

In addition to administratively based rules, many contracts between drug makers and PBMs are reported to have MFN clauses. While the contracts between drug makers and PBMs are closely guarded trade secrets, details are sometimes made available in litigation—often in contractual disputes between PBMs and drug makers when "best price" is at issue. We learned from discussions with lawyers and economists who have been intimately involved in such litigation that MFN clauses are common. Specifically, the contracts between PBMs and drug makers will state that the PBM is entitled to rebate amounts that reflect the contracts drug makers make with their peers.[14] These arrangements are also described in Feldman and Frondorf (2017) and Feldman (2019).

3 Model Setup

Our model describes a stylized setting in which multiple makers of branded drugs sell their products on formularies run by intermediaries. The intermediaries in our setup are either health insurers (payers) or a PBM hired by the payers. In either case, customers must enroll in an insurance plan and pay the plan's premium to

units of each drug purchased by the URA and invoice the drug maker for that amount. Drug makers then pay states the statutory rebate amount as well as any negotiated supplemental rebates.

[13]Earlier studies of the MDRP program have found that MDRP modestly increased the price of some drugs Scott Morton (1996)

[14]These clauses tend to be included in the first contract with the drug maker, but may not be mentioned in the contract renewals or "amendments."

gain access to drugs sold on the formulary. Drug makers compete for a favorable formulary position by offering higher rebates, i.e., by lowering the net price at which they sell drugs to the intermediary.

3.1 Drug Makers

Each drug maker produces a drug targeted at a distinct disease. The drugs are produced at zero marginal cost, but each is patent protected so that the drug maker is a monopolist in its own product market.[15] Drug maker i has a list price, $\bar{p}_i$ at which it sells its drug to the uninsured who lack access to a formulary. We initially treat the list prices as exogenous, but allow them to be chosen endogenously in an extension to the basic model.

Drug makers compete for a favorable position in the formulary by selling drugs to the intermediary at a net price that is below their list price. Thus the net price for drug i is $p_i \leq \bar{p}_i$. The difference between the list price and the net price at which the drug is sold to the formulary is the per unit rebate. Because the drugs treat separate and unrelated diseases, each drug's demand is independent of the other's—clinically they are neither substitutes nor complements.[16] Drug makers choose prices to maximize profit, which is equal to the net price times the quantity of drug sold. The quantity, of course, depends on the copay in the formulary tier to which the intermediary assigns the drug. In most of our analyses there are two drug makers; in an extension we also consider the general case with $m \geq 2$ drug makers.

3.2 Payers, PBMs, and Formularies

Each payer is also assumed to be a monopolist in its market. Payers receive a premium payment, p_0, from enrollees, and subsidize drug transactions on the formulary. The magnitude of the per transaction subsidy is the difference between the price they are charged for the drug and the copay in the formulary tier to which the drug is assigned.

Should payers themselves act as the intermediary between drug makers and consumers, they are charged the net price for each drug. When a payer delegates oper-

[15] Here we follow Scherer (1993); Scott Morton (1999, 2000); Grabowski and Vernon (1992) in treating drug makers as monopolists in their own market.

[16] This assumption simplifies our model of the competition for formulary tiers. For example, if two drugs were imperfect substitutes and both landed in a favorable tier, one might expect drug makers to encourage the PBM to promote one drug or another through additional discounts linked to sales volume. Indeed these sort of discounts are reported by industry observers as in Feldman (2020). Our current setup abstracts from these concerns.

ation of the formulary to a PBM, the flow of funds is altered. The PBM pays the net price for the drugs to the drug maker but charges the payer a (possibly higher) reimbursement price, r_i, for drug i. When a consumer purchases a drug, he or she pays a copay to the PBM. The PBM then charges the payer the difference between the reimbursement price and the copay. By setting a high reimbursement price, the PBM can transfer surplus from the payer to itself.

In some versions of our model, payers will operate the formulary and in others the PBM takes on this role. Indeed part of the purpose of the model is to explain why payers may delegate the formulary function to PBMs. The entity in charge of the formulary specifies a copay amount for each tier: c_L is the copay for the "low" or favorable tier, and c_H is the copay for the "high" or unfavorable tier. The formulary operator also decides the rules assigning drugs to tiers. The greater the difference in copays across tiers, the greater the value to the drug makers of winning a favorable formulary position. As we will show, the formulary assigns drugs to tiers by comparing the net prices (or equivalently, rebates) offered by the drug companies. In this way, the formulary creates an "all-pay" contest where the bidding takes the form of drug makers offering rebates off of list prices. Abusing notation slightly, we denote the copay assigned to drug d by c_d, where c_d takes on the value c_L if drug d was assigned to the generous tier, or c_H otherwise.

When a payer is the intermediary, it chooses the premium p_0, copays c_L and c_H, and drug tier assignments that maximize its profit. Payer profit in this case is equal to the revenues they get from premiums minus the cost of drug subsidies. Drug subsidy costs are the product of net price minus copay and the volume of drug sold.

3.3 Consumers

Consumers purchase health insurance when healthy and then become patients in need of treatment. Treatments take the form of purchasing one of the two branded drugs, depending on which illness becomes manifest. We model uncertainty over the type of medical condition as a discrete random variable $D \in \{1, \ldots, m\}$ with $\Pr(D = i) = 1/m$ for $i \in \{1, \ldots, m\}$. Consumer willingness to pay for the treatment depends on illness severity, which we denote by random variable V with complementary cdf denoted by $q(p) := \Pr(V > p)$, independent of D. We refer to $q(p)$ as the consumer demand function and assume that it is strictly downward sloping and differentiable on the support of V. In some illustrative special cases we assume it is uniform on the unit interval, which corresponds to a linear demand curve. Our baseline model does not rely on this assumption.

Consumers who purchase insurance pay a premium p_0 to gain access to the for-

mulary. If the drug that becomes relevant for their condition ends up in the generous tier, the consumer pays the low copay, c_L. If the relevant drug is in the other tier, they pay a high copay, $c_H \geq c_L$. Thus consumers using the formulary face a two-part pricing schedule for accessing drugs: an upfront fixed premium and a copay per unit of drug purchased. Contrary to conventional two-part pricing, however, the marginal cost of the drug to the formulary is endogenous to the copays the intermediary assigns to the formulary tiers.

Consumers, regardless of insured status, also have the option to purchase a drug at its list price out of pocket. In our baseline model, we assume that these list prices are identical and exogenously determined to be $\bar{p}$. In subsequent sections we relax this assumption in order to examine more fully the economics of list prices.

Consumers decide whether to purchase health insurance and whether to purchase a drug by maximizing expected utility. Utility is equal to V minus the sum of the amount paid for the drug (if he or she purchases the drug relevant to his or her clinical condition) and the premium (if he or she purchases insurance coverage), and zero otherwise.

We make two other noteworthy assumptions regarding consumers. The first is that they are all identical before their health shocks are realized. This assumption rules out any problems with adverse selection. The second assumption may seem more unusual given the centrality of insurers to the model—consumers are all assumed to be risk neutral. Why do risk neutral consumers purchase health insurance at all? Because insurance subsidizes consumer drug purchases.[17]

4 Baseline model: Payer operates the formulary

In the baseline model, a single payer operates a formulary with two tiers. We develop the model in two steps. First we solve for the equilibrium when two drugs compete for a single slot in the favorable formulary tier. We then allow for $m \geq 2$ drugs. This extension allows us to analyze how many "slots" the payer will create for drugs in the favored tier. As we shall see, as the number of slots allowed in the generous tier increases, the closer the formulary approximates efficient two part pricing for patented drugs.

In our baseline model, the list prices for drugs are exogenously set to $\bar{p}$, the monopoly price of the drug. The timing is as follows:

[17] Assuming that consumers were either risk averse (Rothschild and Stiglitz, 1976; Zeckhauser, 1970) and / or liquidity constrained (Ericson and Sydnor, 2018) would greatly complicate the model without altering the basic message. Risk aversion and liquidity constraints would likely have the effect of reducing the less generous copay on the formulary.

1. the payer chooses the formulary copays c_L and c_H;
2. drug makers set net prices p_1 and p_2;
3. the payer assigns drugs to formulary tiers and sets the premium, p_0;
4. consumers decide whether to purchase insurance;
5. nature chooses the consumer's medical condition, D, and its intensity, V;
6. consumers decide whether to purchase the drug relevant to their condition.

4.1 Equilibrium

We describe each player's equilibrium strategy by working backwards. Consumers decide whether to purchase a drug, taking list prices, copays, tier assignments, their health insurance enrollment decision, their medical condition D, and its intensity V as given. Consumers who enrolled in insurance purchase the drug corresponding to their medical condition if either the copay or the list price is less than their willingness to pay for the drug, V. Consumers who do not enroll in insurance purchase the drug if the list price is less than V. Consumers decide whether to enroll in insurance taking list prices, copays, tier assignments, and the premium as given. Consumers enroll in insurance if their expected utility with insurance exceeds their expected utility without insurance by the amount of the premium. Expected utility without insurance is

$$U_0 := E\left[(V - \bar{p})\, 1\left(V > \bar{p}\right)\right].$$

Expected utility with insurance is

$$U_1 = \frac{1}{2}\sum_{i=1}^{2} E\left[(V - \min\left\{c_i, \bar{p}\right\})\, 1\left(V > \min\left\{c_i, \bar{p}\right\}\right)\right].$$

The following lemma formalizes the consumer's equilibrium strategies.

Lemma 1 (**Consumer insurance and drug purchase decisions**). *In the baseline model with the payer operating the formulary, in every subgame-perfect Nash equilibrium, drug purchasing and insurance enrollment decisions are as follows. Consumers who enrolled in the insurance plan and have medical condition $D = d$ purchase drug d if and only if $V \geq \min\left\{c_d, \bar{p}\right\}$. They purchase it through the formulary if $c_d \leq \bar{p}$ and out-of-pocket otherwise. Consumers who did not enroll in insurance purchase drug d if and only if $D = d$ and $V \geq \bar{p}$. Consumers enroll in insurance if and only if*

$$p_0 \leq U_1 - U_0. \tag{1}$$

Next, consider the payer's choice of premium and tier assignment. The payer chooses the premium taking list prices, net prices, and the tier assignment as given, and does so to maximize its expected profit, which is equal to the premium minus drug subsidies,

$$\pi_{\text{payer}}(p_0, c_1, c_2, p_1, p_2) = p_0 - \frac{1}{2}\left((p_1 - c_1)\, q(c_1) + (p_2 - c_2)\, q(c_2)\right),$$

if consumers purchase insurance, and equal to zero otherwise. The payer will set the premium so the consumer's enrollment condition, (1), binds, if the profit from doing so is nonnegative; otherwise it will set a premium that is higher, resulting in a profit of zero. The payer makes the tier assignment taking list prices and net prices as given. The payer assigns drug 1 to the generous tier (that is, sets $c_1 = c_L$ and $c_2 = c_H$) if the profit from doing so is greater than the profit from setting $c_2 = c_L$ and $c_1 = c_H$. That is, drug 1 is assigned to the generous tier if and only if

$$\pi_{\text{payer}}(p_0, c_L, c_H, p_1, p_2) \geq \pi_{\text{payer}}(p_0, c_H, c_L, p_1, p_2).$$

This turns out to be satisfied if and only if $p_1 \leq p_2$. The following lemma formalizes these results.

Lemma 2 (**Payer's choice of premium and tier assignment**). *In the baseline model with the payer operating the formulary, in every subgame-perfect Nash equilibrium, strategies for premium and tier assignment are as follows. The payer sets premium $p_0 = U_1 - U_0$ if*

$$\pi_{payer}(U_1 - U_0, c_1, c_2, p_1, p_2) \geq 0 \tag{2}$$

and $p_0 > U_1 - U_0$ otherwise. The payer assigns drug 1 to the generous tier (that is, sets $c_1 = c_L$ and $c_2 = c_H$) if and only if $p_1 \leq p_2$.

Next, each drug maker takes list prices and copays as given and sets its net price to maximize expected profit, anticipating, of course, the resulting tier assignment. Drug maker 1's expected profit as a function of p_1, taking p_2 as given is

$$\pi_1(p_1; p_2) = \begin{cases} \frac{1}{2} p_1 q(c_L) & , \quad p_1 \leq p_2 \\ \frac{1}{2} p_1 q(c_H) & , \quad p_1 > p_2 \end{cases},$$

provided the payer's participation condition (2) is satisfied and $\bar{p}q(\bar{p})/2$ otherwise. Drug maker 2's profit is similar. Because $q(c_L) > q(c_H)$ whenever $c_L < c_H$ (as will be the case in equilibrium), a drug maker's profit discretely increases as it undercuts

the other drug maker's net price. Consequently, there will be no pure strategy equilibrium.[18] Drug makers 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 winning the formulary contest is equal to the profit from setting a maximal price ($\bar{p}$) and losing. The following lemma characterizes the mixed strategy equilibrium at this stage of the game.

Lemma 3 (**Drug net price equilibrium distribution**). *In the baseline model with the payer operating the formulary, 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_L and c_H:*

$$F\left(p; c_L, c_H\right) = \begin{cases} 0 & , \quad p < \bar{p}\frac{q(c_H)}{q(c_L)} \\ \frac{q(c_L)-\frac{\bar{p}}{p}q(c_H)}{q(c_L)-q(c_H)} & , \quad \bar{p}\frac{q(c_H)}{q(c_L)} \leq p < \bar{p} \\ 1 & , \quad p \geq \bar{p} \end{cases}.$$

Note that modal price in the equilibrium cumulative net price distribution is also the lowest price in the support:

$$\underline{p} = \bar{p}\frac{q\left(c_H\right)}{q\left(c_L\right)}.$$

The formulary structure is identical to an all-pay contest in which drug companies bid by offering a low net price and the copays determine the size of the prize. The greater the demand for the drug at the generous copay and the smaller the demand at the non-generous copay, the greater the incentive to offer a low net price. The following lemma formalizes this effect of the formulary copays on the equilibrium net price distribution.

Lemma 4 (**Effect of copays on drug net price distribution**). *The equilibrium net-price distribution is stochastically increasing in c_L and stochastically decreasing in c_H.*

[18] Mixed strategies are a general feature of all-pay auctions (Siegel, 2009). Intuitively, suppose both companies offered the same price and so were equally likely to be in either tier. One drug maker could break the equilibrium by undercutting the other's price and getting placed in the generous tier. This logic holds for a drug price above zero. Zero is not an equilibrium either because at this point neither company is making positive profits. One company could therefore increase their profits by offering a positive price and being placed in the less generous tier. By similar reasoning, there is also no asymmetric pure strategy equilibrium where the two companies offer different prices. The lower priced drug can break the equilibrium by slightly raising prices. Their profits increase and they win the generous tier.

A consequence of the lemma is that the payer can induce lower net prices for drugs by increasing the spread between the generous and nongenerous copays. However, increasing the spread introduces inefficiency because the socially optimal copays would be set equal to the marginal cost of each drug and marginal cost is assumed to be zero. Increasing the spread between copays also affects other determinants of the payer's profit: raising c_H reduces the value of insurance coverage and thus reduces premium revenue; lowering c_L reduces copay revenue. The payer's optimal choice of c_L and c_H navigates these tradeoffs and (as we show formally in the proposition below) results in a socially inefficient (but profit-maximizing) spread between the generous and non-generous copay. The following lemma describes the optimal copays for the payer.

Lemma 5 (**Optimal copays**). *Suppose* $\bar{p} \leq q^{-1}(0)$. *Then the profit-maximizing choices of copays are* $c_L = 0$ *and* $c_H = \bar{p}$.

In summary, in the baseline model where the payer operates the formulary, the equilibrium formulary consists of a generous tier with a copay of zero and a non-generous tier with a copay equal to the list price; drug makers compete for the favorable position on the formulary by offering a distribution of net prices, or, equivalently, rebates; and the payer sets the premium to extract surplus from consumers. To build intuition for these and subsequent results the next section offers a graphical representation of the model.

4.2 Graphical Representation of the Formulary

We can build intuition for the model by representing it graphically in the special case of a linear demand curve ($q(p) = 1 - p$). The main economic forces in the model are captured in the tradeoff the intermediary faces in setting the formulary copays. Figure 2 illustrates several aspects of this tradeoff, plotting total surplus and combined drug profit and consumer surplus as functions of the generous copay, c_L, holding c_H fixed at $\bar{p}$. The difference between the two curves is the payer's profit. Reducing the generous copay has several countervailing effects on the profit produced by the formulary. First, reducing the copay increases drug purchases, which increases total surplus, as shown in the solid blue curve in Figure 2. This also increases the value of insurance, which the payer captures by charging higher premiums. Consumer surplus is thus unaffected by the payer's choice of copays. Reducing the generous copay also increases the value to drug makers of winning the formulary contest. This potential benefit to drug makers is competed away as drug makers offer a stochastically lower distribution of net prices, as shown in Lemma

4. In equilibrium therefore drug makers always receive a payoff equal to what they would earn if they lose the tournament and are assigned to the unfavorable tier. For this reason, drug maker profit is also unaffected by payer's choice of copays. The constant consumer surplus and drug maker profit is represented by the horizontal dashed red curve in the figure. The difference between the two curves is the payer's profit from operating the formulary. Because total surplus increases as the favorable copay becomes more generous, while consumer surplus and drug maker profit remain flat, the payer's profit is maximized at $c_L = 0$.

5 Formularies with Many Drugs: Approximately Efficient

Intermediaries in the drug market can attract consumers and drug makers because the formulary generates a larger economic surplus than the alternative of drug makers selling directly to consumers at monopoly prices. Indeed, if this were not so, it would be hard to explain the presence of intermediaries in the drug market.

In principle, intermediaries could generate even more surplus by adopting an efficient two-part pricing strategy where consumers pay a premium for access to the formulary plus a copay equal to the marginal cost of each drug (which in our model is zero). In the previous section, however, we showed this was not the case in our baseline model: instead, the payer sets one of the copays to the list price which is set at the monopoly price. The result is some deadweight loss. Some consumers with willingness to pay higher than the marginal cost of producing the drug do not receive the drug.

The inefficiency of our formulary is entirely due to the high copay for the drug assigned to the non-generous tier. This raises the question of how many slots the payer will optimally create for drugs in the non-generous tier. Extending our model to the case where there are many drugs we find that in equilibrium only one drug is assigned to the non-generous tier. The remaining drugs are sold using the efficient two part pricing. This result suggests that formulary tournaments are "approximately" efficient. Indeed, when the clinical conditions treated by the drugs are equally distributed in the population, the allocation approaches full efficiency as the number of drugs grows.

The timing of the model extension with $m \geq 2$ drugs is as follows:

1. the payer chooses the copays associated with each of m formulary tiers, $c_1 \leq c_2 \leq \cdots \leq c_m$;

2. drug makers set net prices $p_1, \ldots, p_m$;

3. the payer assigns drugs to formulary tiers and sets p_0;

4. consumers decide whether to purchase insurance;

5. nature chooses the consumer's medical condition, $D \in \{1, \ldots, m\}$, and its intensity, V;

6. consumers decide whether to purchase the drug.

We assume the medical condition D is distributed uniformly over the m medical conditions, so that $\Pr(D = i) = 1/m$, for $i \in \{1, \ldots, m\}$. The payer's assignment of drugs to tiers is formally a choice of permutation, t, on $\{1, \ldots, m\}$, so that the copay charged to a consumer for drug i is $c_{t(i)}$.

As before, we describe each player's equilibrium strategy working backwards. Consumers' drug purchasing decisions and insurance enrollment decisions are unchanged from the baseline case (see Lemma 1); that is, the consumer enrolls if the premium is less than the utility surplus from insurance:

$$p_0 \leq U_1 - U_0,$$

where the only change is that now the expression for utility under insurance accommodates several drugs:

$$U_1 = \frac{1}{m} \sum_{i=1}^{m} E\left[\left(V - \min\left\{c_{t(i)}, \bar{p}\right\}\right) 1\left(V > \min\left\{c_{t(i)}, \bar{p}\right\}\right)\right].$$

The payer's choice of premium is also unchanged:

$$p_0 = U_1 - U_0,$$

as long as its profit is positive. Tier assignment is similar to the baseline case: drugs are placed in tiers in order of their net prices, as the following lemma states.

Lemma 6 (**Tier assignment with m drugs**). *The equilibrium tier assignment t sorts drugs by net prices; that is, t is the permutation on $\{1, \ldots, m\}$ such that for any i and i' in $\{1, \ldots, m\}$,*

$$p_i < p_{i'} \Longrightarrow t(i) < t(i'),$$

and ties are broken randomly.

Like the two-drug case, the formulary structure induces an all pay contest among the drug makers in which net prices are chosen according to a symmetric mixed strategy equilibrium, as the following result shows.

Lemma 7 (**Equilibrium net-price distribution with m drugs**). *There exists a symmetric equilibrium. Any symmetric equilibrium involves continuously mixed strategies with an interval support $\left[\underline{p}, \bar{p}\right]$ for some $\underline{p} < \bar{p}$, where $\bar{p}$ is the list price.*

As in the two-drug case, lower copays in more favorable formulary tiers provide the incentive for drug companies to offer discounts off list price to the intermediary. Lower copays also increase the value of insurance, and thus premium revenue, but also increase drug subsidy costs. The payer's profit-maximizing choice of copays sets the least-favorable copay to the list price, and the remaining to zero, as the following lemma shows.

Lemma 8 (**Equilibrium copays with m drugs**). *Equilibrium copays with m drugs are as follows:*

$$\begin{aligned} c_1 &= c_2 = \cdots = c_{m-1} = 0; \\ c_m &= \bar{p}. \end{aligned}$$

The fact that all but one of the drugs are assigned a copay of zero means the equilibrium is approximately efficient: as the number of drugs m increases, the equilibrium converges to full efficiency. The following proposition formalizes this result.

Proposition 1 (**Formulary equilibrium is approximately efficient**). *The symmetric subgame-perfect Nash equilibrium with m drugs yields total surplus*

$$TS = E\left[V\right] - \frac{1}{m} E\left[1\left(V \leq \bar{p}\right) V\right].$$

Because the first-best surplus is $E\left[V\right]$, the result means that as m increases, equilibrium surplus converges to full efficiency. For any given number of drugs, m, however, the equilibrium is inefficient. The inefficiency stems entirely from the drug assigned to the least favorable tier where the copay is nonzero. Why doesn't the intermediary assign all drugs to a tier with a copay of zero and thereby achieve a fully efficient equilibrium? The reason is that the possibility of being relegated to an unfavorable tier, even if the probability is only $1/m$, induces drug makers to offer substantial rebates off of list price, increasing profit for the intermediary. If all tiers had a copay of zero, drug makers would offer no rebates.

6 Why Do Payers Delegate Formulary Operations to a PBM Acting as a Common Agent for Many Payers?

We have argued that formularies generate economic surplus relative to the alternative of selling drugs at monopoly prices. Nothing in our analysis so far suggests that these formularies need to be operated by PBMs. In this section we pose the following question: why would payers delegate such a critical and potentially profitable function to a PBM acting as a common agent for many payers?

Our answer builds on a contracting externality found in pharmaceutical markets, most favored nation (MFN) clauses. As described in Section 2, MFN clauses require that the net prices offered to a specific purchaser be at least as low as those offered to any other purchaser in the market. MFN clauses create the following externality. If one formulary manages to win lower average net drug prices, the average net drug prices offered to other formularies with MFN clauses in their contracts must also decline. Since higher powered incentives are costly to the formulary operator, when the formulary does not capture all the benefits of a reduction in net prices, equilibrium formulary incentives are weakened. Weaker formulary incentives increase average net drug prices and also reduce the efficiency of drug markets. Large PBMs acting as a common agent for many payers can better internalize this externality. As a result, equilibrium incentives become more powerful, average net drug prices fall and market efficiency increases. These efficiency gains favor delegation of formulary operations to PBMs acting as a common agent for many payers.

Industry observers typically assert that MFN clauses are widespread, but the terms of these contracts are closely held secrets and so these assertions are rarely based on direct knowledge. We have consulted, however, with economists and lawyers who work directly with these contracts and they confirm that MFN clauses are ubiquitous. In addition to these private contractual clauses, Medicaid and the 340B program have statutorily mandated MFN clauses, as described in Section 2. These also introduce contracting externalities because purchasers under these programs use the same PBMs.

In what follows we analyze the effects of this contracting externality in detail. We first consider the case with several payers and no PBM, and then the case with a single PBM acting as a common agent. In both cases we revert to our baseline assumptions that there are only two drugs and that the list prices for these drugs are exogenously set to $\bar{p}$.

6.1 Equilibrium with Several Payers: Contracting Externalities in the Absence of PBMs

We return to the baseline model with two drugs but extend it to two payers, indexed by $j \in \{1, 2\}$. Each payer is a monopolist in its own segment of the insurance market and serves consumers with mass $1/2$. The timing is as follows:

1. Each payer $j \in \{1, 2\}$ sets formulary copays c_L^j and c_H^j;
2. drug makers set net prices p_1 and p_2;
3. each payer assigns drugs to formulary tiers and sets p_0^j;
4. consumers decide whether to purchase insurance;
5. nature chooses the consumer's medical condition, $D \in \{1, 2\}$, and its intensity, V;
6. consumers decide whether to purchase the drug.

At each stage, these choices are made simultaneously and noncooperatively with the other payer. To reflect the existence of MFN clauses or other frictions, drug makers continue to set net prices p_1 and p_2, which apply to all payers. As before, we describe each player's equilibrium strategy in the usual way, working backwards. Consumers' drug purchasing decisions and insurance enrollment decisions are unchanged from the single payer case (see Lemma 1), except naturally consumers in payer j's market make their decision based on p_0^j, c_1^j and c_2^j. That is, a consumer in payer j's market enrolls in insurance if and only if

$$p_0^j \leq U_1^j - U_0,$$

where

$$U_1^j = \frac{1}{2} \sum_{i=1}^{2} E\left[\left(V - \min\left\{c_i^j, \bar{p}\right\}\right) 1\left(V > \min\left\{c_i^j, \bar{p}\right\}\right)\right].$$

Each payer's choice of premium and tier assignment also unchanged from the result in Lemma 2: payer j's premium is

$$p_0^j = U_1^j - U_0,$$

as long as its profit is positive, and it assigns $c_1^j = c_L^j$ and $c_2^j = c_H^j$ if $p_1 \leq p_2$.

Drug makers' net price choices are similar, except drug maker profit now depends on the aggregation of consumer demand for the drug across each payer's copays. Drug maker 1's profit as a function of its own net price, taking drug 2's net price as given is

$$\pi_1(p_1; p_2) = \begin{cases} \frac{1}{2} p_1 \bar{q}(\mathbf{c}_L) & , \quad p_1 \leq p_2 \\ \frac{1}{2} p_1 \bar{q}(\mathbf{c}_H) & , \quad p_1 > p_2 \end{cases},$$

where $\bar{q}(\mathbf{c}_L) = \left(q\left(c_L^1\right) + q\left(c_L^2\right)\right)/2$ and $\bar{q}(\mathbf{c}_H) = \left(q\left(c_H^1\right) + q\left(c_H^2\right)\right)/2$. Similar to the single-payer case described in Lemma 3, drug makers set net prices in a mixed strategy equilibrium with the following cumulative distribution:

$$F(p; \mathbf{c}_L, \mathbf{c}_H) = \begin{cases} 0 & , \quad p < \bar{p}\frac{\bar{q}(\mathbf{c}_H)}{\bar{q}(\mathbf{c}_L)} \\ \frac{\bar{q}(\mathbf{c}_L) - \frac{\bar{p}}{p}\bar{q}(\mathbf{c}_H)}{\bar{q}(\mathbf{c}_L) - \bar{q}(\mathbf{c}_H)} & , \quad \bar{p}\frac{\bar{q}(\mathbf{c}_H)}{\bar{q}(\mathbf{c}_L)} \leq p < \bar{p} \\ 1 & , \quad p \geq \bar{p} \end{cases}.$$

The payers' choices of formulary copays c_L^j and c_H^j are different from the single payer case, however. The reason is that an individual payer's choice of formulary tier copay has less influence on drug prices, because drug prices respond only to the aggregate incentives provided by all payers. As a result the marginal benefit of setting a low generous copay (which encourages drug makers to set low net prices) decreases with the number of payers. The following proposition formalizes this.

Proposition 2 (**With multiple payers, contracting externalities increase the generous copay, reduce payer profits, and reduce total surplus**). *In any symmetric equilibrium, the generous copay c_L is greater than zero, and total payer profit and total surplus are lower than in the one-payer case.*

The proposition states that when multiple payers operate their own formularies, contracting externalities weaken incentives for drug makers to lower prices and reduce total profit to the payers. Figure 3 illustrates the effect of these externalities in the special case of linear demand when we go from $n = 1$ payer to $n = 2$ payers. The blue line in the drawing depicts total surplus generated by pharmaceutical sales. The red dashed line represents the combined consumer surplus and drug maker profit. The black dashed curve shows combined consumer surplus, drug maker expected profit, and the other payer's profit. Consumer surplus and drug maker profit do not depend on the generous copay. The premium extracts all consumer surplus beyond the outside option which is determined by the list price. Drug maker expected profit in the formulary tournament is determined by the "loser's" reward, which is a function of the non-generous copay only. The difference between the black and the red curves is the other payer's profit, which increases as the one payer's generous copay becomes

more generous. This reflects the contracting externality: as one payer's generous copay falls, other payers benefit from lower net drug prices. Because formularies do not capture the full benefit of lower drug prices, the payer's profit is no longer maximized at $c_L = 0$, but rather at a strictly higher value. Higher generous copays also reduce consumers' consumption and consequently reduce efficiency.

6.2 PBM Acting as a Common Agent Internalizes the Externality

The previous section found that when several payers operate their own formularies, externalities lead to reduced profits, high drug net prices, and lower total surplus. In this section we consider how a PBM acting as a common agent for many payers can internalize the externality and so raise joint profits among payers and the PBM, and improve market efficiency. To make this argument we introduce a single PBM that operates a formulary on behalf of many payers. The PBM specifies copays, assigns drugs to tiers, and sets reimbursement prices r_1 and r_2 which payers must remit to the PBM for each drug transaction.

An important feature of this version of the model is that the price of drugs to payers (reimbursement prices) may differ from the net price a drug company charges the PBM. Indeed the spread between reimbursement prices and net prices is an important source of profits for PBMs. A second key feature is that the PBM offers a contract to each payer in which the payer delegates operation of the formulary to the PBM in exchange for a transfer. The contract offer to each payer is contingent on all other payers accepting the contract. This set up allows for the possibility of trivial equilibria in which all or some payers refuse the contract. We focus our analysis on the principal's preferred equilibrium in which all payers accept the contract (Segal, 1999). We continue to assume that there are only two drugs and that list prices are set exogenously at the monopoly price of the patented drugs. The timing of events is as follows:

1. the PBM simultaneously offers a contract to each payer in which the payer delegates formulary operation to the PBM and the PBM in exchange makes a transfer of π_0 to each payer; each payer chooses whether to accept the PBM contract or to reject in favor of acting as its own intermediary;

2. the PBM chooses the formulary copays c_L and c_H; these copays are common for all payers contracting with the PBM;

3. drug makers set net prices p_1 and p_2;

4. the PBM assigns drugs to formulary tiers and sets reimbursement prices r_1 and r_2;

5. the payer sets the premium p_0;

6. consumers decide whether to purchase insurance;

7. nature chooses the consumer's medical condition, D, and its intensity, V;

8. consumers decide whether to purchase the drug.

As before, consumers purchase insurance if the premium is less than the utility gain from doing so:

$$p_0 \leq U_1 - U_0,$$

where utilities are the following:

$$\begin{aligned} U_0 &= E\left[(V - \bar{p})\, 1\left(V > \bar{p}\right)\right] \\ U_1 &= \frac{1}{2}\sum_{i=1}^{2} E\left[(V - \min\left\{c_i, \bar{p}\right\})\, 1\left(V > \min\left\{c_i, \bar{p}\right\}\right)\right]. \end{aligned}$$

The payer chooses the premium to maximize its profit:

$$\pi_{\text{payer}}\left(p_0, c_1, c_2, r_1, r_2\right) = p_0 + \frac{1}{2}\sum_{i=1}^{2} q\left(c_i\right)\left(c_i - r_i\right).$$

Because profit is increasing in the premium, the payer chooses the premium so that the consumer's insurance decision condition binds, as in Lemma 2:

$$p_0 = U_1 - U_0,$$

as long as its profit is nonnegative.

The PBM sets reimbursement prices and makes tier assignments to maximize its profit,

$$\pi_{\text{PBM}}\left(c_1, c_2, r_1, r_2; p_1, p_2\right) = \frac{1}{2}\sum_{i=1}^{2} q\left(c_i\right)\left(r_i - p_i\right), \tag{3}$$

subject to the constraint that the payer's profit is nonnegative, and taking net prices as given. The PBM's profit is increasing in the reimbursement prices, meaning the PBM will set r_1 and r_2 so that the payer's profit condition binds. This determines the weighted average reimbursement price, but does not pin down the individual

reimbursement prices separately, because the payer's profit depends on the reimbursement prices only through their weighted average. As in the baseline model where the payer was the intermediary, the PBM maximizes profit by assigning drugs to tiers by a simple comparison of the net prices. The following lemma establishes these results.

Lemma 9 (**PBM's choice of reimbursement prices and tier assignment**). *In the PBM model with exogenous list prices, the PBM sets reimbursement prices to satisfy*

$$\frac{1}{2}\sum_{i=1}^{2} q\left(c_i\right) r_i = p_0 + \frac{1}{2}\sum_{i=1}^{2} q\left(c_i\right) c_i.$$

The PBM assigns drug 1 to the generous tier (that is, sets $c_1 = c_L$ and $c_2 = c_H$) if and only if $p_1 \leq p_2$.

The fact that the PBM is acting as common agent does not change the drug makers' problem in setting net prices. The mixed strategy equilibrium determining the net price distribution is identical to the baseline model:

$$F\left(p; c_L, c_H\right) = \begin{cases} 0 & , \quad p < \bar{p}\frac{q(c_H)}{q(c_L)} \\ \frac{q(c_L) - \frac{\bar{p}}{p} q(c_H)}{q(c_L) - q(c_H)} & , \quad \bar{p}\frac{q(c_H)}{q(c_L)} \leq p < \bar{p} \\ 1 & , \quad p \geq \bar{p} \end{cases} .$$

Likewise, after substituting the PBM's reimbursement price choice shown in Lemma 9 into the PBM's profit function, (3), the PBM's profit is identical to the payer's profit in the baseline model. Consequently, the PBM's choice of copays is identical to the baseline model. That is, the PBM will set $c_L = 0$ and $c_H = \bar{p}$. The PBM thus resolves the externality in the previous section when several payers acted as intermediaries on their own. The result is that when a PBM acts as intermediary, the joint profit among the PBM and payers is higher than when payers act as intermediary and total surplus is higher, as the following proposition formalizes.

Proposition 3 (**When payers select a PBM as a common intermediary, total surplus and joint profits rise**). *Suppose there are two payers. Total surplus and joint PBM and payer profit is higher when the PBM acts as a common intermediary than when payers act as their own intermediaries.*

This result provides the economic rationale for the intermediary role PBMs play in the industry. When several payers each act as their own intermediary, pricing externalities among them raise drug prices and reduce profits. Payers can do better

by delegating formulary design to a common agent, the PBM. The presence of a PBM not only raises joint profit among the payers and the PBM, but also improves efficiency because the PBM will choose a lower generous copay than payers would on their own. Thus, in the first step of the model, all payers accept the PBM's contract so long as the transfer, π_0, is greater than the equilibrium profit when each payer operates its own formulary.

7 Endogenous List Prices

In this section we analyze the economics of list prices by allowing the two drug makers to set list prices endogenously. We will find that list prices matter because they determine consumers' outside options. High list prices reduce the value of purchasing drugs outside the formulary and so make participating in the formulary more valuable for consumers. PBMs can capture this increase in value and so will bias formulary incentives *in favor* of drugs offering high list prices. The result is an equilibrium in which the list prices of some drugs become detached from their underlying clinical value and the average list price exceeds the monopoly price. These high list prices increase the joint surplus of drug makers and PBMs, but reduce consumer surplus and make drug markets less efficient.

To accommodate endogenous list prices, we extend our baseline model by allowing drug makers to choose their respective list prices, $\bar{p}_1$ and $\bar{p}_2$, before the formulary design is chosen. For ease of exposition, we assign the label "drug 1" to the drug with the (weakly) lower list price, so that without loss of generality $\bar{p}_1 \leq \bar{p}_2$. Unequal list prices allow for the possibility that c_H may be lower than one list price, but not the other. In this case, if the drug with the lower list price is placed in the non-generous tier, we assume that the effective copay reverts to that drug's list price.[19] For example, if $\bar{p}_1 < c_H \leq \bar{p}_2$, and drug 1 "loses" the formulary tournament so that it is assigned to the unfavorable tier, we assume the copay charged consumers would be $\bar{p}_1$, while if drug 2 were to lose, the copay would be c_H. To simplify our analysis, we return to our baseline assumption that a single payer operates a single formulary.

The timing is as follows:

1. drug makers simultaneously choose list prices $\bar{p}_1$ and $\bar{p}_2$;

[19]This assumption is without loss of generality: it is optimal for payers to set copays no higher than the list price because consumers have the option to purchase at the list price out of pocket. The substantive assumption here is that consumers cannot commit to giving up their option to purchase at the list price.

2. the payer chooses the formulary copays c_L and c_H, where $0 \leq c_L \leq c_H \leq \bar{p}_2$;

3. drug makers set net prices p_1 and p_2;

4. the payer assigns drugs to formulary tiers and sets the premium p_0;

5. consumers decide whether to purchase insurance;

6. nature chooses the consumer's medical condition, D, and its intensity, V;

7. consumers decide whether to purchase the drug.

As before, consumers purchase insurance if the premium is less than the utility gain from doing so, that is, if $p_0 \leq U_1 - U_0$, where utilities now are functions of both list prices:

$$\begin{aligned} U_0 &= \frac{1}{2}\sum_{i=1}^{2} E\left[\left(V - \bar{p}_i\right) 1\left(V > \bar{p}_i\right)\right], \\ U_1 &= \frac{1}{2}\sum_{i=1}^{2} E\left[\left(V - \min\left\{c_i, \bar{p}_i\right\}\right) 1\left(V > \min\left\{c_i, \bar{p}_i\right\}\right)\right]. \end{aligned}$$

The payer's choice of premium is unchanged from the result in Lemma 2: $p_0 = U_1 - U_0$, as long as its profit is positive. Tier assignment, however, differs importantly: the possibility of different list prices means the rule for tier assignment is not a simple comparison of net prices. Instead, the formulary tournament may be tilted in favor of one drug or the other, as the following result shows:

Lemma 10 (**Choice of tier assignment with endogenous list prices**). *The formulary assigns drug 1 to the generous tier (that is, sets $c_1 = c_L$ and $c_2 = c_H$) if and only if $p_2 \geq \phi(p_1)$, where $\phi(p) = p$ if $c_H \leq \min\left\{\bar{p}_1, \bar{p}_2\right\}$ (Case 1), and*

$$\phi(p) = \frac{q(c_L) - q(\bar{p}_1)}{q(c_L) - q(c_H)} p + \frac{E\left[V | V > \bar{p}_1\right] q(\bar{p}_1) - E\left[V | V > c_H\right] q(c_H)}{q(c_L) - q(c_H)}$$

if $\bar{p}_1 < c_H \leq \bar{p}_2$ (Case 2).

The lemma shows that when list prices differ, the intermediary may bias the formulary contest. When both list prices exceed the non-generous copay (Case 1), the tier assignment is as before: the drug with the lower net price is placed in the generous tier. But when one of the list prices is lower than the non-generous copay, the formulary compares the higher list-price drug's net price, p_2, to a transformation

of p_1, rather than to p_1 itself. In equilibrium, this second rule is chosen so that the formulary is biased toward the drug with the higher list price. Why would the PBM favor the drug with the higher list price? There are two reasons. First, consumers derive more value from insurance when the formulary favors the higher list price drug rather than the lower list price drug. Biasing the formulary toward the higher list price drug therefore raises the amount of surplus the payer can extract in the premium. Second, when the drug with the lower list price (drug 1) loses the formulary contest, the high copay is only $\bar{p}_1$, not c_H. Consequently, the toll on total surplus is not so great as if drug 2 were to lose the formulary contest. Because the payer can extract the increase in total surplus via the premium, it biases the formulary to make it more likely for drug 2 to win.

A biased formulary encourages very high list prices. We show this in the special case of linear demand for the drugs: $q(p) = 1 - p$ for $p \in [0, 1]$ with unit demand when $p < 0$ and zero demand for $p > 1$. In this case, as we show below, drug maker 2 sets its list price to the maximum possible, $\bar{p}_2 = 1$, and drug maker 1 sets its list price to the monopoly level: $\bar{p}_1 = 1/2$. Before presenting the formal proposition, we build intuition for the result by describing the basic tradeoffs faced by drug makers and the intermediary in the formulary contest.

In the formulary contest, drug makers can always earn their **default payoff** simply by bidding their list price and losing for certain. For drug maker 1, this payoff is $\underline{\pi}_1(\bar{p}_1; c_H) = q(\min\{\bar{p}_1, c_H\})\bar{p}_1/2$, and for drug maker 2 it is $\underline{\pi}_2(\bar{p}_2; c_H) = q(c_H)\bar{p}_2/2$. Any payoff above this amount we term **contest rents**. In the baseline version of the model where drug makers are symmetric, contest rents are always zero. When list prices are allowed to differ, the contest participants are no longer on an equal footing, and in principle one of the drug makers could earn contest rents. One might expect the payer to set copays to minimize contest rents for the drug makers because contest rents come at the expense of payer profit. This is indeed the case: as the result below shows, the payer sets copays to ensure contest rents are zero for each drug maker, and this turns out to mean c_H is set higher than $\bar{p}_1$ but less than $\bar{p}_2$.

The fact that the payer sets copays to eliminate contest rents simplifies the analysis of the drug makers' choice of list price: they set list prices to maximize their default payoff. Given that $c_H > \bar{p}_1$, drug maker 1's default payoff is $q(\bar{p}_1)\bar{p}_1/2$. This is simply its monopoly profit at price $\bar{p}_1$, and is maximized at $\bar{p}_1 = 1/2$. Drug maker 2's default profit is $q(c_H^*)\bar{p}_2/2$, where c_H^* is the intermediary's optimal choice of non-generous copay given list prices. Drug maker 2's default payoff turns out to be increasing in $\bar{p}_2$, and so is maximized at the upper end of its choice set, $\bar{p}_2 = 1$. Neither drug maker earns contest rents, but drug maker 2 has the higher default

payoff and so enjoys higher equilibrium profit.

The following result formalizes this intuition:

Proposition 4 (**High equilibrium list price when list prices are endogenous**). *Suppose drug demand is linear. Without loss of generality let $\bar{p}_1 \leq \bar{p}_2$. Then in the endogenous list price model the unique subgame-perfect Nash equilibrium list prices are $\bar{p}_1^* = 1/2$ (the monopoly price) and $\bar{p}_2^* = 1$ (the maximum possible price). Drug maker 2 earns higher profit than drug maker 1, and combined drug maker profit is higher and the formulary's profit is higher than when list prices are exogenously fixed at the monopoly level.*

It may not seem surprising that one of the list prices is set to the monopoly level, since the drug maker's payoff is tied to revenues in the non-generous tier, which is maximized at the monopoly list price. But the extremely high value for the other list price is a surprising result: demand at that price is zero, so no transactions actually occur at that price. Instead, the extremely high list price on the part of one drug maker is a response to the biased formulary incentives that tilt the contest in favor of the drug with the higher list price. This triggers a "race to the top" in list prices in which one drug company sets a list price as high as possible, while the other chooses the monopoly level.[20]

Figure 4 depicts the list price equilibrium graphically. The figure plots each drug maker's best response list price as a function of the other's list price. The blue points show that when drug maker 1 sets a low enough list price, drug maker 2 will optimally set its list price as high as possible. When drug maker 1's list price is high, however, drug maker 2 optimally sets its list price to the monopoly level (one-half). The figure shows two equilibria where the best response functions intersect: one where drug maker 2 sets $\bar{p}_2 = 1$ and drug maker 1 sets $\bar{p}_1 = 1/2$ and another where they are reversed.

8 Common Agency and Vertical Integration

Our analysis so far takes a rosy view of the problem of aligning the interests of PBMs and payers. Formularies, we argue, enable "near" efficient pharmaceutical markets that benefit formulary operators. Contracting externalities reduce these

[20]This race to the top follows from the logic of our model, but industry observers note closely related price dynamics. For example Feldman (2020, p. 327) comments that drug makers have an incentive to offer high list prices because this allows the PBM to offer their clients what appears to be a more attractive discount

benefits when numerous payers operate their own formularies, but near efficiency can be restored when payers delegate the operation of formularies to a single PBM acting as a common agent.

Because PBMs in our model capture the joint surplus produced by themselves and payers, there is an easy alignment of interests between principal and agent. This simplifies the analysis but at the cost of downplaying the possibility that the PBM may take actions that are not in the interest of payers. For example, suppose that contrary to our prior analysis, PBMs do not have full information about the demand for drugs within each payer's population. This information asymmetry prevents the PBM from capturing all the joint surplus and breaks the alignment between PBMs and payers. To illustrate the issues created by asymmetric information, consider a PBM decision that we did not include in our baseline model: Payers would prefer if the PBM promoted generics so that they could offer their members lower-priced formulary services. The surplus resulting from these lower cost services, however, need not flow to the PBM.[21]

One way to resolve this agency problem is through a contract. We have already reported that contracts between PBMs and payers include penalties if the *aggregate* use of generics falls below some pre-specified threshold. Aggregate caps are, however, a crude instrument for promoting the use of generics. In a conventional principal agent setting, a payer could motivate the PBM to do more by writing a shared savings incentive contract with the PBM. Under common agency, however, such agreements may not be workable. To see this consider that when a PBM invests in the software and information systems that improve generic substitution, this will likely enable more generic usage by all its payer clients. This externality leads to inefficiently weak equilibrium incentives. Indeed, if investments in generic substitution involve substantial fixed costs, the equilibrium can be one in which no payers will write any incentive contracts at all (Frandsen et al., 2019).

Vertical mergers between PBMs and payers may reduce or eliminate the contracting inefficiencies resulting from common agency. The merged entity's profits will include the value created by enhanced use of generics. As the stock of generic drugs grows, the benefits of substitution likely increase, and so PBMs will come under increasing pressures to integrate vertically. Consistent with this logic, in the past several years, large PBMs have vertically consolidated with substantial insurers,

[21]Similar problems can arise within the market for branded drugs. Feldman (2020) describes how the use of volume-based rebates for individual drugs or bundled rebates for groups of drugs can induce PBMs to exclude less expensive or more clinically desirable drugs from a favored formulary position. Here again, payers would benefit if the PBM promoted the less expensive or clinically desirable drug, but these benefits needn't flow to the PBM.

including UnitedHealth Plans (health plan) with OptumRx (PBM), Aetna (health plan) with CVSCaremark (PBM), and many Blue Cross Blue Shield plans (health plan) with PrimeTherapeutics (PBM).

In justifying vertical integration between PBMs and payers, the business press often emphasizes the returns to better integrating the information held separately by PBMs and payers. For example, in the press release announcing the final merger of CVS with Aetna, the CVS Health President and CEO, Larry Merlo, is quoted as saying,

> By fully integrating Aetna's medical information and analytics with CVS Health's pharmacy data, we can develop new ways to engage consumers in their total health and wellness through personal contacts and deeper collaboration with their primary care physicians. As a result, we expect patients will benefit from earlier interventions and better-connected care, leading to improved health outcomes and low medical costs. (CVS Health, 2018)

Recent research finds that the incentives to integrate information systems are also influenced by the limits that common agency imposes on incentive contracts (Frandsen et al., 2019, Section 5). To see this, consider that both CVS and Aetna likely benefit from having sole control over their own information systems, but information sharing becomes more efficient when they sacrifice some of this autonomy and operate their systems in close concert. As separate organizations, the weak incentives induced by common agency may provide inadequate compensation for giving up this autonomy. Under integrated governance, however, these distortions are removed, and incentives for maximizing the value created by integrated information systems increase. In this way, common agency creates a complementarity between vertically integrated governance structures and integrating information systems.

9 Conclusion

Pharmacy benefit managers (PBMs) dominate the market for branded pharmaceuticals in the US. Our analysis offers insights into otherwise puzzling questions about the economics of PBMs. First, why do drug makers pay rebates to PBMs? Rebates are drug maker bids in an all pay contest for placement in favorable formulary tiers. The additional surplus generated by these near-efficient tournaments accrues as rents to the PBM rather than to consumers or pharmaceutical manufacturers. This result suggests that the challenges PBMs pose for economic policy have more to do

with distribution than static efficiency. Secondly, why do payers delegate the crucial and potentially profitable formulary function to an independent actor and why do large PBMs acting as a common agent for many other payers dominate the market? Payers delegate because a common agent PBM is better able to internalize the contracting externality created by most favored nation arrangements. By internalizing this externality, large PBMs can deliver lower net drug prices and improved market efficiency. Third, what role do high list prices play in a pharmaceutical market where relatively few transactions actually take place at list price? Because drugs can be purchased outside of the formulary at list price, high list prices increase the value of participating in the PBM's formulary. If PBMs can capture this surplus, they may bias formulary contests in favor of drugs with high list prices. In equilibrium, some drug makers will set list prices at the monopoly price while others will choose much higher list prices. The net result is an increase in joint surplus for drug makers and PBMs, but consumers are worse off and markets become less efficient.

Our framework may have implications for efforts to reform and regulate the market for branded pharmaceuticals. Some reform proposals focus on altering who receives rebates from drug makers or propose eliminating them entirely.[22] Our analysis suggests that such an approach may prove disappointing. In our baseline model, passing rebates through to payers or consumers, for example, would not improve the efficiency of formularies or alter the distribution of economic benefits. This is because payers would respond to such a transfer by raising their premiums and PBMs would respond to payers' higher premiums by increasing the reimbursement prices they charge payers. A richer model that allows for more consumer heterogeneity may produce a less stark distributional result, but our findings are sufficient to suggest that the ultimate distributional effects may not work as planned.

Efforts to eliminate rebates altogether are similarly likely to have negative effects because the all-pay contest that reduces the net price of pharmaceuticals cannot operate without rebates or their equivalent. Some observers have noted that the secrecy surrounding net prices puts payers and consumers at a disadvantage relative to PBMs and should therefore be eliminated (Feldman, 2020). Our analysis suggests a slightly different approach. A well functioning formulary requires that the rebates offered on any given drug be kept secret—otherwise the competition driving the desireable consequences of the all-pay contest would stop. There is, however, no equivalent economic rationale for keeping the total rebates received by the PBM a secret.

[22]The Trump Administration in Fall 2020 finalized an administrative rule that would require rebates paid to PBMs by branded drug makers to be passed through to consumers (Department of Health and Human Services, 2020).

Other approaches to reform are motivated by the enormous market power accumulated by large PBMs and recommend creating greater competition between a larger number of smaller PBMs (Garthwaite and Scott Morton, 2017). Our analysis does not explicitly model competition between PBMs, but it suggests that some pro-competitive reforms will be more effective than others. Breaking up PBMs without eliminating the contracting externality resulting from most favored nation arrangements may directly reduce market efficiency and increase drug prices. Eliminating most favored nation arrangements, however, will reduce the efficiency advantages enjoyed by large PBMs and so make the PBM market place more competitive in a way that benefits consumers.

The mergers of large PBMs and large payers also raises questions for competition policy. We find that under common agency, vertical integration creates value because it can mitigate otherwise severe contracting and coordination problems between a PBM and payers. It is of course also possible that vertical integration between large PBMs and large payers has anti-competitive effects that lie outside of our model. Understanding any potentially anti-competitive consequences of vertical integration and how these may interact with the efficiency enhancing consequences is an important area for future research.

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Appendix

Proof of Lemma 1. First consider the consumer's drug purchasing decision. The consumer receives zero utility when not purchasing a drug. The consumer whose medical condition is $D = d$ receives $V - \bar{p}$ when purchasing drug d out of pocket and $V - c_d$ when purchasing it through the formulary if she purchased insurance. The consumer's utility is therefore maximized by purchasing the drug if and only if $V \geq \min\{c_d, \bar{p}\}$, and, if the consumer purchases the drug, she will do so at the lower price: through the formulary if $c_d \leq \bar{p}$ and out of pocket otherwise. If she did not enroll in insurance she purchases the drug if and only iff $V \geq \bar{p}$. Now consider the consumer's insurance enrollment decision. Her net utility if not enrolling is U_0 and if enrolling is $U_1 - p_0$. She therefore enrolls if and only if $p_0 \leq U_1 - U_0$. □

Proof of Lemma 2. First consider the payer's premium choice. The payer can guarantee zero profit by setting $p_0 > U_1 - U_0$. Subject to the consumer enrolling in

insurance, the payer's profit is increasing in the premium, p_0, and so it will set the premium as high as possible subject to the consumer's enrollment constraint:

$$p_0 = U_1 - U_0,$$

provided $\pi_{\text{payer}}(U_1 - U_0, c_1, c_2, p_1, p_2) \geq 0$, and any value $p_0 > U_1 - U_0$ otherwise. Now consider the payer's tier-assignment choice. The payer assigns drug 1 to the generous tier if and only if the profit from doing so is greater than or equal to the profit from assigning drug 2 to the generous tier:

$$\pi_{\text{payer}}(p_0, c_L, c_H, p_1, p_2) \geq \pi_{\text{payer}}(p_0, c_H, c_L, p_1, p_2).$$

Substituting in the expressions for the payer's profit, and noting that $c_L \leq c_H$ by definition, this condition simplifies to

$$p_1 \leq p_2.$$

□

Proof of Lemma 3. Note that the formulary contest is a 2-player, 2-prize all-pay auction with complete information of the sort analyzed by Barut and Kovenock (1998). We refer to their Theorem 2, Part A to establish that there is a unique equilibrium in which drug makers randomize continuously over a closed interval. Note also that the upper bound of the support is $\bar{p}$, because at the upper bound the drug maker loses with probability one, and drug maker profit given loss is maximized at $\bar{p}$. Let F be the cdf corresponding to drug maker 2's equilibrium strategy. First, note that Drug maker 1's expected profit at support point p is

$$E[\pi_1(p)] = (1 - F(p))\, pq(c_L) + F(p)\, pq(c_H).$$

Noting that $F(\bar{p}) = 1$, the equilibrium condition that profit be equal at all points in the support of F means

$$\bar{p}q(c_H) = (1 - F(p))\, pq(c_L) + F(p)\, pq(c_H).$$

Solving this condition for $F(p)$ yields

$$F(p) = \frac{q(c_L) - \frac{\bar{p}}{p} q(c_H)}{q(c_L) - q(c_H)}.$$

The lower bound of the support occurs where F equals zero:

$$p = \bar{p} \frac{q(c_H)}{q(c_L)}.$$

□

Proof of Lemma 4. Recall that the equilibrium net whole price cdf is

$$F\left(p; c_L, c_H\right) = \frac{q\left(c_L\right) - \frac{\bar{p}}{p} q\left(c_H\right)}{q\left(c_L\right) - q\left(c_H\right)}.$$

The derivative of the cdf with respect to c_L is

$$\frac{\partial F\left(p; c_L, c_H\right)}{\partial c_L} = \frac{q\left(c_H\right)\left(\frac{\bar{p}}{p} - 1\right)}{\left(q\left(c_L\right) - q\left(c_H\right)\right)^2} q'\left(c_L\right) < 0.$$

The derivative of the cdf with respect to c_H is

$$\frac{\partial F\left(p; c_L, c_H\right)}{\partial c_H} = -\frac{q\left(c_L\right)\left(\frac{\bar{p}}{p} - 1\right)}{\left(q\left(c_L\right) - q\left(c_H\right)\right)^2} q'\left(c_H\right) > 0.$$

□

Proof of Lemma 5. The payer's expected profit is

$$E\left[\pi_{\text{payer}}\left(c_L, c_H\right)\right] = TS\left(c_L, c_H\right) - CS - \bar{p} q\left(c_H\right),$$

where $TS\left(c_L, c_H\right)$ is total surplus:

$$TS\left(c_L, c_H\right) = \frac{1}{2}\left(E\left[1\left(V > c_H\right) V\right] + E\left[1\left(V > c_L\right) V\right]\right),$$

and CS is consumer surplus:

$$CS = E\left[\left(V - \bar{p}\right) 1\left(V > \bar{p}\right)\right],$$

which holds by an implication of Lemma 2. By the proof of Lemma 3, $\bar{p} q\left(c_H\right)$ is the sum of the drug makers' expected profit. Note that $E\left[\pi_{\text{payer}}\left(c_L, c_H\right)\right]$ is clearly decreasing in c_L, so the profit maximizing choice is $c_L = 0$. Payer profit is increasing in c_H:

$$\frac{\partial E\left[\pi_{\text{payer}}\left(c_L, c_H\right)\right]}{\partial c_H} = -q'\left(c_H\right)\left(\bar{p} - \frac{1}{2} c_H\right) > 0,$$

where the equality follows from Leibniz' rule and the fact that the slope of the demand curve is the opposite of the density of willingness to pay. The inequality follows from the assumption that demand is strictly downward sloping and the constraint that $c_H \leq \bar{p}$. The profit maximizing choice of c_H is therefore $\min\left\{q^{-1}\left(0\right), \bar{p}\right\}$, which is $\bar{p}$ by assumption. □

Proof of Lemma 6. Let i and i' index two drugs such that $p_i < p_{i'}$. Fix the tier assignments for all other drugs at $\{t_j\}_{j \neq i,i'}$. Without loss of generality, let c_a and c_b be the copays corresponding to the tiers to be assigned to either i or i', where $c_a \leq c_b$. The portion of the payer's revenue that depends on the net prices and tier assignments of drugs i and i' is:

$$B\left(c_{t(i)}, c_{t(i')}\right) = \frac{1}{m}\left[\left(c_{t(i)} - p_i\right) q\left(c_{t(i)}\right) + \left(c_{t(i')} - p_{i'}\right) q\left(c_{t(i')}\right)\right].$$

It suffices to show that $p_i < p_{i'}$ implies $B\left(c_a, c_b\right) \geq B\left(c_b, c_a\right)$ with the inequality strict when $c_a < c_b$. The condition $B\left(c_a, c_b\right) \geq B\left(c_b, c_a\right)$ simplifies to

$$\left(p_{i'} - p_i\right)\left(q\left(c_a\right) - q\left(c_b\right)\right) \geq 0,$$

which holds with strict inequality with $c_a < c_b$. □

Proof of Lemma 7. First, we will argue that there are no mass points. Suppose there was a mass point at some price p. Then with strictly positive probability, all drug makers will simultaneously choose price p, and at that price, they would have an equal chance of winning each of the prizes. One of the drug makers could deviate by allocating all that mass instead to price $p - \varepsilon$ for ε arbitrarily small and for sure win $q\left(c_1\right)\left(p - \varepsilon\right)$, so there is a profitable deviation. So there cannot be any mass points.

Next, suppose the upper bound of the price distribution is $\tilde{p} < \bar{p}$. Then since there are no mass points, by choosing price $p_i = \tilde{p}$, drug maker i can only get revenues of $q\left(c_i\right)\tilde{p}$. It could obtain $q\left(c_i\right)\bar{p}$ by bidding $p_i = \bar{p}$ and would get strictly higher profits since $\bar{p} > \tilde{p}$. So the upper bound of the price distribution must be $\bar{p}$. A similar argument establishes that the support of the distribution is an interval: suppose $\hat{p}^1$ and $\hat{p}^2 > \hat{p}^1$ are in the support of the distribution, but there is a gap in the support between these two points. Then drug maker i would strictly prefer to choose price $\hat{p}^2$ over $\hat{p}^1$, which again is a contradiction. So any symmetric equilibrium price distribution is continuous and has support $\left[\underline{p}, \bar{p}\right]$ for some $\underline{p} < \bar{p}$.

The preceding shows that if there is a symmetric equilibrium price distribution F^*, it is continuous and has support $\left[\underline{p}, \bar{p}\right]$. Let $F\left(p\right)$ be the cdf of a candidate equilibrium mixing distribution. Let

$$F^{k,m-1}\left(p\right) = \binom{m-1}{k} F\left(p\right)^k \left(1 - F\left(p\right)\right)^{m-1-k}$$

be the probability that exactly k of the other $m-1$ prices is less than p if all drug makers mix with continuous distribution F on $\left[\underline{p}, \bar{p}\right]$. Then the expected profit for

firm i if it chooses net price p_i is

$$\pi(p_i) = \sum_{k=0}^{m-1} F^{k,m-1}(p_i)\, q(c_{k+1})\, p_i.$$

Let F^* be such that

$$\pi(p) = \sum_{k=0}^{m-1} \binom{m-1}{k} F^*(p)^k (1 - F^*(p))^{m-1-k}\, q(c_{k+1})\, p$$

is constant on $\left[\underline{p}, \bar{p}\right]$. Then F^* is an equilibrium price distribution.

To see why such an F^* exists, we will show that for any strictly decreasing and differentiable function $Q(p)$ satisfying $Q\left(\underline{p}\right) = q(c_1)$ and $Q(\bar{p}) = q(c_m)$, there exists a CDF $F(p)$ such that $Q(p) = \sum_{k=0}^{m-1} F^{k,m-1}(p)\, q(c_{k+1})$ for all p.

Towards this end, define $\tilde{F}^{k,m-1}(p) = \sum_{j=k}^{m-1} F^{j,m-1}(p)$ to be the probability that at least k of the other $m-1$ prices is less than p, so that if drug maker i sets price p_i, the probability it will be placed in a tier with a copay at least as bad as c_{k+1} is $\tilde{F}^{k,m-1}(p_i)$. While $F^{k,m-1}(p)$ is not necessarily monotonic in $F(p)$, $\tilde{F}^{k,m-1}(p)$ is a monotonically increasing in $F(p)$, as it corresponds to one minus the cdf of a binomial distribution with success probability $F(p)$ and $m-1$ trials evaluated at $k-1$, which is increasing in the success probability in the first order stochastic dominance sense. Let

$$\phi(F(p)) = \sum_{k=1}^{m-1} \tilde{F}^{k,m-1}(p)\left(q(c_k) - q(c_{k+1})\right).$$

Then ϕ is a strictly increasing and continuous function that satisfies $\phi(0) = 0$ and $\phi(1) = q(c_1) - q(c_m)$, so it is invertible on the domain $[0,1]$. Given any arbitrary strictly decreasing and continuous function $Q(p)$ satisfying $Q\left(\underline{p}\right) = q(c_1)$ and $Q(\bar{p}) = q(c_m)$, define $\hat{F}$ to satisfy $\hat{F}(p) = \phi^{-1}(q(c_1) - Q(p))$ for all p. Then there exists a symmetric equilibrium price distribution in which each drug maker chooses a continuous mixing distribution $F^*(p) = \hat{F}(p)$ for $Q(p)$ satisfying $pQ(p) = \bar{p}q(c_m)$ on support $\left[\underline{p}, \bar{p}\right]$. □

Proof of Lemma 8. The payer's expected profit is equal to total surplus (TS) minus consumer surplus (CS) minus drug makers' profit. As a function of copays $c_1, \ldots, c_m$, total surplus and consumer surplus are

$$\begin{aligned} TS(c_1, \ldots, c_m) &= \frac{1}{m} \sum_{i=1}^{m} E\left[1(V > c_i)\, V\right], \\ CS &= E\left[(V - \bar{p})\, 1(V > \bar{p})\right]. \end{aligned}$$

Expected drug maker profit is $\bar{p}q\left(c_m\right)$, as shown in the proof of Lemma 7. The payer's expected profit is therefore

$$E\left[\pi_{\text{payer}}\left(c_1,\ldots,c_m\right)\right] = TS\left(c_1,\ldots,c_m\right) - CS - \bar{p}q\left(c_m\right).$$

Note that this is clearly decreasing in $c_1,\ldots,c_{m-1}$, so the profit maximizing choice of the first $m-1$ copays is $c_1 = c_2 = \cdots = c_{m-1} = 0$. Payer profit is increasing in c_m:

$$\frac{\partial E\left[\pi_{\text{payer}}\right]}{\partial c_m} = -q'\left(c_m\right)\left(\bar{p} - \frac{1}{m}c_m\right) > 0,$$

where the equality follows from Leibniz' rule and the fact that the slope of the demand curve is the opposite of the density of willingness to pay. The inequality follows from the assumption that demand is strictly downward sloping and the constraint that $c_m \leq \bar{p}$. The profit maximizing choice of c_m is therefore $\bar{p}$. □

Proof of Proposition 1. As a function of copays, total surplus is

$$TS\left(c_1,\ldots,c_m\right) = \frac{1}{m}\sum_{i=1}^{m} E\left[1\left(V > c_i\right)V\right].$$

Plugging in the equilibrium copays established in Lemma 8, this becomes

$$\begin{aligned} TS\left(0,\ldots,\bar{p}\right) &= \frac{1}{m}\left(\left(m-1\right)E\left[V\right] + E\left[1\left(V > \bar{p}\right)V\right]\right) \\ &= E\left[V\right] - \frac{1}{m}E\left[1\left(V \leq \bar{p}\right)V\right]. \end{aligned}$$

□

Proof of Proposition 2. We will first establish that $c_L^j = 0$, $j = 1, 2$, cannot be part of an equilibrium by supposing that it is and showing that payer 1 can profitably deviate to some $c_L^1 > 0$. Payer 1's expected profit is equal to total surplus (TS) minus consumer surplus (CS) minus the other payer's profit minus drug makers' profit:

$$\pi_1 = TS\left(\mathbf{c}_L, \mathbf{c}_H\right) - CS - \pi_2 - \overline{pq}\left(\mathbf{c}_H\right),$$

where total surplus and consumer surplus are

$$\begin{aligned} TS\left(\mathbf{c}_L, \mathbf{c}_H\right) &= \frac{1}{2}\sum_{j=1}^{2}\frac{1}{2}\left(E\left[1\left(V > c_L^j\right)V\right] + E\left[1\left(V > c_H^j\right)V\right]\right), \\ CS &= E\left[\left(V - \overline{p}\right)1\left(V > \overline{p}\right)\right], \end{aligned}$$

and payer 2's profit is

$$\pi_2 = \frac{1}{2}\left[p_0^2\left(c_L^2, c_H^2\right) + \frac{1}{2}\left(\left(c_L^2 - E\left[p_L\right]\right)q\left(c_L^2\right) + \left(c_H^2 - E\left[p_H\right]\right)q\left(c_H^2\right)\right)\right].$$

Note that neither consumer surplus nor drug maker 2's profit depends on c_L^1. To see that payer 1 can profitably deviate from $c_L^1 = 0$, note that

$$\begin{aligned}\left.\frac{\partial \pi_1}{\partial c_L^1}\right|_{c_L^1=0} &= \left.\frac{\partial TS}{\partial c_L^1}\right|_{c_L^1=0} - \left.\frac{\partial \pi_2}{\partial c_L^1}\right|_{c_L^1=0} \\ &= \frac{1}{4}\left(\frac{\partial E\left[p_L\right]}{\partial c_L^1}q\left(c_L^2\right) + \frac{\partial E\left[p_H\right]}{\partial c_L^1}q\left(c_H^2\right)\right) > 0,\end{aligned}$$

where $\partial TS/\partial c_L^1|_{c_L^1=0} = 0$ because a zero copay maximizes total surplus, and the final inequality follows from Lemma 4. Therefore, $c_L^1 = 0$ cannot be part of an equilibrium, and any symmetric equilibrium will involve $c_L^1 = c_L^2 = c_L > 0$.

Next, we will establish that in any symmetric equilibrium, $c_H^j = \overline{p}$ for $j = 1, 2$. Let $q_L = q\left(c_L^1\right) + q\left(c_L^2\right)$ be the total sales for a drug assigned to the generous tier and $q_H = q\left(c_H^1\right) + q\left(c_H^2\right)$ be the total sales for a drug assigned to the less-generous tier. Define the expected drug expenditures for payer j to be $E\left[C^j\right] = q\left(c_L^j\right)E\left[p_L\right] + q\left(c_H^j\right)E\left[p_H\right]$ and the expected total drug expenditures to be $E\left[C\right] = q_L E\left[p_L\right] + q_H E\left[p_H\right]$. Using the endogenous price distributions described in Lemma 3, we can compute the following objects, which will be helpful: $(i.)$ $E\left[C\right] = 2\overline{p}q_H$; $(ii.)$ $q_L\frac{\partial E[p_L]}{\partial q_L} + q_H\frac{\partial E[p_H]}{\partial q_L} = -E\left[p_L\right]$; and $(iii.)$ $q_L\frac{\partial E[p_L]}{\partial q_H} + q_H\frac{\partial E[p_H]}{\partial q_H} = \frac{q_L}{q_H}E\left[p_L\right]$.

Given c_L^2 and c_H^2, payer 1's problem is to choose c_L^1 and c_H^1 to maximize π_1. Payer 1's optimality conditions, if $0 < c_L^{1*}, c_H^{1*} < \overline{p}$, satisfy

$$\begin{aligned}c_L^{1*} &= E\left[p_L\right] + \frac{\partial E\left[C^1\right]}{\partial q\left(c_L^1\right)} \\ c_H^{1*} &= E\left[p_H\right] + \frac{\partial E\left[C^1\right]}{\partial q\left(c_H^1\right)},\end{aligned}$$

that is, the optimal low copay is equal to the expected marginal cost of the low-net-price drug plus a term that captures the impact of an increase in the low copay on the net-price distribution, and similarly for the high copay. These optimality conditions immediately imply that $c_H^{1*} = c_H^{2*} = c_H^*$ and $c_L^{1*} = c_L^{2*} = c_L^*$ in equilibrium. Next, note that $\frac{\partial E\left[C^1\right]}{\partial q\left(c_H^1\right)} = \frac{1}{2}\frac{\partial E[C]}{\partial q_H} = \overline{p}$, so the optimality conditions above give us that $c_H^* = E\left[p_H\right] + \overline{p}$, which is not interior. We therefore have that $c_H^* = \overline{p}$.

Finally, note that the symmetric equilibrium values $c_L^* > 0$ and $c_H^* = \overline{p}$ were in the payer's choice set in the one-payer model but were dominated by $c_L^* = 0$ and $c_H^* = \overline{p}$. Therefore total payer profit is reduced when $n = 2$. Note also that total surplus is strictly decreasing in c_L and c_H. Because c_L is strictly higher when $n = 2$, and c_H is the same, total surplus is also reduced. □

Proof of Lemma 9. The PBM's profit as a function of copays and reimbursement prices, taking net prices as given is

$$\pi_{PBM}\left(c_1, c_2, r_1, r_2; p_1, p_2\right) = \frac{1}{2}\sum_{i=1}^{2} q\left(c_i\right)\left(r_i - p_i\right).$$

Profit is increasing in the reimbursement prices r_1 and r_2. The PBM will therefore set them so that the payers' zero profit condition binds. Profit for payer j is

$$\pi_j = \frac{1}{2}\left(p_0 + \frac{1}{2}\sum_{i=1}^{2} q\left(c_i\right)\left(c_i - r_i\right)\right).$$

Setting this equal to zero gives the following expression for the weighted average reimbursement price:

$$\frac{1}{2}\sum_{i=1}^{2} q\left(c_i\right) r_i = p_0 + \frac{1}{2}\sum_{i=1}^{2} q\left(c_i\right) c_i,$$

as stated in the lemma.

Substituting this condition into the PBM's profit function gives

$$\pi_{PBM}\left(c_1, c_2; p_1, p_2\right) = p_0 + \frac{1}{2}\sum_{i=1}^{2} q\left(c_i\right)\left(c_i - p_i\right),$$

which is identical to the payer's profit function in the one-payer case. Tier assignment is therefore identical to the one-payer case established in Lemma 2. □

Proof of Proposition 3. As established in the proof to Lemma 9, the PBM's profit function after substituting in the profit-maximizing choice of reimbursement prices, is identical to the payer's profit in the one-payer case. Therefore the PBM's equilibrium choice of copays and the drug makers' net price strategies coincide with the one-payer case. The result of Proposition 2 therefore means that total surplus and joint PBM and payer profit is higher with a PBM than when each payer acts as its own intermediary. □

Proof of Lemma 10. The intermediary's profit as a function of copays assignments c_1 and c_2, taking net prices as given, is

$$\pi\left(c_1, c_2; p_1, p_2\right) = p_0 + \frac{1}{2}\sum_{i=1}^{2} q\left(\min\left\{c_i, \bar{p}_i\right\}\right)\left(\min\left\{c_i, \bar{p}_i\right\} - p_i\right),$$

where $p_0 = U_1 - U_0$ and

$$\begin{aligned} U_0 &= \frac{1}{2}\sum_{i=1}^{2} E\left[\left(V - \bar{p}_i\right) 1\left(V > \bar{p}_i\right)\right], \\ U_1 &= \frac{1}{2}\sum_{i=1}^{2} E\left[\left(V - \min\left\{c_i, \bar{p}_i\right\}\right) 1\left(V > \min\left\{c_i, \bar{p}_i\right\}\right)\right]. \end{aligned}$$

The intermediary assigns $c_1 = c_L$ and $c_2 = c_H$ if its profit from doing so is greater than its profit from doing otherwise; that is, it assigns drug 1 to the generous tier if and only if $\pi\left(c_L, c_H; p_1, p_2\right) \geq \pi\left(c_H, c_L; p_1, p_2\right)$. In Case 1 ($c_H \leq \min\left\{\bar{p}_1, \bar{p}_2\right\}$) this condition becomes

$$p_1 \leq p_2,$$

as in Lemma 2. In Case 2 ($\bar{p}_1 < c_H \leq \bar{p}_2$), the condition becomes

$$p_2 \geq \frac{q\left(c_L\right) - q\left(\bar{p}_1\right)}{q\left(c_L\right) - q\left(c_H\right)} p_1 + \frac{E\left[V | V > \bar{p}_1\right] q\left(\bar{p}_1\right) - E\left[V | V > c_H\right] q\left(c_H\right)}{q\left(c_L\right) - q\left(c_H\right)}.$$

□

Proof of Proposition 4. The equilibrium list price vector $\left(\bar{p}_1^*, \bar{p}_2^*\right)'$ is a fixed point of the drug makers' best response function:

$$BR\left(\begin{pmatrix} \bar{p}_1 \\ \bar{p}_2 \end{pmatrix}\right) = \begin{pmatrix} \arg\max_x \pi_D\left(\mathbf{c}^*\left(x, \bar{p}_2\right), x, \bar{p}_2\right) \\ \arg\max_x \pi_D\left(\mathbf{c}^*\left(\bar{p}_1, x\right), x, \bar{p}_1\right) \end{pmatrix},$$

where $\pi_D\left(\mathbf{c}, \bar{p}_i, \bar{p}_{-i}\right)$ is drug maker i's expected profit given formulary copays $\mathbf{c} = \left(c_L, c_H\right)'$, own list price $\bar{p}_i$ and the other drug maker's list price $\bar{p}_{-i}$. The function $\mathbf{c}^*\left(\bar{p}_1, \bar{p}_2\right)$ gives the intermediary's equilibrium choice of $\left(c_L, c_H\right)'$ given list prices:

$$\mathbf{c}^*\left(\bar{p}_1, \bar{p}_2\right) = \arg\max_{\mathbf{c}} \pi_I\left(\mathbf{c}, \bar{p}_1, \bar{p}_2\right).$$

The intermediary's expected profit in turn is given by total surplus minus consumer surplus minus combined drug maker profit:

$$\pi_I\left(\mathbf{c}, \bar{p}_1, \bar{p}_2\right) = TS\left(\mathbf{c}, \bar{p}_1, \bar{p}_2\right) - CS\left(\bar{p}_1, \bar{p}_2\right) - \left(\pi_D\left(\mathbf{c}, \bar{p}_1, \bar{p}_2\right) + \pi_D\left(\mathbf{c}, \bar{p}_2, \bar{p}_1\right)\right).$$

Total surplus is

$$\begin{aligned} TS\left(\mathbf{c},\bar{p}_1,\bar{p}_2\right) &= \frac{1}{2}\sum_{i=1}^{2} E\left[E\left[V|V>c_i\right]q\left(c_i\right)\right] \\ &= \frac{1}{2}\left(1-\frac{1}{2}E\left[c_1^2+c_2^2\right]\right), \end{aligned}$$

where the second equality follows from the assumed linear demand function, and c_1 and c_2 are the copays corresponding to the tier to which drugs 1 and 2 (respectively) are assigned. These are random quantities because the tier assignment depends on the net prices, which in equilibrium are drawn from a mixed strategy. The distribution of net prices and thus the distribution of $c_i, i = 1, 2$ is derived below, and depends on $\mathbf{c}$, $\bar{p}_1$, and $\bar{p}_2$. Consumer surplus is determined by the list prices:

$$\begin{aligned} CS\left(\bar{p}_1,\bar{p}_2\right) &= \frac{1}{2}\sum_{i=1}^{2} E\left[\left(V-\bar{p}_i\right)1\left(V>\bar{p}_i\right)\right] \\ &= \frac{1}{4}\sum_{i=1}^{2}\left(1-\bar{p}_i\right)^2, \end{aligned}$$

where the second equality follows from the linear demand function. The final component of $\pi_I\left(\mathbf{c},\bar{p}_1,\bar{p}_2\right)$ is drug maker profit, which Lemma 12 shows is as follows. Drug maker 1's profit is

$$\pi_D\left(\mathbf{c},\bar{p}_1,\bar{p}_2\right) = \begin{cases} \frac{1}{2}\left(1-c_L\right)\min\left\{\bar{p}_1,\phi^{-1}\left(\frac{1-c_H}{1-c_L}\bar{p}_2\right)\right\} & , \quad \text{Case 1,2a} \\ \frac{1}{2}\left(1-\bar{p}_1\right)\bar{p}_1 & , \quad \text{Case 2b} \end{cases},$$

and drug maker 2's expected profit is

$$\pi_D\left(\mathbf{c},\bar{p}_2,\bar{p}_1\right) = \begin{cases} \frac{1}{2}\left(1-c_H\right)\bar{p}_2 & , \quad \text{Case 1,2a} \\ \frac{1}{2}\left(1-c_L\right)\phi\left(\frac{1-\bar{p}_1}{1-c_L}\bar{p}_1\right) & , \quad \text{Case 2b} \end{cases},$$

where Cases 1 and 2 are defined in Lemma 10, and within Case 2, Case 2a obtains when

$$\frac{1-c_H}{1-c_L}\bar{p}_2 \geq \frac{\bar{p}_1-c_L}{c_H-c_L}\frac{1-\bar{p}_1}{1-c_L}\bar{p}_1+\frac{1}{2}\frac{\left(c_H^2-\bar{p}_1^2\right)}{c_H-c_L}$$

is satisfied and Case 2b otherwise. In the case of a non-degenerate contest, drug maker 1's profit becomes

$$\pi_D\left(\mathbf{c},\bar{p}_1,\bar{p}_2\right) = \underline{\pi}_1\left(\mathbf{c},\bar{p}_1,\bar{p}_2\right)+\frac{1}{2}\left(1-c_L\right)x_1,$$

where the default payoff is

$$\underline{\pi}_1(\mathbf{c},\bar{p}_1,\bar{p}_2) = \frac{1}{2}(1-\min\{\bar{p}_1,c_H\})\,\bar{p}_1$$

and the excess reach is

$$x_1 = \max\left\{\phi^{-1}\left(\frac{1-c_H}{1-c_L}\bar{p}_2\right) - \frac{1-\min\{\bar{p}_1,c_H\}}{1-c_L}\bar{p}_1, 0\right\}.$$

In a non-degenerate contest drug maker 2's profit becomes

$$\pi_D(\mathbf{c},\bar{p}_2,\bar{p}_1) = \underline{\pi}_2(\mathbf{c},\bar{p}_1,\bar{p}_2) + \frac{1}{2}(1-c_L)\,x_2,$$

where the default payoff is

$$\underline{\pi}_2(\mathbf{c},\bar{p}_2,\bar{p}_1) = \frac{1}{2}(1-c_H)\,\bar{p}_2$$

and the excess reach is

$$x_2 = \max\left\{\phi\left(\frac{1-\min\{\bar{p}_1,c_H\}}{1-c_L}\bar{p}_1\right) - \frac{1-c_H}{1-c_L}\bar{p}_2, 0\right\}.$$

It remains only to find $E[c_1^2+c_2^2]$. In Case 1, where both list prices are higher than c_H, $c_1^2+c_2^2$ is non-random because the identity of the "winning" drug does not affect the value of the higher copay, so

$$E\left[c_1^2+c_2^2\right] = c_L^2+c_H^2 \text{ (Case 1)}.$$

In Case 2, the value of the higher copay depends on which drug wins the formulary contest, and this is random. We therefore have:

$$E\left[c_1^2+c_2^2\right] = c_L^2 + c_H^2\gamma(\mathbf{c},\bar{p}_1,\bar{p}_2) + \bar{p}_1^2(1-\gamma(\mathbf{c},\bar{p}_1,\bar{p}_2)) \text{ (Case 2)},$$

where $\gamma(\mathbf{c},\bar{p}_1,\bar{p}_2)$ is the probability that drug maker 1 wins the formulary contest:

$$\begin{aligned}\gamma(\mathbf{c},\bar{p}_1,\bar{p}_2) &= \Pr(\phi(p_1)\le p_2)\\ &= \int F_1(p_2;\mathbf{c},\bar{p}_1,\bar{p}_2)\,dF_2(p_2;\mathbf{c},\bar{p}_1,\bar{p}_2),\end{aligned}$$

and F_1 and F_2 are the equilibrium mixed strategy distributions given $\mathbf{c}$,$\bar{p}_1, \bar{p}_2$, shown in Lemma 11 to be, for Case 2a,

$$F_1(p) = \begin{cases} \frac{(1-c_L)\left(1-\frac{\underline{p}_2}{p}\right)}{c_H-c_L} & , \quad \underline{p}_2 < p < \phi(\bar{p}_1) \\ 1 & , \quad p = \phi(\bar{p}_1) \end{cases},$$

$$F_2(p) = \begin{cases} \frac{(1-c_L)\left(1-\frac{\phi^{-1}\left(\underline{p}_2\right)}{\phi^{-1}(p)}\right)}{\bar{p}_1-c_L} & , \quad \underline{p}_2 < p < \phi(\bar{p}_1) \\ 1 & , \quad p = \bar{p}_2 \end{cases},$$

and, for Case 2b

$$F_1(p) = \begin{cases} \frac{1-c_L}{c_H-c_L}\left(1-\frac{\underline{p}_1}{p}\right) & , \quad \underline{p}_1 < p < \phi(\bar{p}_1) \\ 1 & , \quad p = \phi(\bar{p}_1) \end{cases},$$

$$F_2(p) = \begin{cases} \frac{1-c_L-(1-\bar{p}_1)\frac{\bar{p}_1}{\phi^{-1}(p)}}{\bar{p}_1-c_L} & , \quad \underline{p}_1 < p \leq \phi(\bar{p}_1) \end{cases},$$

where

$$\begin{aligned} \underline{p}_2 &= \frac{1-c_H}{1-c_L}\bar{p}_2, \\ \underline{p}_1 &= \phi\left(\frac{1-\bar{p}_1}{1-c_L}\bar{p}_1\right). \end{aligned}$$

Drug companies' best response functions now depend on no unknowns and can be inspected directly. Figure 4 plots the best responses. By inspection, there is a single fixed point such that $\bar{p}_1 \leq \bar{p}_2$ located at $\bar{p}_1^* = 1/2$ and $\bar{p}_2^* = 1$. □

Lemma 11 (**Drug net price equilibrium distribution with endogenous list prices**). *Suppose demand is linear. Then given (c_L, c_H) and $\bar{p}_1 \leq \bar{p}_2$, the unique equilibrium mixed strategy net price distributions are, for Case 2a,*

$$F_1(p) = \begin{cases} \frac{(1-c_L)\left(1-\frac{\underline{p}_2}{p}\right)}{c_H-c_L} & , \quad \underline{p}_2 < p < \phi(\bar{p}_1) \\ 1 & , \quad p = \phi(\bar{p}_1) \end{cases},$$

$$F_2(p) = \begin{cases} \frac{(1-c_L)\left(1-\frac{\phi^{-1}\left(\underline{p}_2\right)}{\phi^{-1}(p)}\right)}{\bar{p}_1-c_L} & , \quad \underline{p}_2 < p < \phi(\bar{p}_1) \\ 1 & , \quad p = \bar{p}_2 \end{cases},$$

and, for Case 2b

$$\begin{aligned} F_1(p) &= \begin{cases} \frac{1-c_L}{c_H-c_L}\left(1-\frac{\underline{p}_1}{p}\right) & , \quad \underline{p}_1 < p < \phi(\bar{p}_1) \\ 1 & , \quad p = \phi(\bar{p}_1) \end{cases}, \\ F_2(p) &= \begin{cases} \frac{1-c_L-(1-\bar{p}_1)\frac{\bar{p}_1}{\phi^{-1}(p)}}{\bar{p}_1-c_L} & , \quad \underline{p}_1 < p \leq \phi(\bar{p}_1) \end{cases}. \end{aligned}$$

where

$$\begin{aligned} \underline{p}_2 &= \frac{1-c_H}{1-c_L}\bar{p}_2, \\ \underline{p}_1 &= \phi\left(\frac{1-\bar{p}_1}{1-c_L}\bar{p}_1\right). \end{aligned}$$

Proof. Note that the upper bound on the support of F_1 is $\phi(\bar{p}_1)$ and the upper bound on the support of F_2 is $\bar{p}_2$, because net prices cannot exceed list prices. Note also that a lower bound on the support of F_i is $\max\{1-T, 1-a_i\}$.

Take Case 2a first, where drug maker 2 is marginal. This means that drug maker 2's reach, where it is indifferent between winning and settling for a loss, determines the threshold price, which is a lower bound on the support of F_2:

$$\underline{p}_2 = \frac{1-c_H}{1-c_L}\bar{p}_2.$$

Suppose first that $\underline{p}_2 > \phi(\bar{p}_1)$ (that is, drug maker 2's lower bound is greater than drug maker 1's maximum possible bid). Then F_1 will be degenerate at $\phi(\bar{p}_1)$ and F_2 will be degenerate at $\bar{p}_2$ and drug maker 1 wins with probability one. Now suppose $\underline{p}_2 \leq \phi(\bar{p}_1)$. The supports of both F_1 and F_2 will then have a lower bound of $\underline{p}_2$. Note that $\phi(\bar{p}_1)$ is an upper bound on the support of F_1. Any continuous portion of F_2 will therefore have an upper bound of $\phi(\bar{p}_1)$. We first derive the continuous portion (if any) of F_2 by considering drug company 1's profit as a function of some bid p in the continuous portion of the support of F_2:

$$\pi_1(p) = \frac{1}{2}(1-\bar{p}_1)\phi^{-1}(p)F_2(p) + \frac{1}{2}(1-c_L)\phi^{-1}(p)(1-F_2(p)).$$

Equilibrium requires that $\pi_1(p)$ be equal to the profit derived above using Siegel (2009), which allows us to solve for the the continuous portion of F_2:

$$F_2^{\text{cont}}(p) = \frac{(1-c_L)\left(1-\frac{\phi^{-1}(\underline{p}_2)}{\phi^{-1}(p)}\right)}{\bar{p}_1-c_L}.$$

We can similarly find the continuous portion of F_1 by considering drug maker 2's profit at some net price p in the continuous portion of the support of F_1:

$$\pi_2(p) = \frac{1}{2}(1-c_H)\,pF_1(p) + \frac{1}{2}(1-c_L)\,p\,(1-F_1(p)).$$

Again, using the profit derived above for drug maker 2, indifference determines the continuous portion of F_1:

$$F_1^{\text{cont}}(p) = \frac{(1-c_L)\left(1-\frac{\underline{p}_2}{p}\right)}{c_H-c_L}.$$

We now determine any mass points in the distributions. Note that F_1^{cont} and F_2^{cont} are both zero at $\underline{p}_2$, meaning there is no mass point at the lower end of the support. Note also that $\phi(\bar{p}_1)$ is an upper bound on the support of F_1 and thus also on the continuous portion of F_2. Because $F_1^{\text{cont}}(\phi(\bar{p}_1)) < 1$, F_1 has a mass point of $\lambda_1 = 1 - F_1^{\text{cont}}(\phi(\bar{p}_1))$ at $\phi(\bar{p}_1)$. Because $F_2^{\text{cont}}(\phi(\bar{p}_1)) < 1$ (which is true because we are in Case 2a), Drug maker 2 will put all remaining mass above $\phi(\bar{p}_1)$ at $\bar{p}_2$, for a mass point of $\lambda_2 = 1 - F_2^{\text{cont}}(\phi(\bar{p}_1))$ at $\bar{p}_2$. In summary, in Case 2a, the equilibrium distributions are

$$F_1(p) = \begin{cases} \frac{(1-c_L)\left(1-\frac{\underline{p}_2}{p}\right)}{c_H-c_L} & , \quad \underline{p}_2 < p < \phi(\bar{p}_1) \\ 1 & , \quad p = \phi(\bar{p}_1) \end{cases},$$

$$F_2(p) = \begin{cases} \frac{(1-c_L)\left(1-\frac{\phi^{-1}\left(\underline{p}_2\right)}{\phi^{-1}(p)}\right)}{\bar{p}_1-c_L} & , \quad \underline{p}_2 < p < \phi(\bar{p}_1) \\ 1 & , \quad p = \bar{p}_2 \end{cases},$$

if $\underline{p}_2 \leq \phi(\bar{p}_1)$, and degenerate at $\phi(\bar{p}_1)$ and $\bar{p}_2$ otherwise.

Now take Case 2b, where drug maker 1 is marginal. Now the threshold price is determined by drug maker 1's reach, where it is indifferent between winning and settling for losing. This establishes a lower bound on the support of F_1:

$$\underline{p}_1 = \phi\left(\frac{1-\bar{p}_1}{1-c_L}\bar{p}_1\right).$$

Note that $\underline{p}_1 < \bar{p}_2$, so $\underline{p}_1$ is also a lower bound on the support of F_2. As before, we can determine the continuous portion of F_2 by looking at drug maker 1's profit as a function of some bid p in the continuous portion of the support of F_2:

$$\pi_1(p) = \frac{1}{2}(1-\bar{p}_1)\,\phi^{-1}(p)\,F_2(p) + \frac{1}{2}(1-c_L)\,\phi^{-1}(p)\,(1-F_2(p)).$$

Using the profit for drug maker 1 derived above for Case 2b, indifference determines the continuous portion of F_1:

$$F_2^{\text{cont}}(p) = \frac{1 - c_L - (1 - \bar{p}_1)\frac{\bar{p}_1}{\phi^{-1}(p)}}{\bar{p}_1 - c_L}.$$

Similarly, we determine the continuous portion of F_1 by looking at drug maker 2's profit at some bid b in the continuous portion of the support of F_1:

$$\pi_2(p) = \frac{1}{2}(1 - c_H)\, pF_1(p) + \frac{1}{2}(1 - c_L)\, p(1 - F_1(p)).$$

Using the profit for drug maker 1 derived above for Case 2b, indifference determines the continuous portion of F_2:

$$F_1^{\text{cont}}(p) = \frac{1 - c_L}{c_H - c_L}\left(1 - \frac{\underline{p}_1}{p}\right).$$

Now we determine mass points. Note F_1^{cont} and F_2^{cont} are both zero at $\underline{p}_1$, meaning neither distribution has a mass point at the lower end of the support. Note that F_1^{cont} reaches one at $\frac{1-c_L}{1-c_H}\underline{p}_1 > \phi(\bar{p}_1)$, meaning F_1 has a mass point at $\phi(\bar{p}_1)$ equal to $\lambda_1 = 1 - F_1^{\text{cont}}(\phi(\bar{p}_1))$. Because $F_2^{\text{cont}}(\phi(\bar{p}_1)) = 1$, F_2 has no mass point. In summary, in Case 2b, the equilibrium distributions are

$$\begin{aligned} F_1(p) &= \begin{cases} \frac{1-c_L}{c_H-c_L}\left(1 - \frac{\underline{p}_1}{p}\right) & , \quad \underline{p}_1 < p < \phi(\bar{p}_1) \\ 1 & , \quad p = \phi(\bar{p}_1) \end{cases}, \\ F_2(p) &= \begin{cases} \frac{1-c_L-(1-\bar{p}_1)\frac{\bar{p}_1}{\phi^{-1}(p)}}{\bar{p}_1-c_L} & , \quad \underline{p}_1 < p \leq \phi(\bar{p}_1) \end{cases}. \end{aligned}$$

□

Lemma 12 (**Drug maker profit with endogenous list prices**). *Suppose drug demand is linear. Then given formulary copays* $\mathbf{c} = (c_L, c_H)'$ *and list prices* $\bar{p}_1 \leq \bar{p}_2$*, drug maker 1's expected profit is*

$$\pi_D(\mathbf{c}, \bar{p}_1, \bar{p}_2) = \begin{cases} \frac{1}{2}(1 - c_L)\min\left\{\bar{p}_1, \phi^{-1}\left(\frac{1-c_H}{1-c_L}\bar{p}_2\right)\right\} & , \quad \textit{Case 1,2a} \\ \frac{1}{2}(1 - \bar{p}_1)\,\bar{p}_1 & , \quad \textit{Case 2b} \end{cases},$$

and drug maker 2's expected profit is

$$\pi_D(\mathbf{c}, \bar{p}_2, \bar{p}_1) = \begin{cases} \frac{1}{2}(1 - c_H)\,\bar{p}_2 & , \quad \textit{Case 1,2a} \\ \frac{1}{2}(1 - c_L)\,\phi\left(\frac{1-\bar{p}_1}{1-c_L}\bar{p}_1\right) & , \quad \textit{Case 2b} \end{cases},$$

where Cases 1 and 2 are defined in Lemma 10, and within Case 2, Case 2a obtains when

$$\frac{1-c_H}{1-c_L}\bar{p}_2 \geq \frac{\bar{p}_1-c_L}{c_H-c_L}\frac{1-\bar{p}_1}{1-c_L}\bar{p}_1+\frac{1}{2}\frac{(c_H^2-\bar{p}_1^2)}{c_H-c_L}$$

is satisfied and Case 2b otherwise.

Proof. Drug maker profit $\pi_D(\mathbf{c},\bar{p}_i,\bar{p}_{-i})$ is determined by the equilibrium of the formulary contest and is characterized as follows. Applying the linear demand function to the general result in Lemma 10, the intermediary awards the generous tier to drug 1 if $p_2 \geq \phi(p_1)$, where

$$\phi(p)=\begin{cases} p & , \quad c_H \leq \min\{\bar{p}_1,\bar{p}_2\} \text{ (Case 1)} \\ \frac{\bar{p}_1-c_L}{c_H-c_L}p+\frac{1}{2}\frac{(c_H^2-\bar{p}_1^2)}{c_H-c_L} & , \quad \bar{p}_1 < c_H \leq \bar{p}_2 \text{ (Case 2)} \end{cases}.$$

The net price-setting game between the drug makers thus takes the form of an all-pay contest, in which drug maker 2 bids p_2 and drug maker 1 bids $\tilde{p}_1=\phi(p_1)$. If drug maker 2 wins it receives payoff $q(c_L)p_2$ and if it loses it receives $q(c_H)p_2$. If drug maker 1 wins it receives payoff $q(c_L)p_1$ and if it loses it receives $q(\min\{c_H,\bar{p}_1\})p_1$. Equilibrium payoffs in contests like this are characterized in Siegel (2009). In the notation of Siegel (2009), the number of players is $n=2$. The number of prizes (placement in the generous tier) is $m=1$. Because in Siegel's framework, higher scores win the contest, we define each player's score s_i as one minus the price bid, transformed by ϕ in the case of drug maker 1. Specifically, drug maker 1's score is $s_1=1-\phi(p_1)$. Drug maker 2's score is $s_2=1-p_2$. Drug maker 1 wins if $s_1 \geq s_2$. Drug makers have "initial scores" (lowest possible score they can choose): $a_1=1-\phi(\bar{p}_1)$ and $a_2=1-\bar{p}_2$, since net prices can be at most equal to the list price. Given $s=(s_1,s_2)'$, drug maker 1's payoff is

$$u_1(s)=1(s_1 \geq s_2)v_1(s_1)-1(s_1<s_2)c_1(s_1),$$

where

$$v_1(s_1)=\frac{1}{2}(1-c_L)\phi^{-1}(1-s_1)-\frac{1}{2}(1-\min\{c_H,\bar{p}_1\})\bar{p}_1$$

is drug maker 1's valuation for winning, which is defined to be net of the profit obtained by losing for sure, and

$$c_1(s_1)=-\left(\frac{1}{2}(1-\min\{c_H,\bar{p}_1\})\phi^{-1}(1-s_1)-\frac{1}{2}(1-\min\{c_H,\bar{p}_1\})\bar{p}_1\right)$$

is drug maker 1's cost of losing, also defined to be net of the profit obtained by losing for sure. Given s, drug maker 2's payoff is

$$u_2(s) = 1(s_1 < s_2) v_2(s_2) - 1(s_1 \geq s_2) c_2(s_2),$$

where

$$v_2(s_2) = \frac{1}{2}(1 - c_L)(1 - s_2) - \frac{1}{2}(1 - c_H)\bar{p}_2$$

is drug maker 2's valuation for winning, and

$$c_2(s_2) = -\left(\frac{1}{2}(1 - c_H)(1 - s_2) - \frac{1}{2}(1 - c_H)\bar{p}_2\right)$$

is drug maker 2's cost of losing.

We now verify Siegel's (2009) Assumptions A1, A2, and A3. Assumption A1 is that v_i and $-c_i$ are continuous and nonincreasing. Noting that ϕ is an increasing function, this is true by inspection. Assumption A2 is that $v_i(a_i) > 0$ and $\lim_{s_i \to \infty} v_i(s_i) < c_i(a_i) = 0$. To see this, note that

$$v_1(a_1) = \frac{1}{2}\bar{p}_1(\min\{c_H, \bar{p}_1\} - c_L),$$

which is greater than zero if $c_L < \min\{c_H, \bar{p}_1\}$, which is true by assumption. Also, note that

$$\begin{aligned}\lim_{s_1 \to \infty} v_1(s_1) &= \lim_{p_1 \to -\infty} \frac{1}{2}(1 - c_L) p_1 - \frac{1}{2}(1 - \min\{c_H, \bar{p}_1\})\bar{p}_1 \\ &= -\infty,\end{aligned}$$

which is certainly less than

$$\begin{aligned}c_1(a_1) &= -\left(\frac{1}{2}(1 - \min\{c_H, \bar{p}_1\})\bar{p}_1 - \frac{1}{2}(1 - \min\{c_H, \bar{p}_1\})\bar{p}_1\right) \\ &= 0.\end{aligned}$$

For drug maker 2, note that

$$v_2(a_2) = \frac{1}{2}\bar{p}_2(c_H - c_L) > 0,$$

and

$$\begin{aligned}\lim_{s_2 \to \infty} v_2(s_2) &= \frac{1}{2}(1 - c_L)(1 - s_2) - \frac{1}{2}(1 - c_H)\bar{p}_2 \\ &= -\infty,\end{aligned}$$

which is less than

$$\begin{aligned} c_2(a_2) &= -\left(\frac{1}{2}(1-c_H)\bar{p}_2 - \frac{1}{2}(1-c_H)\bar{p}_2\right) \\ &= 0. \end{aligned}$$

Assumption A3 is that $c_i(s_i) > 0$ if $v_i(s_i) = 0$. For drug maker 1, v_1 is zero at its *reach* (the highest score at which v_i is zero), which is:

$$r_1 = 1 - \phi\left(\frac{1 - \min\{c_H, \bar{p}_1\}}{1 - c_L}\bar{p}_1\right).$$

c_1 evaluated at this value is

$$c_1(r_1) = \frac{1}{2}(1 - \min\{c_H, \bar{p}_1\})\bar{p}_1\left(\frac{\min\{c_H, \bar{p}_1\} - c_L}{1 - c_L}\right),$$

which is positive as required. For drug maker 2, $v_2(s_2) = 0$ at

$$r_2 = 1 - \frac{1 - c_H}{1 - c_L}\bar{p}_2.$$

c_2 evaluated at this value is

$$c_2(r_2) = \frac{1}{2}\bar{p}_2(1 - c_H)\left(\frac{c_H - c_L}{1 - c_L}\right),$$

which is positive as required. Siegel's Assumptions A1-A3 are therefore satisfied in our setting.

The following concepts in Siegel's framework help characterize equilibrium payoffs. The *marginal player* is the drug maker with the lower reach. In Case 1 ($c_H \leq \min\{\bar{p}_1, \bar{p}_2\}$), $r_2 \leq r_1$ so long as $\bar{p}_2 \geq \bar{p}_1$, which is true by definition. Therefore, drug maker 2 is marginal in Case 1. In Case 2 ($\bar{p}_1 < c_H \leq \bar{p}_2$), drug maker 2 is marginal if

$$\frac{1 - c_H}{1 - c_L}\bar{p}_2 \geq \frac{\bar{p}_1 - c_L}{c_H - c_L}\frac{1 - \bar{p}_1}{1 - c_L}\bar{p}_1 + \frac{1}{2}\frac{(c_H^2 - \bar{p}_1^2)}{c_H - c_L}.$$

This condition may or may not hold, depending on the values of $c_L, c_H, \bar{p}_1, \bar{p}_2$. We therefore consider both cases. In Case 2a, the above condition holds, so drug maker 2 is marginal. In Case 2b, the above condition does not hold, so drug maker 1 is marginal. In Cases 1 and 2a, therefore, drug maker 2 is marginal ($r_2 \leq r_1$), and in Case 2b, drug maker 2 is marginal ($r_2 > r_1$).

The contest's *threshold*, T, is the reach of the marginal player. Therefore, in Cases 1 and 2a, $T = 1 - \frac{1-c_H}{1-c_L}\bar{p}_2$. In case 2b, $T = 1 - \phi\left(\frac{1-\bar{p}_1}{1-c_L}\bar{p}_1\right)$.

Each drug maker's *power* is its valuation for winning at the threshold: $w_i = v_i\left(\max\left\{a_i, T\right\}\right)$. By construction the power of the marginal player is zero. In Case 1, each drug maker's power is the following:

$$\begin{aligned} w_1 &= \frac{1}{2}\left(1-c_L\right)\min\left\{\bar{p}_1, \frac{1-c_H}{1-c_L}\bar{p}_2\right\} - \frac{1}{2}\left(1-c_H\right)\bar{p}_1, \\ w_2 &= 0. \end{aligned}$$

In Case 2a, the powers are the following:

$$\begin{aligned} w_1 &= \frac{1}{2}\left(1-c_L\right)\min\left\{\bar{p}_1, \phi^{-1}\left(\frac{1-c_H}{1-c_L}\bar{p}_2\right)\right\} - \frac{1}{2}\left(1-\bar{p}_1\right)\bar{p}_1 \\ w_2 &= 0. \end{aligned}$$

In Case 2b, where drug maker 1 is marginal, the powers are:

$$\begin{aligned} w_1 &= 0 \\ w_2 &= \frac{1}{2}\left(1-c_L\right)\phi\left(\frac{1-\bar{p}_1}{1-c_L}\bar{p}_1\right) - \frac{1}{2}\left(1-c_H\right)\bar{p}_2. \end{aligned}$$

Theorem 1 in Siegel (2009) tells us the expected payoff of each drug maker is equal to its power. Recall that payoffs here are defined net of the drug maker's profit if it loses for sure. Therefore we have that drug maker 1's expected profit is

$$\begin{aligned} \pi_D\left(\mathbf{c}, \bar{p}_1, \bar{p}_2\right) &= w_1 + \frac{1}{2}\left(1 - \min\left\{c_H, \bar{p}_1\right\}\right)\bar{p}_1 \\ &= \begin{cases} \frac{1}{2}\left(1-c_L\right)\min\left\{\bar{p}_1, \phi^{-1}\left(\frac{1-c_H}{1-c_L}\bar{p}_2\right)\right\} & , \quad \text{Case 1,2a} \\ \frac{1}{2}\left(1-\bar{p}_1\right)\bar{p}_1 & , \quad \text{Case 2b} \end{cases}. \end{aligned}$$

Drug maker 2's expected profit is

$$\begin{aligned} \pi_D\left(\mathbf{c}, \bar{p}_2, \bar{p}_1\right) &= w_2 + \frac{1}{2}\left(1-c_H\right)\bar{p}_2 \\ &= \begin{cases} \frac{1}{2}\left(1-c_H\right)\bar{p}_2 & , \quad \text{Case 1,2a} \\ \frac{1}{2}\left(1-c_L\right)\phi\left(\frac{1-\bar{p}_1}{1-c_L}\bar{p}_1\right) & , \quad \text{Case 2b} \end{cases} \end{aligned}$$

□

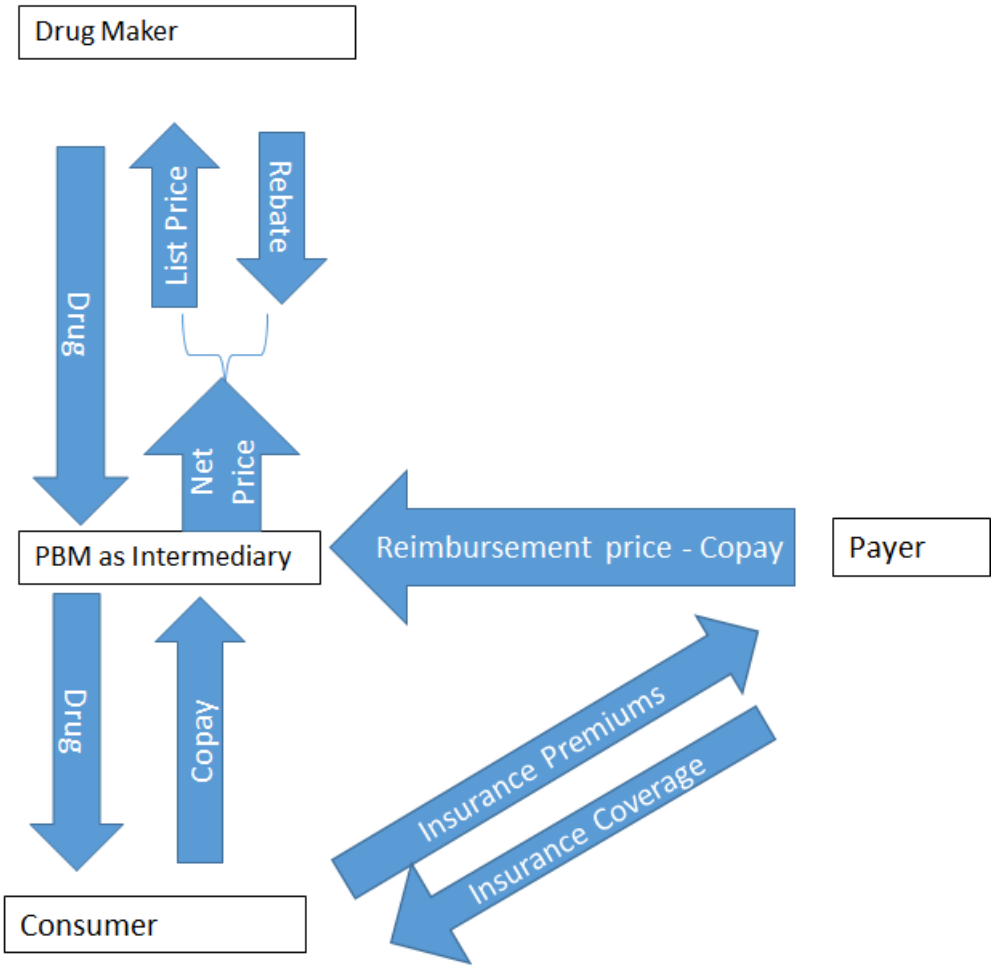

Figure 1: PBM as Intermediary Between Drug Makers, Payers and Consumers

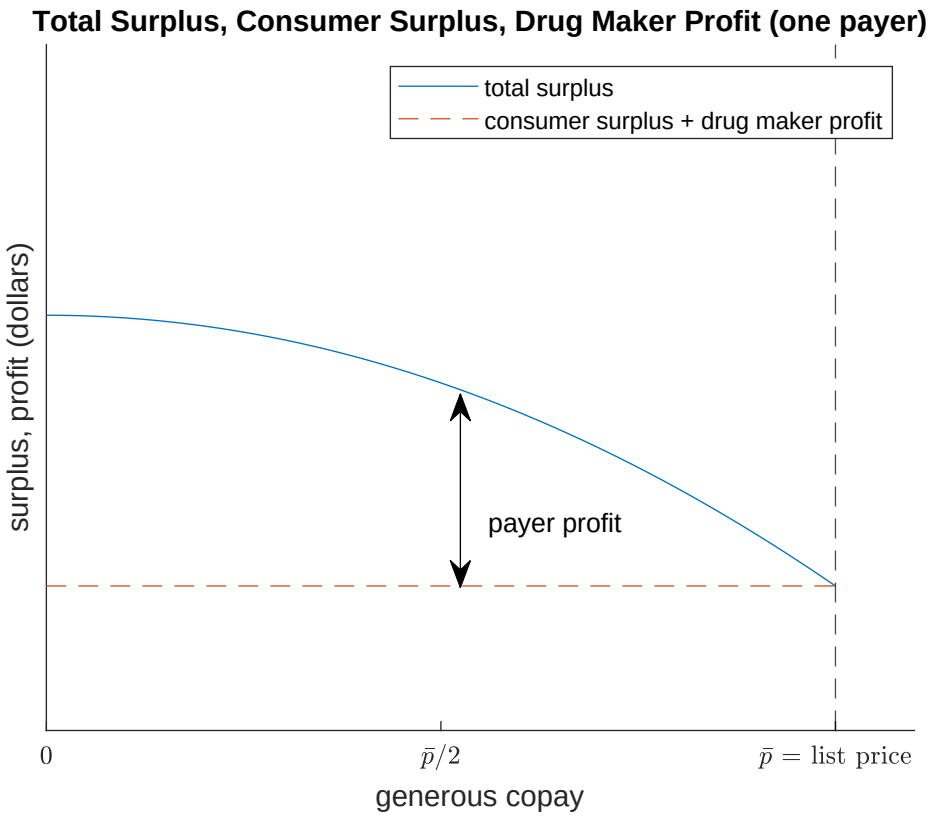

Figure 2: Total surplus and combined consumer surplus and drug maker profit as a function of the copay in the favorable tier. Unfavorable copay set at the list price, $\bar{p}$.

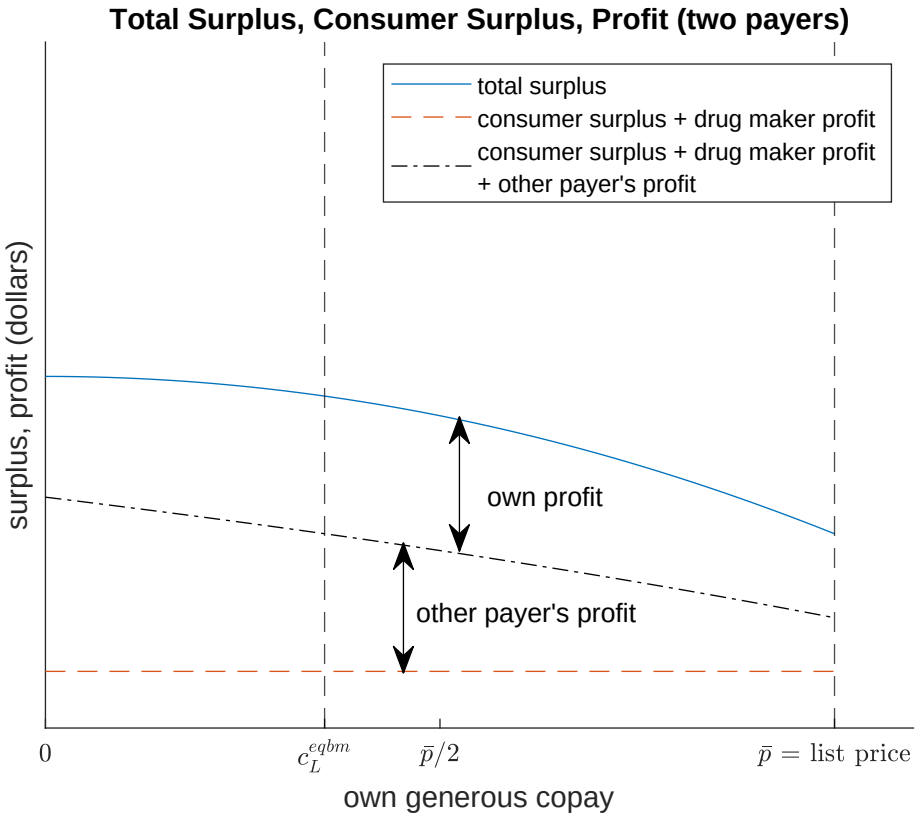

Figure 3: Total surplus and combined consumer surplus, drug maker profit, and other payer's profit as a function of one payer's own copay in the generous tier. Copay in the non-generous tier set at the list price, $\bar{p}$, and other payer's copay set at the equilibrium value.

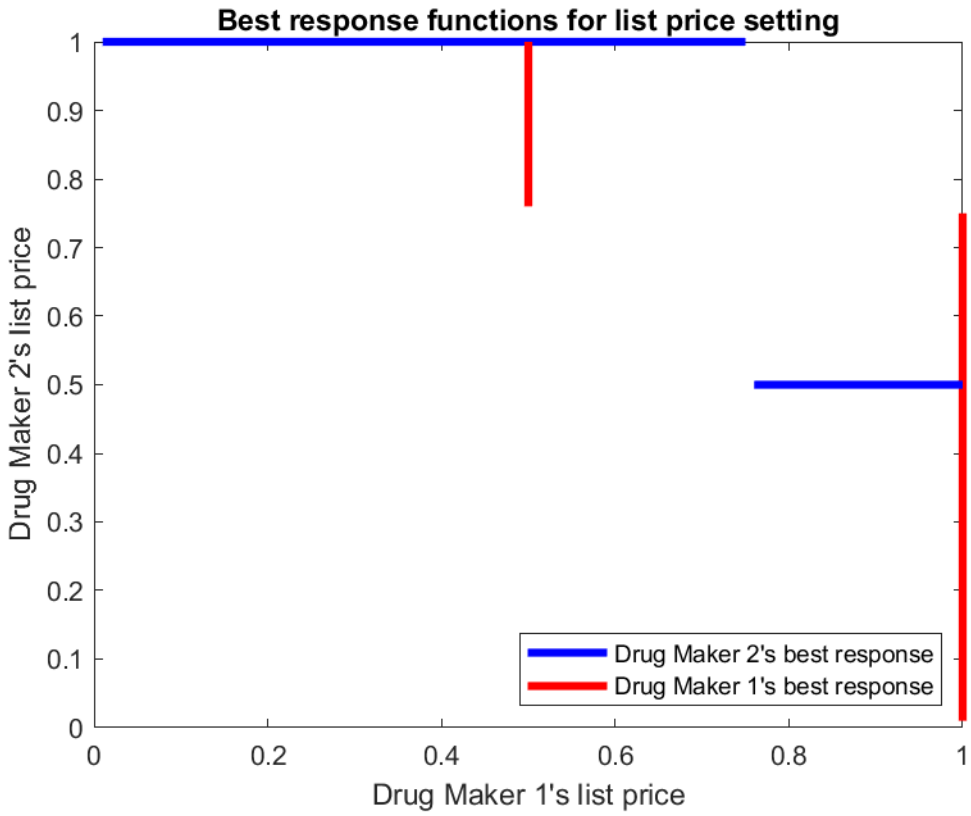

Figure 4: Best response function for one drug maker's list price as a function of the other drug maker's list price.