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

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Abstract

A small number of pharmacy benefit managers (PBMs) dominate the market for branded pharmaceuticals in the United States, but they are controversial, and their economic significance is poorly understood. Large PBMs are market intermediaries. They are also a common agent operating formularies on behalf of various third-party payers. We present a model that captures these dual roles and also clarifies the economics of drug rebates. We find that PBM-run formularies enhance the efficiency of drug markets, but when PBMs are highly concentrated these gains accrue to PBMs rather than consumers or drug makers. We also identify threats to formulary efficiency including most favored nation agreements between drug makers and PBMs and the strategic setting of high list prices by drug makers. Our model also offers insights into current market structures and a framework for assessing market reforms.

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1 Introduction

Pharmacy benefit managers (PBMs) play a central role in U.S. drug markets. As their name suggests, PBMs manage pharmacy benefits on behalf of health plans and their patient beneficiaries. Drug makers sell their products to members enrolled in commercial health plans largely through contracts with PBMs. Drug makers also rely on PBMs to sell their products to beneficiaries of government programs, including Medicare Part D drug plans, Medicare Advantage plans, and many Medicaid prescription drug plans. (Kaiser Family Foundation, 2020; Yost, 2018; Royce et al., 2019). The market for PBM services is dominated by a handful of large, for-profit, companies each acting as a common agent for diverse payers. In 2018, three PBMs accounted for 80 percent of national sales volume of prescription drugs (Fein, 2019; Feldman, 2020). The CVS-Health/Caremark PBM alone reports contracting for prescription drugs on behalf of about 105 million beneficiaries (CVS Health, 2021).

PBMs are controversial and their economic function is poorly understood. An important source of controversy is that PBMs take payments from drug makers for every unit of a drug they sell. These payments are known in the industry as rebates because they are typically negotiated as discounts off of list price. Critics worry that drug rebates are side payments that undermine PBM incentives to obtain the best price for the drugs their clients demand. Rebates play an especially significant role in the market for branded prescription drugs. Branded drugs are patent protected and so tend to be much more expensive than generic drugs. If rebates turn PBMs into compromised "double agents," why do payers contract with PBMs to acquire branded drugs for their members? If rebates are not side payments, what role do they play in the delivery of PBM services?

The model we present in this paper aims to answer these questions and, in so doing, sheds light on some fundamental economics of the U.S. market for branded prescription drugs. Our answers build on three insights gained from discussions with market participants and also from an examination of confidential contracts between PBMs and payers. The first insight is that the primary service PBMs offer payers

is to run formularies on their behalf.[1] A formulary is a list of covered drugs with associated prices for consumers and plans. It is common for formularies to feature different tiers of drug coverage. In their role as formulary operators, PBMs allocate drugs to the different formulary tiers. A branded drug assigned to a preferred tier will enjoy a lower copay, the portion of the price paid by the consumer, and hence higher demand.

The second insight is that rebates function as bids in a contest for a favorable formulary position. Specifically, branded drug makers compete for preferred formulary placement by offering PBMs rebates off the drug's list price. Generally, PBMs allocate generic drugs to the most preferred tier. For this reason, our analysis of rebates and formulary competition focuses exclusively on branded drugs. Our third insight is that PBMs are intermediaries between drug makers and payers. To survive as intermediaries, PBM-run formularies must create value upstream, for drug makers, and downstream, for payers.

Our analysis builds these insights into a stylized model of the market for branded drugs. Our model derives equilibrium rebates, equilibrium copays associated with formulary tiers, and the profit-maximizing rules for allocating drugs to tiers. In an extension, we also endogenize the list prices offered by drug makers who compete on formularies. As we will discuss in detail, understanding the equilibrium determination of these variables is key for understanding how PBMs influence the efficiency of branded drug markets as well as the distribution of any efficiency gains. Our model also offers insights into the economic forces that lead this market to rely on PBMs as intermediaries in the first place.

The model provides two key results. The first is that PBM-run formularies can enhance the efficiency of drug markets relative to the alternative of selling branded drugs directly to consumers at profit-maximizing prices. Indeed, we find that under

[1] In reality, some sophisticated self-insured employers will directly influence some aspects of formulary design such as the co-pays associated with different tiers (Ho and Lee, 2021). PBMs also provide a complex bundle of auxiliary services. For example, they 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, 2020). We do not include these auxiliary functions in our theoretical model of PBMs.

some conditions, competition for preferred formulary position can produce near-efficient drug pricing where consumers pay marginal cost for almost all drugs. Our second result is that the distribution of these efficiency gains is determined by competition in the market for PBM services. When PBMs are highly concentrated, efficiency gains resulting from formularies accrue to PBMs rather than consumers or drug makers.

A third contribution of our model is that it identifies threats to the potential efficiency gains from formularies. The first threat we analyze is widespread use of most favored nation (MFN) guarantees. MFNs promise that a PBM will have access to a drug at the lowest net price available anywhere in the market. These guarantees are, according to market participants with whom we spoke, ubiquitous in contracts between drug makers and PBMs. Certain federal regulations also build MFN-style guarantees into the purchase of a large set of drugs purchased by Medicaid and by hospitals. These MFN guarantees threaten formulary efficiency by introducing a contracting externality. If one PBM secures a lower net price for a branded drug through aggressive formulary incentives, the drug maker must also lower the net price for the other PBMs who have MFN guarantees. The result is an equilibrium in which PBMs operate with muted formulary incentives and market efficiency is reduced. We find that a large PBM acting as an agent for many payers can internalize the contracting externality created by MFNs and so enhance market efficiency. But to the extent that large, common-agent PBMs reduce market competition, the resulting efficiency gains will accrue to PBMs rather than consumers or producers.[2]

The second threat to market efficiency that emerges from our model is the strategic setting of list prices by drug makers. Consumers without access to formularies pay the list price for a drug when dispensed at the pharmacy counter. It follows that high list prices make access to the formulary more valuable to consumers and so give PBMs an incentive to bias the formulary competition in favor of high list-

[2]As we discuss in a subsequent section, common agency also creates its own contracting problems and these could lead payers and PBMs to bypass agency relationships altogether by vertically integrating. Consistent with this possibility, large PBMs have vertically integrated 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).

price branded drugs. Our model predicts that drug makers will respond by engaging in a "race to the top" in list prices. The result is an equilibrium where market efficiency and consumer welfare fall even as the joint surplus of drug makers and PBMs increase. List prices, in this analysis, are not simply a "sticker price" used for calculating rebates. Rather, the strategic setting of list prices by drug makers can adversely influence the efficiency of formularies and drug markets.[3]

We are not the first to observe that competition in contests 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 branded drugs that approximate marginal cost. Contrary to Kremer's analysis, however, in our model the bidding for preferred formulary slots aims to reduce the net price of branded drugs rather than to elicit private information about the value of the product. In our analysis, formularies operate like the all-pay contests analyzed in Siegel (2009) because 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 have not been previously studied. Contest design is also influenced by externalities of the sort MFN guarantees introduce.[4] We are not aware of any other

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

[4]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).

formal models of contest design by market intermediaries.

A number of recent papers derive empirical estimates of rebates that build on structural models of the operation of formularies (Demirer and Olssen; Feng and Maini, 2021; Ho and Lee, 2021). These studies offer valuable insights in an area where empirical work has been scarce, but they necessarily take as exogenous key features of the institutional structure that our model endogenizes, including formulary tiers, list prices of branded drugs, and patient copays. Our approach complements these empirical studies by enabling us to analyze the consequences of these endogenous choices for efficiency of outcomes and distribution of surplus.[5]

The paper proceeds as follows. The next section introduces the institutional setting. Section 3 presents the model setup and section 4 lays out the key results regarding the efficiency and distributional effects of formularies. Section 5 analyzes the effects of MFN guarantees, contracting externalities, and common agency. Section 6 analyzes how the strategic setting of list prices by branded drug makers alters formulary outcomes. Section 7 concludes by discussing broader policy implications of our results as well as directions for further research.

2 Institutional Setting: The PBM Business Model

The U.S. prescription drug market is complex and involves multiple parties including drug makers, health plans, patients, pharmacies, wholesale distributors, and PBMs. Figure 1 depicts the PBM's role as market intermediary. To clarify the relevant features of the market, we omit from the picture wholesale drug distributors and

[5] Ho and Lee (2021), for example, present a model of PBMs to estimate the magnitude of rebates, and the impact of formulary tiers and exclusions on rebates for cholesterol lowering drugs. To accomplish this empirical task, their modeling approach has to treat some aspects of the formulary as exogenous. For example, they take copays as exogenous while our model endogenizes copays. This difference matters because copays are crucial for analyzing the efficiency of formularies. Ho and Lee (2021) also treat list prices as exogenous. In an extension to our baseline model, we endogenize list prices and find that strategic setting of list prices can reduce formulary efficiency and alter distribution of the surplus. Finally Ho and Lee (2021) also take the presence of an intermediary as a given part of the institutional structure while our analysis explores some of the economic forces that produces this institutional structure.

pharmacies. In what follows, we also omit non-branded drugs from our analysis.

Drug manufacturers contract with PBMs to sell their products to plans and their beneficiaries. Drugs are assigned a list price by the manufacturer. The list price minus the per-unit rebate paid to the PBM constitute the drug's net price, that is, the effective wholesale price for each drug sale. The net price is, in other words, the price received by a drug maker for the sale of their drug. When patients insured by a plan purchase a drug, they pay a copay.[6] The PBM bills the plan a reimbursement price for the drug minus the amount that the patient already paid at the pharmacy counter. In addition to copays, patients also pay insurance premiums. Insurance coverage entitles beneficiaries to participate in the formulary and so obtain drugs at the specified copay.

The contracts between health insurance plans and PBMs are closely held trade secrets. We learned about these contracts from a sample of 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 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 patient insured by the plan at a discount off the drug's list price. 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 percent below list; then the PBM earns a profit equal to 19 percent of the list price on each unit of a branded drug sold to their clients.[7]

[6]Patient beneficiaries of some plans may instead pay a coinsurance rate. We do not present this in the Figure because our results are the same whether patients pay a copay or coinsurance.

[7]Many contracts also contain commitments to dispense the majority of drugs as generics rather than branded. 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 plans for the handling of drugs. These charges differ depending on whether the drug order was filled by mail order, in house, or other pharmacies. The fees PBMs charge plans are typically paid in aggregate across many drugs and are calculated retrospectively (i.e. after the drugs have already been dispensed to patient beneficiaries of the plan). Industry reports suggest these fees may be a growing source of revenues for PBMs. (Feldman, 2020; Fein, 2017)

PBMs can make significant profits off rebates. Industry reports estimate that the total value of manufacturers' gross-to-net reductions for brand-name drugs was $175 billion in 2019—of which about two-thirds came from rebates (Fein, 2020).[8]

Finally, the U.S. prescription drug industry features two types of most favored nation guarantees (MFNs). The first are contractual provisions between drug makers and PBMs. 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.[9] These arrangements are also described in Feldman and Frondorf (2017) and Feldman (2019).

The second type of MFN is the result of administrative pricing rules guaranteeing certain safety net providers the lowest net price prevailing in the market. The most important of these is the Medicaid Prescription Drug Rebate Program (MDRP) (Scott Morton, 1996; Congressional Budget Office, 2005).[10] The Medicaid rebate amount is set in statute and ensures that state Medicaid plans get the lowest net price (with some exceptions), through statutory and supplemental rebates. A recent Congressional investigation found evidence that drug makers took MDRP's MFN provisions into account when setting prices. "Internal memoranda and correspondence collected for this investigation suggest that drug makers are cognizant of Medicaid 'best price' when developing their net prices arrangements with PBMs and commercial plans (Grassley and Wyden, 2021, p.68)."[11]

[8]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.

[9]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."

[10]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.

[11]Earlier studies found that the implementation of the MDRP program modestly increased the list prices of some drugs (Scott Morton, 1996).

Medicaid's 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. Certain safety net clinics and hospitals, including those that serve vulnerable or underserved populations like the uninsured, participate in 340B. Participation entitles 340B clinics and hospitals to acquire drugs at deeply discounted net prices similar to the net prices given on Medicaid insured drugs (Dolan, 2019). Arguably, the 340B drug discount is more important than the Medicaid MFN, because many more drug purchases are currently 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).

3 Model Setup

Our model describes a stylized setting in which multiple makers of branded drugs sell their products to patients insured by plans who in turn contract with a PBM that runs a formulary. Plans charge their patient beneficiaries a premium to gain access to drugs covered on the formulary. Drug makers compete for preferred formulary position by offering higher rebates to the PBM.

In our baseline model, we consider two drugs that are imperfect substitutes for one another. A convenient way to represent substitution between the drugs is to imagine that half of the consumer population has a condition that responds well to one drug while the other half responds well to the other drug. We introduce substitution by assuming that a fraction $\tau \in [0, 1)$ of the population benefits equally from either drug. This means that the remaining fraction $(1 - \tau)$ gain no benefit from substituting to the other drug. When $\tau = 1$, the two drugs are perfect substitutes and when $\tau = 0$, no substitution is possible.[12]

[12]This setup is analytically tractable, but it also captures some clinical realities. For example, most patients respond well to all statin drugs, but a subset experience side effects that reduce their tolerance for many potential substitutes.

Consumer willingness to pay for the treatment depends on illness severity, denoted by random variable V which has a complementary cdf denoted by $q(p) := \Pr(V > p)$ and is independent of the illness type, or ability to substitute. 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's results do not rely on this assumption.

3.1 Drug Makers

Drug makers each produce one of the drugs at zero marginal cost. Maker d sets its drug's list price, $\bar{p}_d$. Insured consumers can purchase drugs covered on their plan's formulary, which assigns each drug to a tier with an associated copay. In the case of two drugs, the formulary has two tiers, without loss of generality. We denote the copay associated with the lower, "preferred" tier by c_L, and the copay in the higher, "non-preferred" tier by c_H. We initially analyze a market with two drug makers and exogenous list prices. Later we allow for $m \geq 2$ drugs and still later we consider the effects of strategic list price setting by allowing list prices to be chosen endogenously by drug makers.

Drug makers compete for a preferred position on the formulary by offering drugs to the PBM at a net price that is below list price. Thus, the net price for drug d is $p_d \leq \bar{p}_d$. The difference between the list price and the net price is the per-unit rebate. Drug makers choose net prices to maximize profit, which for drug maker d is given by

$$\pi_d = \begin{cases} \frac{1}{2}(1+\tau)\, p_d q(c_L) & , \quad d \text{ preferred} \\ \frac{1}{2}(1-\tau)\, p_d q(c_H) & , \quad d \text{ not preferred} \end{cases}$$

This expression shows that drug maker profit is the net price times the quantity of their drug sold. The quantity sold depends on the copay in the formulary tier to which the PBM assigns the drug: the drug in the preferred tier has higher demand both because of the lower copay ($q(c_L) \geq q(c_H)$) and because the fraction τ of consumers able to substitute will do so in favor of the drug on the preferred tier.

3.2 PBMs, Payers, and Formularies

The PBM pays the net price for the drugs to the drug maker but charges the payer a (possibly higher) reimbursement price, r_d, for drug d. 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.

In designing the formulary, the PBM specifies the copay for each tier, c_L and c_H.[13] The greater the difference in copays across tiers, the greater the value to drug makers of winning the preferred formulary position.[14] 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 is assigned to the preferred tier, or c_H otherwise.

The PBM also decides on the rules for assigning drugs to tiers on behalf of their clients. Let a denote the identity of the drug assigned to the preferred tier. As we will show, it is optimal for the PBM to assign drugs to tiers by comparing the net prices offered by the drug makers. In this way, the formulary creates an "all-pay" contest where the bidding takes the form of drug makers offering rebates off list prices to PBMs.

The PBM chooses copays, tier assignments, and reimbursement prices (r_1, r_2) to maximize its profit,

$$\begin{aligned} & \pi_{PBM}\left(a, r_1, r_2; p_1, p_2\right) \\ = & \begin{cases} \frac{1}{2}\left(\left(1+\tau\right) q\left(c_L\right)\left(r_1-p_1\right)+\left(1-\tau\right) q\left(c_H\right)\left(r_2-p_2\right)\right) & , \quad a=1 \\ \frac{1}{2}\left(\left(1+\tau\right) q\left(c_L\right)\left(r_2-p_2\right)+\left(1-\tau\right) q\left(c_H\right)\left(r_1-p_1\right)\right) & , \quad a=2 \end{cases} . \end{aligned} \tag{1}$$

Note that the PBM's profit depends on the per-unit *spread* for each drug, which is the difference between the reimbursement price the PBM receives, r_i, and the net

[13] The assumption that PBMs set the copays for each formulary tier is innocuous in the context of this baseline model because the payer and the PBM would each prefer the same copays. The reality in large, common agent PBMs is messier because large and sophisticated self-insured employers sometimes reserve the right to set their own copays (Ho and Lee, 2021). Reports suggest, however, that the setting of copays is primarily the responsibility of the PBM (Pharmacists Society of the State of New York, 2022).

[14] For an empirical estimate of the benefits of winning a preferred position in the formulary see Ho and Lee (2021).

price, p_i. The quantities depend on the tier to which each drug is assigned and the copay in that tier.

Each plan is assumed to be a monopolist in its market. Plans receive a premium payment, p_0, from enrollees in exchange for subsidized drug purchases which are covered on the PBM's formulary. The magnitude of the per-transaction subsidy is the difference between the reimbursement price the PBM charges the plan for the drug and the copay in the formulary tier to which the drug is assigned. The plan sets the premium to maximize its profit, which is zero if the consumer chooses not to enroll in insurance, and the following if the consumer does:

$$\pi_{\text{payer}}\left(p_0; c_L, c_H, r_a, r_{-a}\right) = p_0 - \frac{1}{2}\left(\left(1+\tau\right) q\left(c_L\right)\left(r_a - c_L\right) + \left(1-\tau\right) q\left(c_H\right)\left(r_{-a} - c_H\right)\right),$$

where the subscripts a and $-a$ denote the preferred and non-preferred drugs.

3.3 Consumers

Consumers purchase health insurance when healthy and then become patients in need of treatment when a medical condition manifests. Treatment consists of purchasing one of the branded drugs. We model uncertainty over the type of medical condition as a discrete random variable $D \in \{1, 2\}$ with $\Pr\left(D = d\right) = 1/2$ for $d \in \{1, 2\}$.

Consumers who enroll in insurance pay a premium p_0 to gain access to the formulary. If the drug that becomes relevant for their condition ends up in the preferred tier, the consumer pays the low copay, c_L. If the relevant drug is in the non-preferred tier, they pay a high copay, $c_H \geq c_L$. Thus, insured consumers face a two-part pricing schedule for accessing drugs: an upfront fixed premium and a copay per unit of drug purchased.

Regardless of insured status, consumers also have the option to purchase a drug at its list price. In our baseline model, we assume that list prices are identical and exogenously set at some value $\bar{p}$. In subsequent sections, we relax this assumption in order to examine more fully the economics of list prices.

In deciding whether to purchase health insurance and whether to purchase a

drug, consumers maximize expected utility. Expected utility without insurance is the option value of purchasing the drug at the list price, $\bar{p}$:

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

where $1(\cdot)$ is the indicator function. Expected utility with insurance is $U_1 - p_0$, where U_1 is the option value of purchasing a drug through the formulary. The option value is a weighted average of the value of the drug on the preferred tier, and the value of the drug on the non-preferred tier:

$$\begin{aligned} U_1 &= \frac{1}{2}(1+\tau)\, E\left[(V - \min\{c_L, \bar{p}\})\, 1\left(V > \min\{c_L, \bar{p}\}\right)\right] \\ &\quad + \frac{1}{2}(1-\tau)\, E\left[(V - \min\{c_H, \bar{p}\})\, 1\left(V > \min\{c_H, \bar{p}\}\right)\right]. \end{aligned}$$

3.4 Timing

The timing of events in the main model is as follows:

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

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, its intensity, V, and whether drugs are substitutes for the given consumer;

8. consumers decide whether to purchase the drug.

3.5 Discussion of Model Assumptions

This section discusses three simplifying assumptions our model makes and the consequences of relaxing them.

First, our model assumes that each drug maker offers the PBM a single net price that applies whether or not the drug is assigned to the preferred tier. An alternative would be to allow drug makers to offer contingent net prices: one that applies if their drug is assigned to the preferred tier and another if it is not. In the appendix we solve the model with contingent net prices and show the equilibrium allocation and distribution of surplus are the same as in our main model. The difference is that in the baseline model, drug makers mix over net prices in equilibrium, whereas in the contingent net price alternative, equilibrium net prices are deterministic.[15]

Second, we assume consumers are identical before their health shocks are realized. This assumption simplifies the analysis by ruling out any problems with adverse selection—an important issue in insurance markets but not the focus of this paper. This simplification also implies that consumer surplus above the out-of-pocket outside option can be fully extracted by the insurance premium. If we introduce ex ante heterogeneity among consumers in their valuation of insurance, we would create a downward-sloping demand curve for insurance. In this case, some consumers would enjoy consumer surplus above the out-of-pocket outside option.

Third, we assume consumers are risk neutral. We adopt this assumption to emphasize that even without risk aversion consumers benefit from access to subsidized drugs covered on the formulary through their health insurance plan. Assuming that

[15]An alternative to contingent net prices are menu contracts in which rebates are conditioned on the placement of all relevant drugs in the formulary. When the formulary has only two drugs, contingent net prices are equivalent to menu contracts. Ho and Lee (2021) analyze menu contracts for a three drug formulary. In this case, the results may be sensitive to the menu contracting assumption.

consumers are either risk averse (Rothschild and Stiglitz, 1976; Zeckhauser, 1970) or liquidity constrained (Ericson and Sydnor, 2018) would further increase the value to consumers of purchasing insurance and also reduce the copay associated with the non-preferred tier.

4 The Baseline Model: Key Results

In this section we present the main findings from our baseline model regarding the efficiency and distributional consequences of intermediary-run formularies in the market for branded prescription drugs. We show that formularies are efficiency enhancing relative to drug makers selling directly to consumers at list price. The surplus created by the formulary accrues to the intermediary, not to drug makers or consumers. Competition among PBMs does not affect efficiency, but can mean part of the surplus accrues to payers; competition among payers or heterogeneity among consumers can mean part of the surplus accrues to consumers.

4.1 Formularies are more efficient than selling directly to consumers at list prices

To show that formularies are efficiency enhancing, we begin with a simple setting where a single PBM operates a formulary on behalf of a single monopoly payer. The PBM's formulary allocates two drugs to two tiers. The list price for each drug is exogenously set to $\bar{p}$, the price a monopolist drug maker would charge if selling directly to consumers. The timing is as described in Section 3.4.

4.1.1 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, its intensity V, and whether they can substitute drugs as given. Consumers who enrolled in health

insurance purchase the drug corresponding to their medical condition, or, if they are able to substitute, the drug with the lower copay, 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 at least the amount of the premium.

The following lemma formalizes the consumer's equilibrium strategies.

Lemma 1 (**Consumer insurance and drug purchase decisions**). *In the baseline model, in every subgame-perfect Nash equilibrium, drug purchasing and insurance enrollment decisions are as follows. A consumer who enrolled in the insurance plan purchases the preferred drug through the formulary if $V \geq c_L$ and $c_L \leq \bar{p}$ and the consumer's illness D corresponds to the preferred drug, or the drugs are substitutes in that consumer's treatment. A consumer who enrolled in the insurance plan purchases the nonpreferred drug through the formulary if (1) $V \geq c_H$ and $c_H \leq \bar{p}$; and (2) the consumer's illness D corresponds to the nonpreferred drug and the drugs are not substitutes for that patient. Enrolled consumers who do not purchase through the formulary and unenrolled consumers purchase drug d out of pocket if and only if $D = d$ and $V \geq \bar{p}$. Consumers enroll in insurance if and only if*

$$p_0 \leq U_1 - U_0. \tag{2}$$

Next, consider the health insurer's choice of premium. The payer chooses the premium taking reimbursement prices, copays, and tier assignment as given, and does so to maximize its expected profit. Because the payer's profit, π_{payer}, is increasing in the premium, the payer will set the premium so the consumer's enrollment condition, (2), 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 following lemma formalizes this result.

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

$$\pi_{payer}\left(U_1 - U_0; c_L, c_H, r_a, r_{-a}\right) \geq 0 \tag{3}$$

and $p_0 > U_1 - U_0$ *otherwise.*

The PBM sets reimbursement prices and makes tier assignments to maximize its profit, $\pi_{\text{PBM}}\left(a, r_1, r_2; p_1, p_2\right)$, defined above in equation (1), 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 it does not pin down the individual reimbursement prices separately because the payer's profit depends on the reimbursement prices only through their weighted average. The PBM maximizes its profit by assigning the drug with the lower net price to the preferred tier. The following lemma establishes these results.

Lemma 3 (**PBM's choice of reimbursement prices and tier assignment**). *In the PBM model with exogenous list prices, the PBM sets reimbursement prices to satisfy*

$$\frac{1}{2}\left(r_1\left(1+\tau\right)q\left(c_L\right) + r_2\left(1-\tau\right)q\left(c_H\right)\right) = p_0 + \frac{1}{2}\left(c_L\left(1+\tau\right)q\left(c_L\right) + c_H\left(1-\tau\right)q\left(c_H\right)\right)$$

if $p_1 \leq p_2$, *and*

$$\frac{1}{2}\left(r_2\left(1+\tau\right)q\left(c_L\right) + r_1\left(1-\tau\right)q\left(c_H\right)\right) = p_0 + \frac{1}{2}\left(c_L\left(1+\tau\right)q\left(c_L\right) + c_H\left(1-\tau\right)q\left(c_H\right)\right)$$

otherwise. The PBM assigns drug 1 to the preferred 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 the resulting tier assignment. Recall that

drug maker 1's expected profit as a function of p_1, taking p_2 as given is

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

provided the payer's participation condition (3) is satisfied, and $\bar{p}q(\bar{p})/2$ otherwise. Drug maker 2's profit is defined analogously. Because $(1+\tau) q(c_L) > (1-\tau) q(c_H)$ 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.[16] 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 4 (**Drug net price equilibrium distribution**). *In the baseline model, 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:*

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

Note that the modal price in the equilibrium net-price distribution is also the

[16] Mixed strategies are a general feature of all-pay auctions (Siegel, 2009). Intuitively, suppose both drug makers offered the same price and so were equally likely to be in either tier. One drug maker could profitably deviate by undercutting the other's price and getting placed in the preferred tier. This logic holds for a drug price above zero. Zero is not an equilibrium net price either because at this point neither drug maker is making positive profits. One drug maker could therefore increase its profit by offering a positive price and being placed in the non-preferred tier. By similar reasoning, there is also no asymmetric pure strategy equilibrium where the two drug makers offer different prices. The drug maker with the lower price can deviate by slightly raising prices. Its profit increases, and it wins the preferred tier.

lowest price in the support:

$$\underline{p} = \bar{p}\frac{(1-\tau)\,q\,(c_H)}{(1+\tau)\,q\,(c_L)}.$$

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 low copay and the smaller the demand at the high 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 5 (**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.*

A consequence of the lemma is that the PBM can induce lower net prices for drugs by increasing the spread between the low and high copays. In other words, the formulary provides an arena in which drug makers compete on net price for favorable placement. This competition does not depend on the drugs being substitutes: the result holds even when $\tau = 0$, that is, when there is no substitutability between drugs.

Increasing the spread in copays encourages lower net prices but also introduces inefficiency because the socially optimal copays would be set equal to the marginal cost of both drugs, and marginal cost is assumed to be zero. Increasing the spread between copays also affects other determinants of the PBM's profit: raising c_H reduces the value of insurance coverage and thus reduces premium revenue and consequently the average level of reimbursement prices the PBM can charge the payer; lowering c_L increases the payer's subsidy costs and thus also reduces the level of reimbursement prices that can be charged. The PBM'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 low and high copay. The following lemma describes the optimal copays for the PBM.

Lemma 6 (**Optimal copays**). *Suppose* $\bar{p} \leq q^{-1}(0)$. *Then the profit-maximizing choices of copays are* $c_L = 0$ *and* $c_H = \bar{p}$.

The equilibrium preferred copay of zero makes formularies efficiency enhancing relative to selling directly to consumers at profit-maximizing prices. In the absence of the formulary and copay structure, all consumers face a price $\bar{p}$ for the drug they need.[17] Under the formulary, a fraction $(1+\tau)/2$ get the drug at zero price, and only the remaining $(1-\tau)/2$ face the price $\bar{p}$.

In summary, in the baseline model where a PBM operates the formulary on behalf of payers, the equilibrium formulary consists of a preferred tier with a copay of zero and a non-preferred tier with a copay equal to the list price; drug makers compete for the preferred 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 subsection offers a graphical representation of the model.

4.1.2 Graphical Representation of the Formulary-Design Problem

We can build intuition for the model by representing it graphically in the special case of a linear demand curve and no substitution ($q(p) = 1 - p, \tau = 0$). 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 low copay, c_L, holding c_H fixed at $\bar{p}$. The difference between the two curves is the PBM's profit. Reducing the low 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, allowing the payer to charge

[17] This result depends on the list price being set to the price drug manufacturers charge to consumers in the absence of insurance without responding to formulary incentives—that is, assuming the list price is exogenous to the formulary. The efficiency consequences of formularies change when the list price is endogenous, a case considered in Section 6.

higher premiums, which in turn the PBM captures by charging higher reimbursement prices. Consumer surplus is thus unaffected by the PBM's choice of copays.

Reducing the low 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 5. In equilibrium, therefore, drug makers always receive a payoff equal to what they would earn if they lose the formulary contest and are assigned to the non-preferred tier. For this reason, drug maker profit is also unaffected by the PBM's choice of low copay. The constant consumer surplus and drug maker profit is represented by the horizontal dashed red curve in the figure. Given c_H, the PBM is therefore the residual claimant on the surplus generated by the formulary. Because total surplus increases as the copay in the preferred tier decreases, while consumer surplus and drug maker profit remain flat, the PBM's profit is maximized at $c_L = 0$.

4.1.3 Approximate Efficiency with More than Two Drugs

PBM-run formularies 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 this market.

In principle, PBMs 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). We have shown that this efficient outcome is not the equilibrium outcome in our baseline model: instead, the PBM sets one of the copays to the list price which is set at the monopoly price. The result is deadweight loss: there exist consumers with willingness to pay higher than the marginal cost of producing the drug who do not receive the drug. Put differently, a PBM-run formulary becomes less efficient the more drugs are assigned a copay higher than marginal cost, as in the non-preferred tier.

In this section, we extend our model to the case where there are many drugs, and

ask how copays will be assigned to each drug in equilibrium. To allow for many drugs we assume that consumers are equally likely to fall ill with one of $m \geq 2$ medical conditions. Each of these conditions is treated by a different branded drug produced by a different drug maker, but as before, there is a probability τ that the consumer can substitute across the drugs. We impose no restrictions on the formulary and allow the most general structure possible: as many tiers as there are drugs. The PBM assigns each of the m drugs to one of the m formulary tiers, each with an associated copay, $c_{(1)}, c_{(2)}, \ldots, c_{(m)}$, where $c_{(1)} \leq c_{(2)} \leq \cdots \leq c_{(m)}$. The timing of decisions is the same as in the baseline model.

Equilibrium behavior in this extension is similar to that in the baseline model. Specifically, the PBM assigns drugs to tiers in order of the net price, with the drug whose net price is lowest being placed in the most preferred tier. Drug makers also set net prices using mixed strategies where the net price distribution includes the list price as its upper bound.

The key result is that the equilibrium formulary sets all copays but one to zero, and it sets the remaining copay to the list price. In other words, the optimal formulary design includes two tiers: a preferred tier with a copay of zero that includes all drugs but one, and a non-preferred tier with a copay equal to the list price to which the remaining drug is relegated. 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 surplus converges to the efficient surplus. The following proposition formalizes these results.

Proposition 1 (**Formulary equilibrium with m drugs is approximately efficient**). *Equilibrium copays with m drugs are as follows:*

$$\begin{aligned} c_{(1)} &= c_{(2)} = \cdots = c_{(m-1)} = 0; \\ c_{(m)} &= \bar{p}, \end{aligned}$$

and equilibrium total surplus is

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

Because the first-best surplus is $E[V]$, the result means that as m increases, equilibrium surplus converges to full efficiency. For any given number of drugs, m, however, the equilibrium outcome is inefficient. The inefficiency stems entirely from the drug assigned to the non-preferred 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 a non-preferred tier, even if the probability is only $1/m$, induces drug makers to offer substantial rebates off list price, increasing profit for the PBM. If all tiers had a copay of zero, drug makers would offer no rebates.

4.2 Distributional effects of PBM-run formularies

The simplest version of our baseline model has a single PBM running a formulary on behalf of a single monopoly payer. We have shown that with a large number of drugs, the equilibrium outcome is nearly efficient. But how is the additional value distributed between drug makers, PBMs, and consumers? Our baseline model produces stark distributional effects: all the efficiency gains generated by the formulary accrue to the PBM. In other words, drug makers, payers, and consumers get value equal to their options outside the formulary. The intuition for this result is helpful for understanding the workings of our model.

Drug maker profits are pinned down because in the formulary contest each drug maker bids away its surplus down to what it would gain outside of the formulary selling drugs at the list price. Thus while drug makers sell much higher volume within the formulary, the equilibrium formulary design creates competition that ensures drug makers do not capture the extra profits generated by these additional sales. It follows that drug makers may capture a share of the additional producer surplus only in settings where competition within the formulary is weakened. We analyze two such settings in subsequent sections.

The monopoly payer in our baseline model sells insurance and hence formulary access to a population of homogenous consumers. This monopolist extracts all surplus from consumers by setting insurance premiums equal to the money metric utility

gain to consumers from joining the formulary. If we expanded the model to allow for a population of consumers with heterogeneous willingness to pay, the payer would not be able to capture *all* the value to consumers generated by the formulary—but it would still be able to capture a substantial portion. If the monopoly payer were replaced by a payer operating in a more competitive market environment, an even larger portion of marginal surplus would accrue to consumers.

The monopolist PBM in our baseline model can capture all the surplus generated by the formulary by setting its fixed fee, π_0, for PBM services sufficiently high. This last result is sensitive to the degree of competition in the market for PBM services. In the Appendix, we demonstrate that when there are several PBMs, they compete on the fixed transfer, π_0, giving surplus to the payers. But because the PBM is still the residual claimant on the formulary surplus, the equilibrium design of the formulary is not influenced by the degree of market competition. In other words, no deadweight loss is created by a monopolist PBM. While heightened competition for PBM services does not improve market efficiency, it does force down the fixed fee that PBMs charge payers for access to the formulary. The greater the exent of competition between PBMs, the larger the portion of surplus that will stay with the payer. Conversely, in highly concentrated PBM markets of the sort we observe in the United States, PBMs will be able to capture gains that might otherwise accrue to payers and perhaps their customers.

5 MFNs, Contracting Externalities, and Common Agency

The baseline results described above highlight the efficiency enhancements formularies achieve relative to an alternative of drug makers selling directly to consumers. We now turn attention to factors in the market that might threaten the efficiency of formulary-mediated drug markets. Two such factors that are relevant to the U.S. market for prescription drugs are MFN guarantees and the strategic setting of list prices. We consider each in turn.

5.1 MFN Guarantees and Contracting Externalites

MFNs entail a promise on the part of the drug maker that a PBM will have access to a drug at the lowest net price available anywhere in the market. These guarantees are commonplace in contracts between drug makers and PBMs. Certain federal regulations also build MFN-style guarantees into the purchase of a large set of drugs by Medicaid and by hospitals. From the perspective of our model, MFN guarantees matter because they create a contracting externality. If one PBM wins a lower net price for a drug through aggressive formulary design, other PBMs who have MFN guarantees also enjoy lower net prices. The result is that in equilibrium, formularies set copays in the favored tier above marginal cost. When formularies require consumers to pay more than marginal cost for their drugs, the efficiency gains from formularies are reduced.

In this section we analyze MFN-induced contracting externalities in detail. To keep matters simple, we return to the baseline setting with two drugs and continue to assume that the list prices of these drugs are exogenously set to $\bar{p}$. Contrary to our baseline model, however, we also assume that there are two PBMs whom we index with $j = 1, 2$, each operating a formulary on behalf of a single payer. The PBMs each have an MFN guarantee with each drug maker. Consequently, when the two drug makers set their net prices, p_1 and p_2, these prices apply to both PBMs.

As before, we describe each player's equilibrium strategy 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 the premium set by payer j, p_0^j, and the copays assigned to the drugs in payer j's market, 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

$$\begin{aligned} U_1^j &= \frac{1}{2}(1+\tau)\, E\left[\left(V - \min\left\{c_L^j, \bar{p}\right\}\right) 1\left(V > \min\left\{c_L^j, \bar{p}\right\}\right)\right] \\ &\quad + \frac{1}{2}(1-\tau)\, E\left[\left(V - \min\left\{c_H^j, \bar{p}\right\}\right) 1\left(V > \min\left\{c_H^j, \bar{p}\right\}\right)\right]. \end{aligned}$$

The payer's choice of premium, and the PBM's reimbursement prices and tier assignment rule are also unchanged from the results in Lemmas 2 and 3: payer j's premium is

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

as long as its profit is positive, reimbursement prices are set so the payer's zero-profit condition binds, and the PBM 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 PBM's copays. Drug maker 1's profit as a function of its own net price, taking drug 2's net price as given is

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

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 case described in Lemma 4, drug makers choose a mixed strategy net-price distribution with the following cumulative distribution function:

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

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

The following proposition makes this argument.

Proposition 2 (With an MFN between the drug maker and two PBMs, contracting externalities increase the copay in the preferred tier, reduce PBM profits, and reduce total surplus). *In any symmetric equilibrium, the copay in the preferred tier, c_L, is greater than zero, and total PBM profit and total surplus are lower than in the one-PBM case.*

The proposition shows that with two PBMs, contracting externalities weaken incentives for drug makers to lower prices and reduce total profit to the PBMs and payers. Figure 3 illustrates the effect of these externalities in the special case of linear demand and no substitution. The blue line in the figure depicts total surplus generated by pharmaceutical sales as a function of one PBM's low copay, holding the high copays and the other PBM's low copay fixed at their equilibrium values. Total surplus naturally declines as the first PBM's low copay increases because fewer consumers purchase the drug. The red dashed line represents the combined consumer surplus and drug maker profit. These are flat because neither depends on the low copay: the premium extracts all consumer surplus beyond the outside option which is determined by the list price, and drug maker expected profit is determined by the "loser's" reward, which is a function of the high copay only. The black dashed curve shows by contrast that the other PBM's profit does vary with the first PBM's low copay. This reflects the contracting externality: as one PBM's low copay falls, other PBMs benefit from lower net drug prices. Because the first PBM no longer captures the full benefit of lower drug prices, the PBM's profit is no longer maximized at $c_L = 0$, but rather at a strictly higher value. A higher value for c_L in turn reduces consumers' consumption and consequently reduces efficiency.

5.2 PBM Acting as a Common Agent Internalizes the Externality

The previous section found that when several PBMs 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. The PBM specifies copays on behalf of all payers, and sets the reimbursement prices, r_1 and r_2, which payers must remit to the PBM for each drug transaction. 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, π_0. 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. The timing is as shown in Section 3.4, except the PBM offers its contract to several payers, each of which decides whether to contract with the PBM.

The fact that the PBM is acting as common agent does not change the consumer's problem, nor the payers' problem. The PBM sets reimbursement prices and makes tier assignments as in the baseline model with a single PBM serving a single payer. Because the drug makers face a single formulary designed by a single PBM (operating on behalf of several payers), the drug makers' problem in setting net prices is also identical to the case with a single PBM serving a single payer. The mixed strategy equilibrium determining the net-price distribution is therefore identical to the baseline model. Likewise, the PBM's profit function is identical to the case where it was the only PBM, serving a single payer. Consequently, the PBM's choice of copays is identical to that in the baseline model. That is, the PBM will set $c_L = 0$ and $c_H = \bar{p}$. The PBM thus resolves the externality. The result is that when a PBM acts as intermediary, the joint profit among the PBM and payers is higher than when payers employ separate intermediaries and total surplus is higher, as the following proposition formalizes.

Proposition 3 (**When PBMs operate with MFNs, total surplus and joint profits rise when payers select a single PBM as a common agent.**). *The contracting externality created by MFNs reduces total surplus and joint PBM and payer profit. When payers choose a single PBM as a common agent, the contracting*

externality is internalized and total surplus and joint PBM and payer profit are the same as in the baseline model.

In sum, this proposition suggests that the widespread use of MFNs creates an advantage for large, common-agent PBMs. The presence of a common-agent PBM not only raises joint profit among the payers and the PBM but also improves efficiency because the common-agent PBM chooses a lower copay in the preferred tier.

Two further implications of this result are worth pointing out. First, it suggests that MFN-induced contracting externalities may be part of the explanation for why large payers delegate formulary operations to PBMs rather than running their own. Secondly, policies aimed at enhancing competition by breaking up large PBMs into smaller entities should also consider eliminating MFN-style guarantees from the market. Failure to address MFN-induced contracting externalities could lead to efficiency losses even as competition for PBM services is increased.

5.3 More on Common-Agent PBMs

In the previous section, we discussed how large, common-agent PBMs can be an adaptation to a contracting externality created by MFN guarantees. In this section we briefly discuss how large, common-agent PBMs introduce additional contracting externalities that create an advantage for other organizational adaptations such as vertical integration between payers and PBMs.

PBMs in our model capture the entire surplus produced by payers. This setup leads to an easy alignment of interests between principal (payer) and agent (PBM), but downplays the possibility that the PBM may wish actions that are not in the interest of payers.

Suppose, in contrast, that PBMs cannot capture all the surplus produced by payers. A simple way to model this would be to assume that PBMs do not have full information about the demand for drugs within each payer's population. In this case, payers might prefer for the PBM to promote generics so that insurers could offer their members lower-priced formulary services. PBMs, who in this case capture only a fraction of the gains from generics, might prefer to sell branded drugs offering

higher rebates.[18]

One way to resolve this agency problem between PBMs and payers is through an incentive contract. We have already reported that contracts between PBMs and payers impose 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 contracts may not arise in equilibrium. To see why, consider that when a PBM invests in the software and information systems that improve generic substitution in response to incentive provided by one of its payer clients, this will likely increase generic use by all of its other payer clients, as well. This contracting externality leads to inefficiently weak equilibrium incentives. Indeed, if investments in generic substitution involve substantial fixed costs, the equilibrium can be one in which payers write no incentive contracts at all (Frandsen et al., 2019).

Vertical mergers between PBMs and payers may reduce or eliminate the contracting externalities resulting from common agency. The merged entity's profits will include the value created by enhanced use of generics.

In the past several years, large PBMs have vertically consolidated with substantial insurers, 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 explaining the reasons for vertical integration between PBMs and payers, the business press does not typically mention common-agency or contracting externalities. Rather they emphasize 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,

[18]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.

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 suggests, however, that the integration of information systems can be inhibited by common-agency induced contracting externalities (Frandsen et al., 2019, Section 5). To see how this might work, 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, incentives for maximizing the value created by integrated information systems increase. Put differently, common agency creates a complementarity between vertically integrated governance structures and integrated information systems.

6 The Strategic Setting of High List Prices

In this section, we analyze the economics of list prices by allowing the two drug makers to set list prices endogenously. List prices matter for welfare in our model 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 they 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-preferred 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 non-preferred tier, we assume the copay charged to 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 intermediary operates a single formulary, appealing to the result in the last section that a PBM acting on behalf of several payers achieves the same allocation as a single intermediary would.

The timing is as follows:

1. drug makers simultaneously choose list prices $\bar{p}_1$ and $\bar{p}_2$;
2. the intermediary 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 intermediary 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, its intensity, V, and whether the drugs are substitutes for the given consumer;

[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.

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:

$$\begin{aligned} U_0 &= \frac{1}{2}(1+\tau) E\left[(V-\bar{p}_1) 1(V>\bar{p}_1)\right] \\ &\quad + \frac{1}{2}(1-\tau) E\left[(V-\bar{p}_2) 1(V>\bar{p}_2)\right], \end{aligned}$$

and

$$\begin{aligned} U_1 &= \frac{1}{2}(1+\tau) E\left[(V-\min\{c_L,\bar{p}_1\}) 1(V>\min\{c_L,\bar{p}_1\})\right] \\ &\quad + \frac{1}{2}(1-\tau) E\left[(V-c_H) 1(V>c_H)\right] \end{aligned}$$

if drug 1 wins, and

$$\begin{aligned} U_1 &= \frac{1}{2}(1+\tau) E\left[(V-c_L) 1(V>c_L)\right] \\ &\quad + \frac{1}{2}(1-\tau) E\left[(V-\min\{c_H,\bar{p}_1\}) 1(V>\min\{c_H,\bar{p}_1\})\right] \end{aligned}$$

if drug 2 wins. The intermediary'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 7 (**Choice of tier assignment with endogenous list prices**). *The intermediary assigns drug 1 to the preferred 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 $c_H \leq \min\{\bar{p}_1, \bar{p}_2\}$ (Case 1), and*

$$\phi(p) = \alpha p_1 + \beta$$

for some $\alpha \leq 1$ *and* $\beta \geq 0$ *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 high copay (Case 1), the tier assignment is as before: the drug with the lower net price is placed in the preferred tier. But when one of the list prices is lower than the high 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. Therefore, biasing the formulary toward the higher list price drug 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 impact on total surplus is smaller 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 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 $\bar{p}_1 = 1/2$, which is the price a profit-maximizing monopolist facing no competition would charge. 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 $\underline{\pi}_1(\bar{p}_1; c_H) = (1 - \tau) q(\min\{\bar{p}_1, c_H\}) \bar{p}_1/2$, and for drug maker 2 it is $\underline{\pi}_2(\bar{p}_2; c_H) = (1 - \tau) q(c_H) \bar{p}_2/2$. Any payoff above this amount we term **contest rents**. In the baseline model where drug makers are symmetric, competition eliminates contest rents. 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 PBM to design the contest so as to level the playing field and minimize contest rents for the drug makers, because contest rents come at the expense of PBM profit. This is indeed the case: as the result below shows, the PBM 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 PBM 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 $(1-\tau)\, q\left(\bar{p}_1\right) \bar{p}_1/2$. This is proportional to its monopoly profit at price $\bar{p}_1$, and is maximized at $\bar{p}_1 = 1/2$. Drug maker 2's default payoff is $(1-\tau)\, q\left(c_H^*\right) \bar{p}_2/2$, where c_H^* is the intermediary's optimal choice of high 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 intermediary'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-preferred 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. One drug maker sets a list price as high as

possible, while the other chooses the monopoly level.[20]

Figure 4 depicts the equilibrium determination of list prices 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.

6.1 Consequences of List Price Caps

Popular discussions of market reform often focus on capping the list price of drugs. Our analysis of formularies highlights the efficiency and distributional benefits of such a policy.

First, a sufficiently aggressive price cap (at, say, $\bar{p}_1^*$), eliminates the possibility of strategic list price setting of the sort that distorts the formulary contest. To see why, note that in our setting the best response to a drug maker setting a list price at $\bar{p}_1^*$ is for the other drug maker to set its list price as high as possible. Binding caps on list prices thus produce a constrained equilibrium in which both drug makers set the list price to the cap. In the resulting formulary contest equilibrium, copays, net prices, and allocation are the same as in our baseline model.

Secondly, further reducing the cap below $\bar{p}_1^*$ has beneficial effects because it limits the outside option of drug makers and and improves that of consumers. Drug makers' surplus decreases because their expected profit is pinned down at their outside option of selling drugs to consumers directly at the cap. Below the cap, profit decreases as the cap decreases. Consumer surplus increases because their surplus is determined by their outside option of purchasing the drugs at list price, which clearly increases

[20]This outcome follows from the incentives in of our model, but industry observers note closely related pricing incentives. 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

as list price decreases. Improving consumers' outside option means that less surplus can be extracted by the payer and ultimately the PBM in the form of premiums. In short, a sufficiently aggressive list price cap increases static efficiency, reduces drug maker and intermediary profits, and increases consumer surplus.

7 Conclusion

A small number of pharmacy benefit managers (PBMs) dominate the market for branded pharmaceuticals in the United States, but they are controversial and their economic significance is poorly understood. At the most basic level, PBMs are market intermediaries who also run formularies on behalf of health plans and other payers. We present a model that captures these dual roles, clarifies the economics of PBM-run formularies, and offers a framework for understanding market institutions and strategies for market reform.

The model provides two key results. First, PBM-run formularies can enhance the efficiency of drug markets relative to the alternative of selling branded drugs directly to consumers at list prices. Indeed, under some conditions, formularies produce near efficient drug pricing in which consumers pay marginal cost for almost all drugs. Second, the distribution of these efficiency gains is determined by competition in the market for PBM services. When PBMs are highly concentrated, efficiencies resulting from formularies accrue to PBMs rather than consumers or drug makers.

Public policy should aim to realize the potential efficiency gains from PBM-run formularies. Our model highlights two threats to formulary efficiency. The first are most favored nation (MFN) guarantees built into private contracts and federal regulations. MFNs create contracting externalities that reduce the efficiency of formularies. Large PBMs acting as a common agent for many payers internalize this externality and so can improve efficiency. In this way MFNs contribute to the dominance of very large, common-agent PBMs. The primary policy implication of this result is that MFNs introduce a "theory of the second best" problem in PBM markets. Attempts to increase competition by breaking up very large PBMs may make drug markets *less* efficient—so long as MFN guarantees are in wide use.

The second threat to formulary efficiency surfaced by our analysis involves the strategic setting of high list prices for drugs. Consumers without access to formularies pay list price for their drugs. It follows that high list prices make access to the formulary more valuable to consumers and so give PBMs an incentive to bias the formulary competition in favor of high list-price drugs. Our model shows that drug makers will respond by engaging in a "race to the top" in list prices. In the resulting equilibrium, market efficiency and consumer welfare fall even as the joint surplus of drug makers and PBMs increase. The primary policy implication of this result is that wildly inflated list prices may be the direct result of the economics of PBMs and market efficiency may be improved if the "race to the top" in list prices is inhibited. Caps on list prices can, in this way, enhance efficiency and produce more desirable distributional effects.

Our framework has additional implications for efforts to reform and regulate the U.S. market for prescription drugs. Some reform proposals focus on altering who receives rebates from drug makers or propose eliminating them entirely.[21] Our analysis suggests that such an approach may prove disappointing. In our baseline model, nominally passing rebates through to payers or consumers, for example, would not improve the efficiency of formularies or even alter the distribution of economic benefits. 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.

We conclude by observing that there are other potential threats to formulary efficiency that are not well captured in our current modeling framework. For example, our model suggests that formularies enhance efficiency by creating competition between drug makers, but we do not analyze the possibility of collusion or side agreements that might undermine formulary competition. Similarly, while our model suggests that vertical mergers between PBMs and payers can enhance efficiency, vertical mergers may also have anti-competitive effects that we do not analyze. Examining

[21]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).

threats to formulary efficiency that lie outside our model is an important area for future research.

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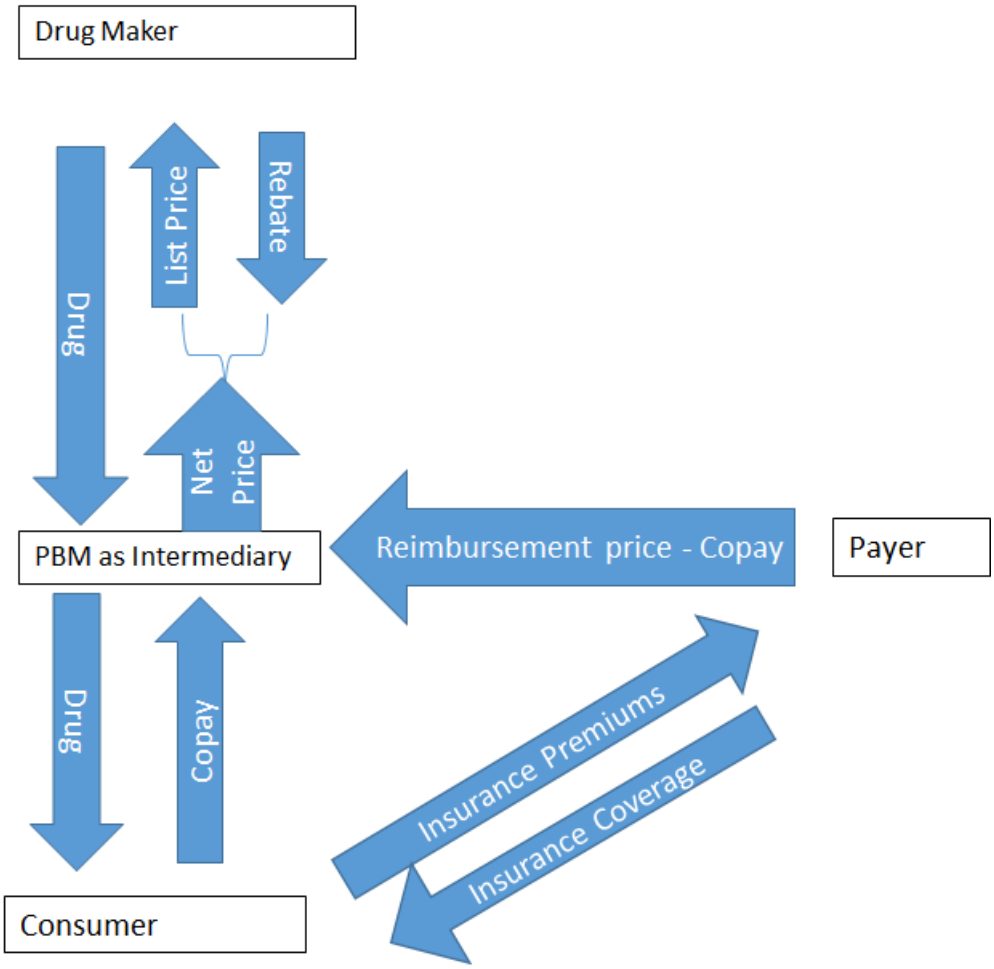

Figure 1: PBM as Intermediary Between Drug Makers, Payers and Consumers

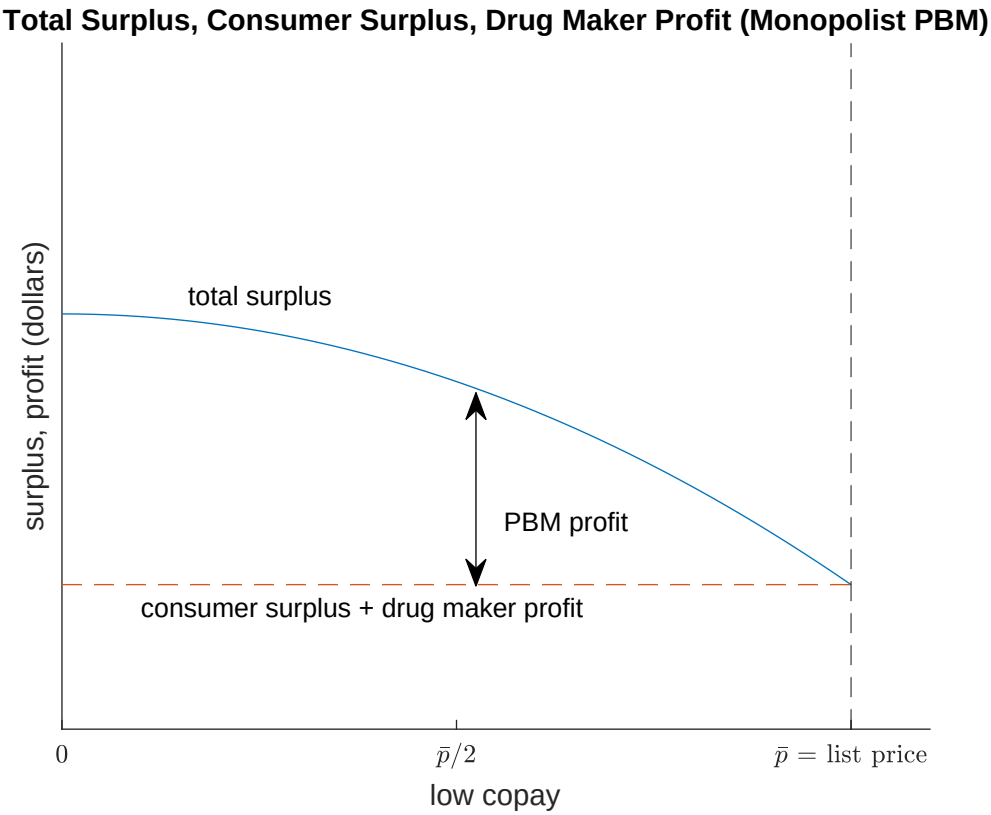

Figure 2: Total surplus and combined consumer surplus and drug maker profit as a function of the copay in the preferred tier. High copay set at the list price, $\bar{p}$.

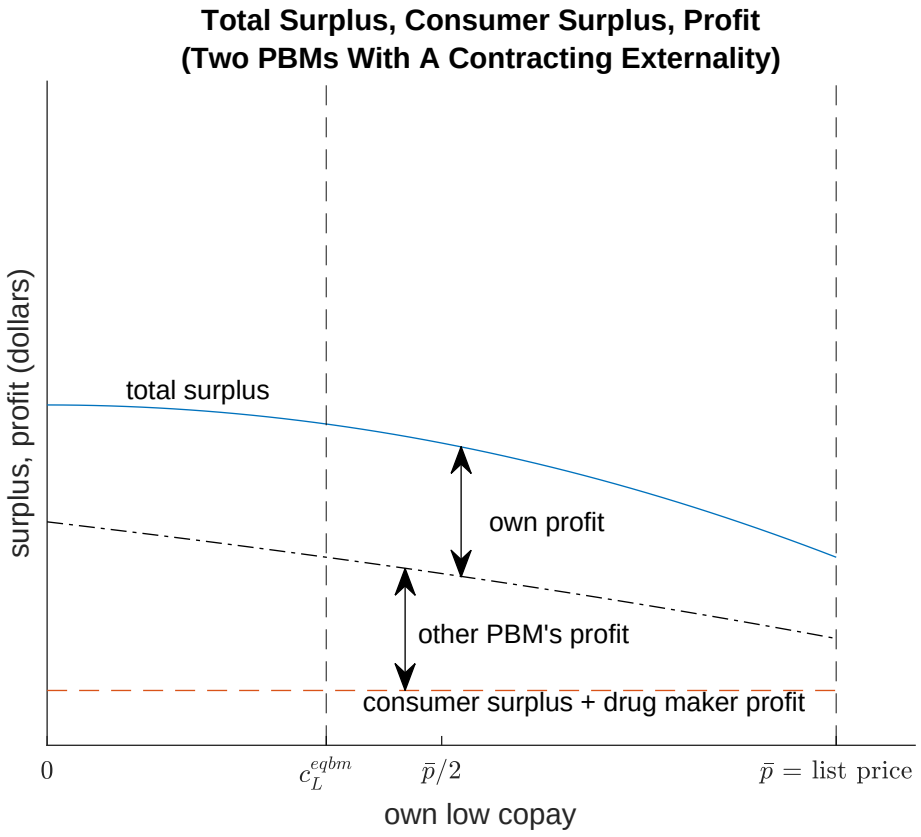

Figure 3: Total surplus and combined consumer surplus, drug maker profit, and other PBM's profit as a function of one PBM's own copay in the preferred tier. Copay in the non-preferred tier set at the list price, $\bar{p}$, and other PBM's copay set at the equilibrium value.

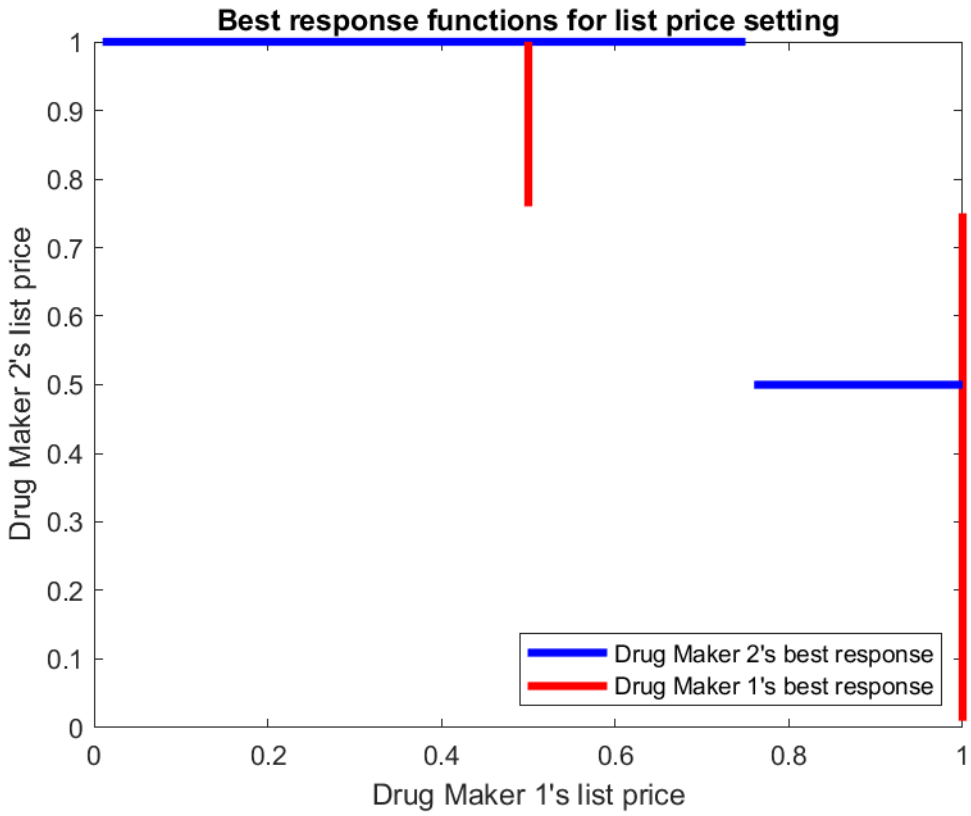

Figure 4: Best response function for one drug maker's list price as a function of the other drug maker's list price.

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

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Appendix A: Proofs of theoretical results

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 $V - \tilde{c}_d$ when purchasing it through the formulary if she purchased insurance, where $\tilde{c}_d$ is $\min\{c_1, c_2\}$ if the drugs are substitutes for the consumer, and $\tilde{c}_d = c_d$ otherwise. The consumer's utility is therefore maximized by purchasing the drug if and only if $V \geq \min\{\tilde{c}_d, \bar{p}\}$, and, if the consumer purchases the drug, she will do so at the lower price: through the formulary if $\tilde{c}_d \leq \bar{p}$ 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. 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. ■

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Proof of Lemma 3. The PBM's profit as a function of copays and reimbursement prices, taking net prices as given is

$$\pi_{PBM}\left(a, r_1, r_2; p_1, p_2\right) = \frac{1}{2}\left(\left(1+\tau\right) q\left(c_L\right)\left(r_a - p_a\right) + \left(1-\tau\right) q\left(c_H\right)\left(r_{-a} - p_{-a}\right)\right),$$

where drug a is the winning drug and $-a$ is the losing drug. 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 the payer is

$$\pi_{\text{payer}} = p_0 + \frac{1}{2}\left(\left(1+\tau\right) q\left(c_L\right)\left(c_L - r_a\right) + \left(1-\tau\right) q\left(c_H\right)\left(c_H - r_{-a}\right)\right),$$

where drug a is the preferred drug. Setting this equal to zero gives the following expression for the weighted average reimbursement price:

$$\frac{1}{2}\left(\left(1+\tau\right) q\left(c_L\right)\left(r_a\right) + \left(1-\tau\right) q\left(c_H\right)\left(r_{-a}\right)\right) = p_0 + \frac{1}{2}\left(\left(1+\tau\right) q\left(c_L\right)\left(c_L\right) + \left(1-\tau\right) q\left(c_H\right)\left(c_H\right)\right),$$

as stated in the lemma.

Substituting this condition into the PBM's profit function gives

$$\begin{aligned} & \tilde{\pi}_{PBM}\left(a; p_1, p_2\right) \\ = \; & p_0 + \begin{cases} \frac{1}{2}\left(\left(1+\tau\right) q\left(c_L\right)\left(c_L - p_1\right) + \left(1-\tau\right) q\left(c_H\right)\left(c_H - p_2\right)\right) & , \quad a = 1 \\ \frac{1}{2}\left(\left(1+\tau\right) q\left(c_L\right)\left(c_L - p_2\right) + \left(1-\tau\right) q\left(c_H\right)\left(c_H - p_1\right)\right) & , \quad a = 2 \end{cases}. \end{aligned}$$

The PBM therefore assigns drug 1 to the preferred tier if and only if $\tilde{\pi}_{PBM}\left(1; p_1, p_2\right) \geq \tilde{\pi}_{PBM}\left(2; p_1, p_2\right)$, is simplifies to $p_1 \leq p_2$ because $c_L \leq c_H$ by definition. ■

Proof of Lemma 4. 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

$$E\left[\pi_1\left(p\right)\right] = \left(1 - F\left(p\right)\right) p\left(1+\tau\right) q\left(c_L\right) + F\left(p\right) p\left(1-\tau\right) q\left(c_H\right).$$

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

$$\bar{p}\left(1-\tau\right) q\left(c_H\right) = \left(1 - F\left(p\right)\right) p\left(1+\tau\right) q\left(c_L\right) + F\left(p\right) p\left(1-\tau\right) q\left(c_H\right).$$

Solving this condition for $F\left(p\right)$ yields

$$F\left(p\right) = \frac{\left(1+\tau\right) q\left(c_L\right) - \frac{\bar{p}}{p}\left(1-\tau\right) q\left(c_H\right)}{\left(1+\tau\right) q\left(c_L\right) - \left(1-\tau\right) q\left(c_H\right)}.$$

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

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

■

Proof of Lemma 5. Recall that the equilibrium net price cdf is

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

The derivative of the cdf with respect to c_L is

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

The derivative of the cdf with respect to c_H is

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

■

Proof of Lemma 6. Lemma 3 implies that the payer's profit (aside from the initial transfer π_0) will be zero. The PBM's expected profit is therefore

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

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

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

and CS is consumer surplus:

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

which holds by an implication of Lemma 2. By the proof of Lemma 4, $\bar{p}\,(1-\tau)\,q\,(c_H)$ is the sum of the drug makers' expected profit. Note that $E\left[\pi_{\text{payer}}\,(c_L, c_H)\right]$ is clearly decreasing in c_L, so the profit maximizing choice is $c_L = 0$. PBM profit is increasing in c_H:

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

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 $\min\left\{q^{-1}\,(0)\,, \bar{p}\right\}$, which is $\bar{p}$ by assumption. ■

Lemma 1 (Reimbursement prices with m drugs) *The equilibrium reimbursement prices in the model with m drugs satisfy*

$$\begin{aligned} & \left(\frac{1}{m}+(m-1)\frac{\tau}{m}\right) q\left(c_1\right) r_1+\frac{1-\tau}{m} \sum_{i=2}^{m} q\left(c_{(i)}\right) r_i \\ = \quad & p_0+\left(\frac{1}{m}+(m-1)\frac{\tau}{m}\right) q\left(c_1\right) c_{(1)}+\frac{1-\tau}{m} \sum_{i=2}^{m} q\left(c_{(i)}\right) c_{(i)}. \end{aligned}$$

Proof. of Lemma 1. The PBM's profit is increasing in the reimbursement prices. Therefore it will set the reimbursement prices so that the payer's participation constraint binds, which in this case is

$$p_0-\left(\frac{1}{m}+(m-1)\frac{\tau}{m}\right) q\left(c_1\right)\left(r_1-c_{(1)}\right)-\frac{1-\tau}{m} \sum_{i=2}^{m} q\left(c_{(i)}\right)\left(r_i-c_{(i)}\right)=0.$$

Rearranging this equation gives the desired result. ■

Lemma 2 (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 $\{1,\ldots,m\}$,*

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

and ties are broken randomly.

Proof of Lemma 2. 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 $c_a\leq c_b$. We consider three cases. In Case 1, $c_a=c_b\leq c_d$ for all other tiers d besides a and b. In Case 2, $c_a<c_b\leq c_d$ for all other tiers d. In Case 3, there is a tier d such that $c_d<c_a$.

Take Case 1 first. In this case the PBM's profit is the same whether drug i is assigned to tier a and i' to tier b or the other way around.

Next take Case 2. Substituting the choice of reimbursement prices from Lemma 1 into the PBM's profit function, the portion of the PBM's profit that depends on the place of drugs i and i' if it assigned i to tier a and i' to tier b is:

$$B\left(a,b\right)=\left(\frac{1}{m}+(m-1)\frac{\tau}{m}\right) q\left(c_a\right)\left(c_a-p_i\right)+\frac{1-\tau}{m} q\left(c_b\right)\left(c_b-p_{i'}\right).$$

Profit if it assigned i to b and i' to a is

$$B\left(b,a\right)=\left(\frac{1}{m}+(m-1)\frac{\tau}{m}\right) q\left(c_a\right)\left(c_a-p_{i'}\right)+\frac{1-\tau}{m} q\left(c_b\right)\left(c_b-p_i\right).$$

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

$$\frac{1+\tau(m-1)}{1-\tau} \geq \frac{q(c_b)}{q(c_a)},$$

which certainly holds with strict inequality when $c_a < c_b$ for all $\tau \in [0,1)$.

Finally take Case 3. Because in this case neither drug will be the target of substitution by consumers who are able to substitute, we have

$$B(a,b) = \frac{1-\tau}{m} q(c_a)(c_a - p_i) + \frac{1-\tau}{m} q(c_b)(c_b - p_{i'}).$$

and

$$B(b,a) = \frac{1-\tau}{m} q(c_a)(c_a - p_{i'}) + \frac{1-\tau}{m} q(c_b)(c_b - p_i).$$

The condition $B(a,b) \geq B(b,a)$ now simplifies to

$$q(c_a) \geq q(c_b),$$

which holds strictly if $c_a < c_b$. ■

Lemma 3 (Equilibrium net-price distribution with m drugs) *There exists a symmetric equilibrium. Any symmetric equilibrium involves continuously mixed strategies with an interval support $[\underline{p}, \bar{p}]$ for some $\underline{p} < \bar{p}$, where $\bar{p}$ is the list price.*

Proof of Lemma 3. First, we will argue that there are no mass points. Suppose there were 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 $\left(\frac{1}{m} + \tau\frac{m-1}{m}\right) q\left(c_{(1)}\right)(p-\varepsilon)$, 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 $\frac{1}{m}(1-\tau) q\left(c_{(m)}\right)\tilde{p}$. It could obtain $\frac{1}{m}(1-\tau) q\left(c_{(m)}\right)\bar{p}$ 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 $[\underline{p}, \bar{p}]$ 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 $[\underline{p}, \bar{p}]$. Let $F(p)$ be the cdf of a candidate equilibrium mixing distribution. Let

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

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

$$\pi\left(p_i\right)=\frac{1}{m}\sum_{k=0}^{m-1}F^{k,m-1}\left(p_i\right)q_{k+1}p_i,$$

where $1\left(\cdot\right)$ is the indicator function and the effective quantity q_k is defined as follows:

$$q_k=\frac{1}{m}q\left(c_{(k)}\right)\left(1-\tau\right)^{1(k>1)}\left(1+\left(m-1\right)\tau\right)^{1(k=1)}.$$

Let F^* be such that

$$\pi\left(p\right)=\frac{1}{m}\sum_{k=0}^{m-1}\binom{m-1}{k}F^*\left(p\right)^k\left(1-F^*\left(p\right)\right)^{m-1-k}q_{k+1}p$$

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 $Q\left(p\right)$ satisfying $Q\left(\underline{p}\right)=\frac{1}{m}\left(1+\left(m-1\right)\tau\right)q\left(c_{(1)}\right)$ and $Q\left(\bar{p}\right)=\frac{1}{m}\left(1-\tau\right)q\left(c_{(m)}\right)$, there exists a CDF $F\left(p\right)$ such that $Q\left(p\right)=\sum_{k=0}^{m-1}F^{k,m-1}\left(p\right)q_{k+1}$ for all p.

Towards this end, define $\tilde{F}^{k,m-1}\left(p\right)=\sum_{j=k}^{m-1}F^{j,m-1}\left(p\right)$ 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 $\tilde{F}^{k,m-1}\left(p_i\right)$. While $F^{k,m-1}\left(p\right)$ is not necessarily monotonic in $F\left(p\right)$, $\tilde{F}^{k,m-1}\left(p\right)$ is a monotonically increasing in $F\left(p\right)$, as it corresponds to one minus the cdf of a binomial distribution with success probability $F\left(p\right)$ and $m-1$ trials evaluated at $k-1$, which is increasing in the success probability in the first order stochastic dominance sense. Let

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

Then ϕ is a strictly increasing and continuous function that satisfies $\phi\left(0\right)=0$ and $\phi\left(1\right)=q_1-q_m$, so it is invertible on the domain $[0,1]$. Given any arbitrary strictly decreasing and continuous function $Q\left(p\right)$ satisfying $Q\left(\underline{p}\right)=q_1$ and $Q\left(\bar{p}\right)=q_m$, define $\hat{F}$ to satisfy $\hat{F}\left(p\right)=\phi^{-1}\left(q_1-Q\left(p\right)\right)$ for all p. Then there exists a symmetric equilibrium price distribution in which each drug maker chooses a continuous mixing distribution $F^*\left(p\right)=\hat{F}\left(p\right)$ for $Q\left(p\right)$ satisfying $pQ\left(p\right)=\bar{p}q_m$ on support $\left[\underline{p},\bar{p}\right]$. ■

Proof of Proposition 1. 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

$$\begin{aligned}TS\left(c_{(1)},\ldots,c_{(m)}\right) &= \frac{1}{m}\left(\left(1+\left(m-1\right)\tau\right)E\left[1\left(V>c_{(1)}\right)V\right]+\left(1-\tau\right)\sum_{i=2}^{m}E\left[1\left(V>c_{(i)}\right)V\right]\right),\\ CS &= E\left[\left(V-\bar{p}\right)1\left(V>\bar{p}\right)\right].\end{aligned}$$

Expected drug maker profit is $(1-\tau)\,\bar{p}q\left(c_{(m)}\right)/m$, as shown in the proof of Lemma 3. The payer's expected profit is therefore

$$E\left[\pi_{\text{payer}}\left(c_{(1)},\ldots,c_{(m)}\right)\right] = TS\left(c_{(1)},\ldots,c_{(m)}\right) - CS - (1-\tau)\,\bar{p}q\left(c_{(m)}\right).$$

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 $c_{(m)}$:

$$\begin{aligned}\frac{\partial E\left[\pi_{\text{payer}}\right]}{\partial c_{(m)}} &= \frac{1-\tau}{m}\frac{\partial}{\partial c_{(m)}}E\left[1\left(V > c_{(m)}\right)V\right] - (1-\tau)\,\bar{p}q'\left(c_{(m)}\right)\\ &= -(1-\tau)\,q'\left(c_{(m)}\right)\left(\bar{p} - \frac{1}{m}c_{(m)}\right) > 0,\end{aligned}$$

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 $\bar{p}$. This proves the proposition's first result.

Plugging in the equilibrium copays established in the first result, total surplus becomes

$$\begin{aligned}TS\left(0,\ldots,\bar{p}\right) &= \frac{1}{m}\left(\left(1+(m-1)\,\tau\right)E\left[V\right] + (1-\tau)\left((m-2)\,E\left[V\right] + E\left[1\left(V>\bar{p}\right)V\right]\right)\right)\\ &= E\left[V\right] - \frac{1-\tau}{m}E\left[1\left(V\leq\bar{p}\right)V\right].\end{aligned}$$

■

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 PBM 1 can profitably deviate to some $c_L^1 > 0$. PBM 1's expected profit is equal to total surplus (TS) minus consumer surplus (CS) minus the other PBM's profit minus drug makers' profit:

$$\pi_{PBM}^1 = TS\left(\mathbf{c}_L,\mathbf{c}_H\right) - CS - \pi_2 - \overline{p}\,(1-\tau)\,\overline{q}\left(\mathbf{c}_H\right),$$

where total surplus and consumer surplus are

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

and PBM 2's profit is

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

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

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

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 5. 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 $q_L = (1+\tau)\left(q\left(c_L^1\right) + q\left(c_L^2\right)\right)$ be the total sales for a drug assigned to the preferred tier and $q_H = (1-\tau)\left(q\left(c_H^1\right) + q\left(c_H^2\right)\right)$ be the total sales for a drug assigned to the non-preferred tier. Define the expected drug expenditures for payer j to be $E[C^j] = (1+\tau)\, q\left(c_L^j\right) E[p_L] + (1-\tau)\, q\left(c_H^j\right) E[p_H]$ and the expected total drug expenditures to be $E[C] = q_L E[p_L] + q_H E[p_H]$. Using the endogenous price distributions described in Lemma 4, we can compute the following objects, which will be helpful: $(i.)$ $E[C] = 2\overline{p} q_H$; $(ii.)$ $q_L \frac{\partial E[p_L]}{\partial q_L} + q_H \frac{\partial E[p_H]}{\partial q_L} = -E[p_L]$; and $(iii.)$ $q_L \frac{\partial E[p_L]}{\partial q_H} + q_H \frac{\partial E[p_H]}{\partial q_H} = \frac{q_L}{q_H} E[p_L]$.

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

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

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 $\frac{\partial E[C^1]}{\partial q\left(c_H^1\right)} = \frac{1}{2}\frac{\partial E[C]}{\partial q_H} = \overline{p}$, so the optimality conditions above give us that $c_H^* = E[p_H] + \overline{p}$, 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 PBM's choice set in the one-PBM model but were dominated by $c_L^* = 0$ and $c_H^* = \overline{p}$. Therefore total PBM 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 Proposition 3. As established in the proof to Lemma 3, the PBM's profit function after substituting in the profit-maximizing choice of reimbursement prices, is identical to the PBM's profit in the one-PBM case. Therefore the PBM's equilibrium choice of copays and the drug makers' net price strategies coincide with

the one-PBM 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 has a separate PBM as its intermediary. ■

Proof of Lemma 7. The intermediary's profit as a function of copays assignments c_1 and c_2, taking net prices as given, is

$$\pi\left(c_1, c_2; p_1, p_2\right) = p_0 + \frac{1}{2}\left(1+\tau\right)\left(c_L - p_1\right) q\left(c_L\right) + \frac{1}{2}\left(1-\tau\right)\left(c_H - p_2\right) q\left(c_H\right)$$

if $c_1 = c_L$ and $c_2 = c_H$, and

$$\pi\left(c_1, c_2; p_1, p_2\right) = p_0 + \frac{1}{2}\left(1+\tau\right)\left(c_L - p_2\right) q\left(c_L\right) + \frac{1}{2}\left(1-\tau\right)\left(\min\left\{c_H, \bar{p}_1\right\} - p_1\right) q\left(\min\left\{c_H, \bar{p}_1\right\}\right)$$

if $c_1 = c_H$ and $c_2 = c_L$, where $p_0 = U_1 - U_0$. 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

$$\begin{aligned} p_2 \quad \geq \quad & \frac{\left(1+\tau\right) q\left(c_L\right) - \left(1-\tau\right) q\left(\bar{p}_1\right)}{\left(1+\tau\right) q\left(c_L\right) - \left(1-\tau\right) q\left(c_H\right)} p_1 \\ & + \frac{\left(1-\tau\right)\left(E\left[V \middle| V > \bar{p}_1\right] q\left(\bar{p}_1\right) - E\left[V \middle| V > c_H\right] q\left(c_H\right)\right)}{\left(1+\tau\right) q\left(c_L\right) - \left(1-\tau\right) q\left(c_H\right)}. \end{aligned}$$

■

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

$$\begin{aligned} TS\left(\mathbf{c},\bar{p}_1,\bar{p}_2\right) &= \frac{1}{2}E\left[V|V>c_L\right]\left(1+\tau\right)q\left(c_L\right) \\ &\quad +\frac{1}{2}E\left[E\left[V|V>\tilde{c}_H\right]\left(1-\tau\right)q\left(\tilde{c}_H\right)\right], \\ &= \frac{1}{2}\left(1-\frac{1}{2}\left(\left(1+\tau\right)c_L^2+\left(1-\tau\right)E\left[\tilde{c}_H^2\right]\right)\right) \end{aligned}$$

where the second equality follows from the assumed linear demand function, and $\tilde{c}_H$ is the copay assigned to the losing drug. This is a random quantity because it potentially depends on which drug loses the formulary contest, which in turn depends on the net prices, which in equilibrium are drawn from a mixed strategy. The distribution of net prices and thus the distribution of $\tilde{c}_H$ is derived below, and depends on $\mathbf{c}$, $\bar{p}_1$, and $\bar{p}_2$. Consumer surplus is determined by the list prices:

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

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 5 shows is as follows. Drug maker 1's expected profit is

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

and drug maker 2's expected profit is

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

where Cases 1 and 2 are defined in Lemma 7, and within Case 2, Case 2a obtains when

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

is satisfied and Case 2b otherwise.

It remains only to find $E\left[\tilde{c}_H^2\right]$. In Case 1, where both list prices are higher than c_H, $\tilde{c}_H$ is non-random because the identity of the "winning" drug does not affect the value of the higher copay, so

$$E\left[\tilde{c}_H^2\right]=c_H^2 \text{ (Case 1).}$$

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

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

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

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

and F_1 and F_2 are the equilibrium mixed strategy distributions given $\mathbf{c},\bar{p}_1,\bar{p}_2$, shown in Lemma 4 to be, for Case 2a,

$$\begin{aligned}F_1\left(p\right) &= \left\{\begin{array}{ccc}\frac{\left(1-c_L\right)\left(1-\frac{\underline{p}_2}{p}\right)}{c_H-c_L} & , & \underline{p}_2 < p < \phi\left(\bar{p}_1\right) \\ 1 & , & p = \phi\left(\bar{p}_1\right)\end{array}\right. , \\ F_2\left(p\right) &= \left\{\begin{array}{ccc}\frac{\left(1-c_L\right)\left(1-\frac{\phi^{-1}\left(\underline{p}_2\right)}{\phi^{-1}\left(p\right)}\right)}{\bar{p}_1-c_L} & , & \underline{p}_2 < p < \phi\left(\bar{p}_1\right) \\ 1 & , & p = \bar{p}_2\end{array}\right. ,\end{aligned}$$

and, for Case 2b

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

where

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

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 4 (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,*

$$\begin{aligned}F_1\left(p\right) &= \left\{\begin{array}{ccc}\frac{(1+\tau)(1-c_L)\left(1-\frac{\underline{p}_2}{p}\right)}{(1+\tau)(1-c_L)-(1-\tau)(1-c_H)} & , & \underline{p}_2 < p < \phi\left(\bar{p}_1\right) \\ 1 & , & p = \phi\left(\bar{p}_1\right)\end{array}\right. , \\ F_2\left(p\right) &= \left\{\begin{array}{ccc}\frac{(1+\tau)(1-c_L)\left(1-\frac{\phi^{-1}\left(\underline{p}_2\right)}{\phi^{-1}\left(p\right)}\right)}{(1+\tau)(1-c_L)-(1-\tau)(1-\bar{p}_1)} & , & \underline{p}_2 < p < \phi\left(\bar{p}_1\right) \\ 1 & , & p = \bar{p}_2\end{array}\right. ,\end{aligned}$$

and, for Case 2b

$$F_1(p) = \begin{cases} \frac{(1+\tau)(1-c_L)\left(1-\frac{p_1}{p}\right)}{(1+\tau)(1-c_L)-(1-\tau)(1-c_H)} & , \quad \underline{p}_1 < p < \phi(\bar{p}_1) \\ 1 & , \quad p = \phi(\bar{p}_1) \end{cases},$$

$$F_2(p) = \left\{ \frac{(1+\tau)(1-c_L)-(1-\tau)(1-\bar{p}_1)\frac{\bar{p}_1}{\phi^{-1}(p)}}{(1+\tau)(1-c_L)-(1-\tau)(1-\bar{p}_1)} \quad , \quad \underline{p}_1 < p \leq \phi(\bar{p}_1) \right. .$$

where

$$\underline{p}_2 = \frac{(1-\tau)(1-c_H)}{(1+\tau)(1-c_L)},$$

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

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:

$$\underline{p}_2 = \frac{(1-\tau)(1-c_H)}{(1+\tau)(1-c_L)}\bar{p}_2.$$

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:

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

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:

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

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:

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

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

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

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

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

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

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:

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

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:

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

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

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

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:

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

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

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

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 $\frac{(1+\tau)(1-c_L)}{(1-\tau)(1-c_H)}\underline{p}_1 > \phi(\bar{p}_1)$, 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

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

■

Lemma 5 (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*

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

and drug maker 2's expected profit is

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

where Cases 1 and 2 are defined in Lemma 7, and within Case 2, Case 2a obtains when

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

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 7, the intermediary awards the generous tier to drug 1 if $p_2 \geq \phi(p_1)$, where

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

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 $(1+\tau) q(c_L) p_2$ and if it loses it receives $(1-\tau) q(c_H) p_2$. If drug maker 1 wins it receives payoff $(1+\tau) q(c_L) p_1$ and if it loses it receives $(1-\tau) q(\min\{c_H, \bar{p}_1\}) p_1$. 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

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

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

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

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

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

is drug maker 2's valuation for winning, and

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

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

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

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

$$\lim_{s_1 \to \infty} v_1(s_1) = -\infty,$$

which is certainly less than

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

For drug maker 2, note that

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

and

$$\lim_{s_2 \to \infty} v_2(s_2) = -\infty,$$

which is less than

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

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:

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

c_1 evaluated at this value is

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

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

$$r_2 = 1 - \frac{(1-\tau)(1-c_H)}{(1+\tau)(1-c_L)}\bar{p}_2.$$

c_2 evaluated at this value is

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

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

$$\frac{(1-\tau)(1-c_H)}{(1+\tau)(1-c_L)}\bar{p}_2 \geq \phi\left(\frac{(1-\tau)(1-\bar{p}_1)}{(1+\tau)(1-c_L)}\bar{p}_1\right).$$

This condition may or may not hold, depending on the values of $c_L, c_H, \bar{p}_1, \bar{p}_2, \tau$. 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 1 is marginal ($r_2 > r_1$).

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

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

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

In Case 2a, the powers are the following:

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

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

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

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

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

Drug maker 2's expected profit is

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

■

Appendix B: Model Extensions

Contingent rebates

In the baseline model drug makers each offer a single net price which the intermediary pays regardless of the drug maker's tier assignment. Another possibility is that drug makers offer contingent net prices, one contingent on preferred tier placement, and the other contingent on non-preferred placement. In this section we allow for this possibility by assuming that drug maker 1 offers the pair of contingent net prices $\left(p_1^L, p_1^H\right)$ and drug maker 2 offers the pair $\left(p_2^L, p_2^H\right)$.

Consumer choices are unchanged as they only depend on the premium, list price, and copays. Likewise the payer's choice of premium will be unchanged. Tier assignment, however, will be different. The intermediary maximizes profit by placing drug 1 in the preferred tier if the following condition holds:

$$(1+\tau)\,q(c_L)\left(p_2^L-p_1^L\right) > (1-\tau)\,q(c_H)\left(p_2^H-p_1^H\right). \tag{1}$$

The above condition is intuitive: the left hand side is the drug subsidy savings from placing drug 1 in the preferred tier. The right hand side is the drug subsidy savings from placing drug 1 in the non-preferred tier. Whichever saving is bigger dictates the tier assignment. If the condition holds with equality the intermediary is indifferent over tier assignments, and we assume it randomizes with equal probability.

Now consider the drug makers' net price equilibrium. Suppose drug maker 2 sets $p_2^L = \bar{p}(1-\tau)\,q(c_H)\,/\,((1+\tau)\,q(c_L))$ and $p_2^H = \bar{p}$. Condition (1) implies drug maker 1 wins preferred placement if

$$p_1^L < p_1^H \frac{(1-\tau)\,q(c_H)}{(1+\tau)\,q(c_L)}.$$

Increasing p_1^H unambiguously increases drug maker 1's profit because it increases the probability that drug maker 1 wins preferred placement, so drug maker 1's best response is $p_1^H = \bar{p}$. Its profit given that it loses is therefore $\bar{p}(1-\tau)\,q(c_H)/2$. It earns strictly less profit if it sets $p_1^L < \bar{p}\frac{(1-\tau)q(c_H)}{(1+\tau)q(c_L)}$ even though it wins with certainty.

It is therefore a best response to set $p_1^L = \bar{p}\frac{(1-\tau)q(c_H)}{(1+\tau)q(c_L)}$. Thus the following net prices are an equilibrium:

$$\begin{aligned} p_i^L &= \frac{(1-\tau)\,q\,(c_H)}{(1+\tau)\,q\,(c_L)}\bar{p}, \\ p_i^H &= \bar{p}, \end{aligned}$$

for $i = 1, 2$. Drug makers earn total profit $\bar{p}\,(1-\tau)\,q\,(c_H)$ as in the baseline model. Lemma 6 then implies that copays are also the same as in the baseline model, $c_L = 0$ and $c_H = \bar{p}$.

Competition Among PBMs

The main text considers a model in which a single PBM serves as an intermediary for one or several payers. In this appendix section we allow competition in the PBM market by introducing a second PBM. The two PBMs compete to be chosen by the payer to provide intermediary services. The timing is as follows:

1. the PBMs (indexed by $k \in \{1, 2\}$) simultaneously offer contracts to the payer in which the payer delegates formulary operation to the PBM and PBM k makes a transfer of π_0^k to the payer;
2. the payer chooses which PBM to contract with;
3. the chosen PBM chooses the formulary copays c_L and c_H;
4. drug makers set net prices p_1 and p_2;
5. the PBM assigns drugs to formulary tiers and sets reimbursement prices r_1 and r_2;
6. the payer sets the premium p_0;
7. consumers decide whether to purchase insurance;
8. nature chooses the consumer's medical condition, D, its intensity, V, and whether drugs are substitutes for the given consumer;
9. consumers decide whether and which drug to purchase.

The timing in this version of the model with PBM competition is identical to the baseline model with a single PBM, except for the first step, in which both PBMs make an offer to the payer and the second step, in which the payer chooses a PBM to contract with. The equilibrium actions in steps 3-9 are accordingly identical to the baseline model.

The payer's equilibrium choice in the second step is to contract with the PBM that offers the largest transfer. That is, the payer chooses PBM k^*, where k^* solves $\max_{k\in\{1,2\}} \pi_0^k$.

In the first step, Bertrand-like competition results in an equilibrium in which both PBMs offer

$$\pi_0^* = \frac{1}{2}(1+\tau)\left(E\left[V1\left(V<\bar{p}\right)\right]\right) + \tau\bar{p}q\left(\bar{p}\right),$$

which is the equilibrium surplus accruing to the formulary operator. In summary, competition among PBMs leaves the allocation of drugs, total surplus, consumer surplus, and drug maker profit unchanged. Competition causes all surplus generated by the formulary to be transferred to the payer.

References

Yasar Barut and Dan Kovenock. The symmetric multiple prize all-pay auction with complete information. *European Journal of Political Economy*, 14(4):627 – 644, 1998.